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Factors Associated with Airborne Microbial Counts in the Inpatient Installation of Hospital X, Semarang City

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ABSTRACT
Background: Healthcare-associated infections (HAIs) remain a challenge in healthcare services, with a prevalence of approximately 5–15% in developed countries and higher rates in developing countries. In Indonesia, the prevalence is estimated at 10–15% among hospitalized patients. Although air quality in the Inpatient Installation of Hospital X met the established standards based on routine monitoring in 2024, the measurements did not include patient visiting hours, which may increase microbial contamination in the air. This study aimed to analyze the factors associated with airborne microbial counts in the Inpatient Installation of Hospital X, Semarang.
Methods: An analytical observational study with a cross-sectional design was conducted in 35 Class III inpatient wards selected as the study sample. Data analysis included univariate analysis, bivariate analysis using the chi-square test, and multivariate analysis using the Backward Wald logistic regression method.
Results: The mean room temperature was 26.5°C, relative humidity was 67.8%, light intensity was 218 lux, and the mean airborne microbial count was 304.5 CFU/m³. Bivariate analysis showed that temperature (p=0.001), relative humidity (p=0.030), number of patients (p=0.044), air circulation system (p=0.013), and personal hygiene (p=0.022) were significantly associated with airborne microbial counts. Multivariate analysis identified relative humidity (p=0.028) and personal hygiene (p=0.024) as the most dominant factors affecting airborne microbial counts.
Conclusion: The findings confirm that temperature, relative humidity, number of patients, air circulation system, and personal hygiene affect airborne microbial counts in the Class III Inpatient Installation of Hospital X, with relative humidity and personal hygiene exerting the strongest influence.

Keywords: Physical Air Quality; Airborne Microorganisms; Nosocomial Infections; Personal Hygiene; Hospital Sanitation.

ABSTRACT
Title: Factors Associated with Airborne Microbial Counts in the Inpatient Installation of Hospital X, Semarang City
Background: *Healthcare-associated infections (HAIs) remain a challenge in healthcare services, with a prevalence of approximately 5–15% in developed countries and even higher rates in developing countries. In Indonesia, the prevalence is estimated to range from 10% to 15% among hospitalized patients. Although routine monitoring conducted in 2024 indicated that the air quality in the Class III Inpatient Installation of Hospital X met the established standards, the measurements did not include patient visiting hours, during which increased*

human activity may elevate airborne microbial contamination. This study aimed to analyze the factors associated with airborne bacterial counts in the Class III Inpatient Installation of Hospital X, Semarang.
Methods: *An analytical observational study with a cross-sectional design was conducted in 35 Class III inpatient wards selected as the study sample. Data were analyzed using univariate analysis, bivariate analysis with the chi-square test, and multivariate analysis using the Backward Wald logistic regression method.*
Results: *The mean room temperature was 26.5°C, relative humidity was 67.8%, light intensity was 218 lux, and the mean airborne bacterial count was 304.5 CFU/m³. Bivariate analysis showed that temperature (p=0.001), relative humidity (p=0.030), number of patients (p=0.044), air circulation system (p=0.013), and personal hygiene (p=0.022) were significantly associated with airborne bacterial counts. Multivariate analysis identified relative humidity (p=0.028) and personal hygiene (p=0.024) as the most influential factors affecting airborne bacterial counts.*
Conclusion: *Temperature, relative humidity, number of patients, air circulation system, and personal hygiene significantly influenced airborne bacterial counts in the Class III Inpatient Installation of Hospital X, with relative humidity and personal hygiene being the most dominant factors.*

Keywords**: **Physical Air Quality; Airborne Microorganisms; Nosocomial Infections; Personal Hygiene; Hospital Sanitation.

INTRODUCTION

Nursing services in Indonesia play a crucial role in the overall healthcare system. As one of the main professional healthcare services, nursing plays a significant role in contributing to the quality of care in hospitals. The quality of nursing services is often used as an indicator of success in achieving hospital goals and influences the hospital's reputation in the community.[1] Hospitals are places where sick and healthy individuals gather. This condition makes hospitals potential sources of disease transmission and may pose environmental risks and other health problems. These health problems may occur among patients, visitors, healthcare workers, and other individuals.[2]

One of the serious problems in healthcare services is nosocomial infection because it increases morbidity, mortality, and patient care costs in hospitals. Transmission of these infections can occur through various media, one of which is air, which is an important factor in the spread of pathogenic microorganisms in hospital environments.[3]According to WHO, 5 to 15% of patients hospitalized in developed countries experience nosocomial infections, while the prevalence exceeds 15% in developing countries. In Indonesia, nosocomial infections are estimated to range from 10% to 15%.[4]

Although contact transmission is the main route, the spread of infections in hospitals is also influenced by airborne transmission. Air quality is a risk factor for increased airborne microbial populations. Particulate matter also contributes to increased susceptibility to infection through inhalation and to disease transmission through interaction with airborne pathogens. Therefore, hospitals must pay attention to the quality of their surrounding air to prevent nosocomial infections that may occur during care in healthcare facilities.[5]

Every hospital is required to provide inpatient rooms that meet environmental health requirements as stipulated in the Decree of the Minister of Health of the Republic of Indonesia Number 1204/MENKES/SK/X/2004 concerning Hospital Environmental Health Requirements and in the Minister of Health Regulation Number 2 of 2023, which implements Government Regulation Number 66 concerning Environmental Health. These requirements cover physical and biological air quality, as well as construction and facility aspects. If inpatient rooms do not comply with these requirements, they may become sources of disease transmission and pose risks to patients, visitors, healthcare workers, and other hospital personnel. Under these regulations, indoor air must be free from pathogens, with airborne microbial counts not exceeding 200–500 CFU/m³.[5,6]

As a government hospital and the main referral center in Central Java Province, Hospital X provides various inpatient facilities, including the President Suite, VIP, and Class I, II, and III wards. Hospital X also applies stricter internal quality standards, namely that airborne microbial counts must not exceed 200 CFU/m³. Based on air quality monitoring in the inpatient installation in 2024, airborne microbial counts at Hospital X met the quality standards stipulated in the Decree of the Minister of Health of the Republic of Indonesia Number 1204/MENKES/SK/X/2004. However, the air quality monitoring was conducted only during hospital staff working hours and did not include periods of high activity, such as patient visiting hours, which may increase the risk of airborne contamination and nosocomial infections.[7]

Based on initial observations, measurements of the physical environmental conditions of the rooms and airborne microbial counts were conducted during patient visiting hours, namely 17.00–19.00 WIB. It was found that the temperature and humidity parameters did not meet the threshold requirements of Minister of Health Regulation No. 2 of 2023 or the criteria for standard inpatient rooms under the KRIS standard. The temperature values did not meet the requirements in 75% of rooms, while 100% of rooms did not meet the humidity requirements. These values did not comply with the temperature standard of 22–26°C and humidity standard of 40–60%. Meanwhile, light intensity ranged from 110–260 lux, which met the minimum standard of 100 lux in patient rooms when patients were not sleeping.

In addition, airborne microbial counts were measured during patient visiting hours. Initial observations showed that 75% of the measurements did not meet the quality standard, with the highest value reaching 504 CFU/m³. This did not meet the requirements for airborne microbial counts in patient care rooms according to Minister of Health Decree No. 1204/MENKES/SK/X/2004 and the standard established by Hospital X, with a maximum limit of 200 CFU/m³. In addition, food distribution activities for patients increased the density of activity during visiting hours.

Based on these conditions, research is needed to identify factors that may be associated with airborne microbial counts in Class III inpatient wards at Hospital X, Semarang City. This study may provide a scientific basis for controlling air quality and preventing nosocomial infections.

MATERIALS AND METHODS

This study employed an analytical observational design with a cross-sectional approach and was conducted in 2025 at the Class III Inpatient Installation of Hospital X, Semarang, Indonesia. The study population included all Class III inpatient wards available in the installation.

The study sample was selected using simple random sampling. Based on hospital facility data from 2023 and Director's Decree Number HK.02.03/I.IV/10/2022, the Class III inpatient installation comprised 72 wards. However, 24 wards were excluded because they were infectious disease wards or special care wards with different environmental characteristics and infection control systems. Thus, 48 wards met the inclusion criteria and formed the study population. Of these, 35 wards were selected using simple random sampling as the study sample. This method was chosen to minimize selection bias and improve the representativeness of the sample relative to the population.

The airborne bacterial count (CFU/m³) served as the dependent variable in this study and was categorized as meeting or exceeding the applicable standard based on the Decree of the Minister of Health of the Republic of Indonesia No. 1204/Menkes/SK/X/2004 on Hospital Environmental Health Requirements. Temperature, relative humidity, and light intensity were categorized based on the requirements stipulated in Minister of Health Regulation No. 2 of 2023 concerning Environmental Health Standards. The independent variables included temperature, relative humidity, light intensity, air circulation system, number of patients, number of visitors, floor disinfection frequency, and personal hygiene. The number of patients and visitors was categorized based on the median value of the observed data. Floor disinfection frequency was assessed based on the standard operating procedure (SOP) implemented by the hospital. The air circulation system was assessed through direct observation, while personal hygiene was assessed using a questionnaire. For variables assessed through observation or questionnaire, categorization into favorable/unfavorable conditions was determined based on weighting scheme. This study used several instruments to assess environmental and behavioral factors associated with airborne bacterial contamination during visiting hours (17:00–19:00). A calibrated thermo-hygrometer and lux meter were employed to measure temperature, relative humidity, and lighting intensity, while a bacterial air sampler with Plate Count Agar (PCA) media collected airborne samples at 1 meter above the floor for 10 minutes at a flow rate of 100 L/min.

Data were analyzed using univariate analysis for each study variable. The relationship between the independent variables and airborne microbial counts was subsequently analyzed using the chi-square test in the bivariate analysis. Variables showing an association with the outcome were then included in multivariate analysis using logistic regression with the Backward Wald method to determine the factors that most dominantly affected airborne microbial counts.

This study received ethical approval from the Health Research Ethics Committee of the Faculty of Public Health, Universitas Diponegoro, based on Ethical Approval Letter Number 167/EA/KEPK-FKM/2025.

RESULTS AND DISCUSSION

The study was conducted at Hospital X, Semarang.The hospital has an area of 193,410 m² and a building area of 82,754 m². The available inpatient facilities consist of President Suite, VIP, and Class I, II, and III wards. The Class III inpatient installation has the largest number of rooms compared with the other classes. Based on Director's Decree No. HK.02.03/I.IV/10/2022, there were 472 beds distributed across 72 rooms. However, 24 of these rooms were infectious disease rooms, including the stroke unit and ICU on floor 1A, the ICU HCU on floor 3B, and wards for patients with TB, HIV, and COVID-19 on floors 6A and 6B.

Based on Table 1, temperatures in the inpatient rooms ranged from 23.90–29.40°C, with a mean of 26.5°C. Relative humidity ranged from 49–83%, with a mean of 67.89%. Light intensity ranged from 96–339 lux, with a mean of 218.23 lux. Airborne microbial counts ranged from 123–500 CFU/m³, with a mean of 304.57 CFU/m³. The number of patients ranged from 3–6 people, with a mean of 4.49, rounded to 4 people. The number of visitors ranged from 0–8 people, with a mean of 2.71, rounded to 3 visitors. Floor disinfection was performed 2–5 times per day, with a mean frequency of 3.94 times.

Table 1. Distribution of independent variables potentially affecting airborne microbial counts in the Inpatient Installation

Variable	n	Mean	Minimum	Maximum
Temperature	35	26.5	23.90	29.40
Relative Humidity	35	67.89	49	83
Light Intensity	35	218.23	96	339
Airborne Microbial Count	35	304.57	123	500
Number of Patients	35	4.49	3	6
Number of Visitors	35	2.71	0	8
Floor Disinfection Frequency	35	3.94	2	5

Based on Table 2, most inpatient rooms had room temperatures categorized as not meeting the requirements (51.4%), while 48.6% of rooms met the established standards. For relative humidity, 74.3% of rooms were outside the required range, while only 25.7% met the standard. Light intensity showed that almost all inpatient rooms met the requirements (94.3%), with only 5.7% having light intensity below the standard. The number of patients categorized as crowded was 88.6%, while 11.4% were not crowded. The number of visitors categorized as crowded was 11.4%, while 88.6% were not crowded. Floor disinfection frequency did not comply with the SOP in 45.7% of rooms, while 54.3% complied with the SOP. The air circulation system was adequate in 62.9% of rooms and inadequate in 37.3%. Personal hygiene conditions were categorized as at risk in 57.1% of rooms and not at risk in 42.9%.

Table 2. Frequency distribution of variables potentially affecting airborne microbial counts in the Inpatient Installation

Variable	Frequency (n)	Percentage (%)
Temperature		
Non-compliant (< 20˚C atau > 26˚C)	18	51.4
Compliant (20 - 26˚C)	17	48.6
Total	35	100
Relative Humidity		
Non-compliant (< 40% atau > 60%)	26	74.3
Compliant (40 - 60%)	9	25.7
Total	35	100
Light Intensity		
Non-compliant (< 100 lux)	2	5.7
Compliant (≥ 100 lux)	33	94.3
Total	35	100
Number of Patients		
Dense (> 3 patients)	31	88.6
Not Dense (≤ 3 patients)	4	11.4
Total	35	100
Number of Visitors		
Dense (> 6 visitors)	4	11.4
Not Dense (≤ 6 visitors)	31	88.6
Total	35	100
Floor Disinfection Frequency		
Not in Accordance with SOP (<5x)	16	45.7
In Accordance with SOP (5x)	19	54.3
Total	35	100
Air Circulation System		
Inadequate (< 80%)	13	37.3
Adequate (≥ 80%)	22	62.9
Total	35	100
Personal Hygiene Condition		
At Risk (< 80%)	20	57.1
Not at Risk (≥ 80%)	15	42.9
Total	35	100

Based on the results of the bivariate analysis, the following findings were obtained:
Table 3. Results of bivariate analysis of variables potentially affecting airborne microbial counts in the Inpatient Installation

No	Variable	Category	Airborne Microbial Count Non-Compliant (n/%)	Airborne Microbial Count Compliant(n/%)	Total (n/%)	*p-value*	PR	95% CI
1	Temperature (°C)	Non-compliant (< 20˚C atau > 26˚C)	18 (100%)	0 (0%)	18 (100%)	0.001	2.125	1.283–3.518
		Compliant (20 - 26˚C)	8 (47.1%)	9 (52.9%)	17 (100%)			
2	Relative Humidity (%)	Non-compliant (< 40% atau > 60%)	22 (84.6%)	4 (15.4%)	26 (100%)	0.030	1.904	0.901–4.025
		Compliant (40 - 60%)	4 (44.4%)	5 (55.6%)	9 (100%)			
3	Light Intensity (Lux)	Non-compliant (< 100 lux)	2 (100%)	0 (0%)	2 (100%)	1.000	1.375	1.116–1.694
		Compliant (≥ 100 lux)	24 (72.7%)	9 (27.3%)	33 (100%)			
4	Number of Patients	Dense (> 3 patients)	25 (80.6%)	6 (19.4%)	31 (100%)	0.044	3.226	0.586–17.766
		Not Dense (≤ 3 patients)	1 (25.0%)	3 (75.0%)	4 (100%)			
5	Number of Visitors	Dense (> 6 visitors)	3 (75%)	1 (25%)	4 (100%)	1.000	1.011	0.553–1.847
		Not Dense (≤ 6 visitors)	23 (74.2%)	8 (25.8%)	31 (100%)			
6	Floor Disinfection Frequency	Not in Accordance with SOP (<5x)	13 (81.3%)	3 (18.8%)	16 (100%)	0.460	1.188	0.808–1.746
		In Accordance with SOP (5x)	13 (68.4%)	6 (31.6%)	19 (100%)			
7	Air Circulation System	Inadequate (< 80%)	13 (100%)	0 (0%)	13 (100%)	0.013	1.692	1.195–2.396
		Adequate (≥ 80%)	13 (59.1%)	9 (40.9%)	22 (100%)			
8	Personal Hygiene Condition	At Risk (< 80%)	18 (90%)	2 (10%)	20 (100%)	0.022	1.688	1.028–2.769
		Not at Risk (≥ 80%)	8 (53.3%)	7 (46.7%)	15 (100%)			

The air temperature variable was significantly associated with airborne microbial counts (p=0.001). The Prevalence Ratio (PR) of 2.125 indicates that inpatient rooms with temperatures that did not meet the quality standard had approximately 2.1 times greater likelihood of having increased airborne microbial counts compared with rooms with temperatures that met the requirements. In addition, the 95% confidence interval (95% CI: 1.283–3.518) did not cross 1, indicating that the magnitude of the risk was statistically significant and had good precision. These findings indicate that temperature is one of the environmental factors contributing to increased airborne microbial counts in inpatient rooms.

These findings are consistent with a study by Daria B.R. Ginting (2022), which reported a significant association between room temperature and airborne microbial counts.[8] Environmental temperature is known to affect the ability of microorganisms to survive and reproduce. Most bacteria have higher growth rates under warm conditions, although some species are still able to survive at lower temperatures. Increasing temperature may also accelerate microbial metabolic activity, thereby increasing the likelihood of proliferation in the air.

An increase in temperature from 15°C to 25°C can increase the viability of several bacteria, such as *Acinetobacter calcoaceticus, Pseudomonas spp., Corynebacterium spp.,* and *Staphylococcus aureus*.[9] This condition indicates that room temperature control is an important part of maintaining air quality in hospital environments. Therefore, maintaining temperature according to established standards should be carried out consistently as an effort to inhibit the growth of airborne microorganisms and reduce the risk of healthcare-associated infections (HAIs).

Relative humidity was significantly associated with airborne microbial counts, as indicated by p=0.030 ($p<0.05$). The Prevalence Ratio (PR) of 1.904 indicates that inpatient rooms with humidity levels that did not meet the standard had nearly twice the likelihood of airborne microbial counts exceeding the quality standard compared with rooms with humidity levels that met the requirements. However, the 95% confidence interval (95% CI: 0.901–4.025) still crossed 1, so the magnitude of the risk should be interpreted cautiously, given its limited precision. Thus, although a statistically significant association was found, humidity cannot yet be confirmed as a strong risk factor for increased airborne microbial counts in this study.

The findings of Queeniza et al. (2020) reported a significant association between relative humidity and airborne microbial counts at Soemitro Air Force Hospital (p=0.021).[10] The study also recommended the use of a Central Air Conditioning Air Handling Unit (AHU) equipped with a High Efficiency Particulate Air (HEPA) filter to improve air quality through more effective filtration of particles and microorganisms.

Excessively high humidity can create an environment that supports the proliferation of bacteria and fungi, whereas excessively low humidity can prolong the viability of some aerosolized viruses, increasing the likelihood of disease transmission. Therefore, maintaining room humidity within the range of 40–60% is an important strategy for maintaining air quality and reducing the risk of airborne disease transmission, particularly in hospital care rooms.[11,12,13,14]

On the other hand, light intensity was not significantly associated with the dependent variable, namely airborne microbial counts, as indicated by p=1.000 ($p>0.05$). Although the Prevalence Ratio (PR) of 1.375 indicated a tendency toward increased risk of airborne microbial counts in rooms with light intensity that did not meet the standard, this result was not supported by statistical significance. In addition, the 95% confidence interval (95% CI: 1.116–1.694) indicates that the risk estimate should still be interpreted cautiously. Therefore, light intensity cannot be stated as an associated factor or a risk factor for increased airborne microbial counts in this study.

These findings are consistent with a study by Citra Kusumawardhani et al. (2019) in inpatient wards at RST Wijayakusuma, which reported no significant association between light intensity and airborne microbial counts (p=0.061).[15] Similar results were reported by Dewi Andika et al. (2022), who found that lighting was not significantly associated with airborne microbial counts (p=0.806).[15] The consistency of findings across several studies indicates that variations in light intensity do not always directly affect the concentration of microorganisms in the air of inpatient rooms.

Theoretically, natural lighting, particularly lighting containing ultraviolet (UV) radiation, is known to inhibit the growth of several types of microorganisms. However, in modern inpatient rooms that predominantly use artificial lighting and have limited access to direct sunlight, the influence of lighting on airborne microbial counts tends to be smaller than that of other environmental factors, such as temperature, humidity, ventilation, occupancy density, and occupant activity. Therefore, although lighting should still be maintained according to standards to support the comfort and safety of patients and healthcare workers, air quality control should focus more on factors that have been shown to be significantly associated with increased airborne microbial counts.

Meanwhile, the number of patients was significantly associated with airborne microbial counts (p=0.044). The Prevalence Ratio (PR) of 3.226 indicates that inpatient rooms with high occupancy (>3 patients) had approximately 3.2 times greater likelihood of having airborne microbial counts exceeding the quality standard compared with rooms with a lower number of patients. However, the 95% confidence interval (95% CI: 0.586–17.766) still crossed 1, so the magnitude of the risk should be interpreted cautiously because its precision was not optimal. Thus, the results indicate a significant association between patient density and airborne microbial counts, but they are not sufficiently strong to establish the number of patients as a definitive risk factor.

These findings are consistent with Windi Wulandari et al. (2016), who reported a significant association between the number of patients and airborne microbial counts in inpatient rooms (p=0.037; r=0.900).[16] Similar findings were reported by Yao Yu et al. (2015), who found that the concentration of airborne microorganisms in a NICU increased as the number of hospitalized patients increased.[17] Theoretically, an increase in the number of patients increases activity in the room, such as patient movement and activities of healthcare workers and attendants, thereby increasing the release of biological particles into the air. In addition, high occupancy density may reduce the effectiveness of air circulation and accelerate the accumulation of microorganisms when not supported by an adequate ventilation system. Therefore, controlling inpatient room capacity according to standards and optimizing ventilation are important measures to maintain air quality and minimize the risk of healthcare-associated infections.

The number of visitors was not significantly associated with airborne microbial counts, as indicated by $p=1.000$ ($p>0.05$). The Prevalence Ratio (PR) of 1.011 indicates that the likelihood of airborne microbial counts exceeding the quality standard in rooms with a high number of visitors was almost the same as in rooms with fewer visitors. In addition, the 95% confidence interval (95% CI: 0.553–1.847) crossed 1, indicating that the magnitude of the risk was not statistically significant. Thus, the number of visitors could not be identified as an associated factor or risk factor for increased airborne microbial counts in inpatient rooms in this study.

These findings align with Didik et al. (2016), who likewise reported no significant association between visitor numbers and airborne microbial counts at Dr. Moewardi Regional General Hospital ($p=0.184$).[18] Nevertheless, visitors still warrant attention in hospital infection prevention efforts. A study by Ming Dow Tsay et al. (2020) found that after visiting hours, the air in the Surgical Intensive Care Unit (SICU) was dominated by microorganisms such as *Micrococcus spp., Staphylococcus spp., Bacillus spp*., and bacteria associated with nosocomial infections, including Acinetobacter spp.[19] These findings indicate that visitor activity may influence the composition of airborne microorganisms, even if it does not always significantly increase the total microbial count. Therefore, regulating visitor numbers, limiting visiting hours, and maintaining good hygiene practices remain necessary as part of infection control and air quality maintenance strategies in inpatient rooms.

Floor disinfection frequency was not significantly associated with airborne microbial counts, as indicated by $p=0.460$ ($p>0.05$). The Prevalence Ratio (PR) of 1.188 indicates a tendency toward increased risk of airborne microbial counts in rooms where floor disinfection frequency did not comply with the standard operating procedure (SOP). However, the 95% confidence interval (95% CI: 0.808–1.746) crossed 1, indicating that the magnitude of the risk was not statistically significant. Based on these results, floor disinfection frequency cannot be stated as an associated factor or risk factor for increased airborne microbial counts in inpatient rooms.

These findings are consistent with Citra Kusumawardhani et al. (2019), who also reported that floor disinfection frequency was not significantly associated with airborne microbial counts ($p>0.05$).[15] These results indicate that routine floor disinfection does not necessarily reduce the concentration of airborne microorganisms, as the procedure focuses more on surface decontamination. The presence of airborne microorganisms is influenced by various other factors, such as temperature, humidity, ventilation systems, occupancy density, and occupant activity. Nevertheless, a study by Kimberly Trosch et al. (2024) showed that continuous floor disinfection technology could reduce contamination levels on hospital environmental surfaces, thereby contributing to infection prevention and control programs.[20] Therefore, floor disinfection according to SOP should be maintained as part of environmental cleanliness efforts, although its effectiveness in reducing airborne microbial counts is influenced by other environmental factors.

The air circulation system was significantly associated with airborne microbial counts, as indicated by $p=0.013$ ($p<0.05$). The Prevalence Ratio (PR) of 1.692 indicates that inpatient rooms with inadequate air circulation systems had approximately 1.7 times greater likelihood of having airborne microbial counts exceeding the quality standard compared with rooms with air circulation systems that met the standard. In addition, the 95% confidence interval (95% CI: 1.195–2.396) did not cross 1, indicating that the risk estimate was statistically significant and consistent. Thus, the air circulation system can be identified as one of the risk factors contributing to increased airborne microbial counts in inpatient rooms.

These findings are consistent with Nicollo Vonci et al. (2019), who reported a negative association between Air Changes per Hour (ACH) and airborne microorganism counts (CFU/m^3).[21] The study showed that increasing the frequency of air changes could reduce microorganism concentrations in both laminar and turbulent ventilation systems. Theoretically, a good air circulation system reduces the accumulation of biological particles through dilution and removal of contaminated air while introducing clean air into the room. Conversely, suboptimal air circulation may cause microorganisms to remain airborne for longer periods, increasing exposure opportunities for patients, healthcare workers, and visitors. Therefore, maintaining ventilation systems, including ensuring adequate air-change rates and proper filtration function, is an important measure for maintaining air quality and supporting efforts to prevent healthcare-associated infections in hospitals.

Personal hygiene was significantly associated with airborne microbial counts, with $p=0.022$ ($p<0.05$). The Prevalence Ratio (PR) of 1.688 indicates that inpatient rooms with poor personal hygiene conditions had approximately 1.7 times greater likelihood of having airborne microbial counts exceeding the quality standard compared with rooms with good personal hygiene conditions. In addition, the 95% confidence interval (95% CI: 1.028–2.769) did not cross 1, indicating that the magnitude of the risk was statistically significant. These findings indicate that suboptimal personal hygiene practices are one of the factors contributing to increased microbial contamination in the air of inpatient rooms.

The results of this study are not consistent with the study by Didik et al. (2016), which reported that personal hygiene was not associated with airborne microbial counts ($p=0.300$).[18] In contrast, the findings of this study support those of Dimple Kubde et al. (2023), which showed that poor personal hygiene practices, particularly regarding hand and body hygiene, can increase the spread of pathogenic microorganisms, including

Staphylococcus aureus and Gram-negative bacteria, in hospital environments.[22] Theoretically, patients, attendants, and healthcare workers can become sources of microorganisms released into the air through direct contact, care activities, and droplets generated during these activities. Therefore, compliance with personal hygiene practices, particularly hand hygiene, body hygiene, and cough and sneeze etiquette, should be continuously improved as part of infection control strategies to maintain air quality.

The bivariate analysis identified five independent variables that affected the dependent variable, allowing the analysis to proceed to multivariate testing using logistic regression. The results of the multivariate analysis of the five variables are as follows:

Table 4. Results of Multivariate Analysis

No	Variable	B Value	Exp (B)	Sig.	95% CI
1	Relative Humidity	2.621	13.753	0.028	1.332-142.030
2	Personal Hygiene Condition	2.689	14.718	0.024	1.420-152.499
	Constant	-8,748	0,001		

The analysis showed that relative humidity and personal hygiene remained significantly associated with airborne microbial counts after controlling for other variables. These variables made the greatest contributions to increased airborne microbial counts in Class III inpatient rooms at Hospital X.

Relative humidity had a significance value of 0.028 ($p<0.05$) with an Exp(B) of 13.753, indicating that inpatient rooms with humidity outside the standard range had approximately 13.8 times greater likelihood of having airborne microbial counts exceeding the quality standard compared with rooms with humidity that met the requirements. The 95% CI (1.332–142.030) further supports that the association was statistically significant. These findings indicate that humidity is an important determinant of air quality in inpatient rooms. Therefore, controlling humidity within the recommended range is an important step in maintaining air quality and reducing the risk of infection transmission in hospitals. These findings also support various studies stating that ideal room humidity is in the range of 40–60% to inhibit microorganism proliferation while maintaining a comfortable care environment.[23,24]

In addition to humidity, personal hygiene was also significantly associated with airborne microbial counts ($p=0.024$), with an Exp(B) of 14.718 and a 95% CI of 1.420–152.499. These results indicate that inpatient rooms with poor personal hygiene practices had nearly 15 times greater likelihood of having airborne microbial counts exceeding the quality standard compared with rooms with good personal hygiene practices. The high Exp(B) value indicates that individual hygiene behavior is a highly influential factor affecting air quality in inpatient rooms. In this study, aspects of personal hygiene that still require attention include patient self-care, handwashing habits, patient attendant hygiene, and the availability of supporting facilities such as covered waste bins and containers for patients experiencing vomiting. [25]

This study has several limitations. The cross-sectional design can only demonstrate associations between variables and cannot establish causal relationships. The study was conducted in a single hospital, so the findings should be interpreted cautiously before being generalized to other healthcare facilities. In addition, the study measured only airborne microbial counts (CFU/m^3) without identifying microorganism species or antimicrobial resistance patterns.

CONCLUSION

This study demonstrates that airborne bacterial contamination in Class III inpatient wards remains a significant environmental health concern, with most rooms exceeding the recommended bacterial threshold. Among the investigated factors, humidity and personal hygiene emerged as the strongest independent determinants. These findings emphasize that effective infection prevention requires not only environmental control measures but also sustained behavioral interventions. Strengthening humidity management, ventilation performance, and personal hygiene compliance may substantially reduce airborne microbial contamination and contribute to safer hospital environments. The results provide evidence that can support hospital environmental health policies, particularly in high-occupancy inpatient settings. These findings emphasize that controlling room humidity and improving personal hygiene practices are important aspects of maintaining air quality and preventing the risk of nosocomial infections in inpatient rooms. Future research is recommended to use a longitudinal design or repeated measurements across several time periods to describe variations in airborne microbial counts more comprehensively. In addition, future studies may include more hospitals to improve the generalizability of the findings.

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