

Determination of the indoor air bacterial profile in Jimma University Specialized Hospital, Southwest Ethiopia

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Abstract

Objective: Microorganisms are one of the main indoor air contaminants. In a hospital setting, a range of hospital-acquired infectious diseases are caused due to indoor air pollution. Studies conducted on hospital patients and healthcare workers revealed that indoor air pollution is causing more severe health problems than outdoor air pollution. Thus, this study aimed to determine the bacterial indoor air quality in Jimma University Specialized Hospital in southwest Ethiopia.

Method: An institution-based cross-sectional study was conducted from late May to October 2020. Indoor air samples were collected through a passive method by exposing prepared sample plates for prescheduled exposure time, and bacterial species were identified using morphology and biochemical tests.

Result: Based on the findings, neither of the wards showed a similar microbial concentration. Among the studied wards, the minimum and the maximum bacterial distribution ranged from 280 to 6369 cfu/m³, respectively. *Staphylococcus aureus*, coagulase-negative spp., *Klebsiella* spp., *Escherichia coli*, *Bacillus* spp., *Proteus* spp., and *Streptococcus* spp. were bacterial isolates. Statistically, the concentration of the bacteria in all the studied wards was tested significantly different ($p \leq 0.001$).

Conclusion: Among studied wards, the emergency outpatient ward showed a maximum bacterial concentration in contrast to the minor operating room. Based on the criteria of the World Health Organization on hospital-acquired infections, studied wards were highly contaminated.

Keywords

Indoor air, bioaerosols, bacterial load, bacterial isolates, hospital wards

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Introduction

Following the industrial development, air pollution is one of the most current environmental health issues. Due to natural and anthropogenic activities, chemicals, biological, and particulate substances enter the atmosphere in multiple routes.¹ Microorganisms are the cause of several infectious diseases like gastroenteritis, bedsores, and urinary tract infection.² Surface contamination, air currents, and dusty materials are some of the sources of these infectious microorganisms. Globally, about 1.4 million people are suffering from hospital-acquired infectious diseases. However, developing countries accounted 2–20 times high risk due to overcrowding, improper facilities design, and lack of adequate ventilation.^{3,4}

In hospital settings, indoor air pollution needs a prompt treatment strategy to prevent indoor air pollution-related problems for health professionals, patients, and their relatives. People spend most of their time around the indoor

environment like hospitals, schools, and prisons, and restaurants, and banks that need emphasis.⁵ The presence of high bioaerosol concentration in hospital environments has been causing a serious health problem to those people.^{6,7} Therefore, designing an effective indoor air pollution prevention strategy is a primary action to create a safe work environment.^{8–10}

As studies indicated, microorganisms such as *Staphylococcus aureus*, *Escherichia coli*, *Streptococcus* spp., *Klebsiella* spp., and *Bacillus* spp. were commonly

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isolated species in tropical countries' hospital. The survival capacity of these bacterial species is influenced by physical parameters of hospital environment such as temperature, light, and humidity.^{3,11} Therefore, this study was aimed to determine the microbial indoor air quality in Jimma University Specialized Hospital (JUSH).

Methods and materials

Study area and period

The study was conducted at JUSH from May to October 2020, which is located 352 km away from the capital, Addis Ababa. The JUSH had 450 beds and about 750 supportive and health professional staff. It provides service for 9000 inpatient and 80,000 outpatient attendances per year from a total catchment population of 15,000 million. From 20 total wards, only 10 wards were selected for sample collection, such as operating room, intensive care unit (ICU), emergency outpatient department (OPD), laboratory, medical ward male and female, surgical male and female, and pediatrics and maternity.

Sampling methods

A laboratory-based cross-sectional study was conducted to isolate and determine the indoor microbial concentration in JUSH.

The purposive method was applied to select wards following the random sampling. Selected rooms were medical ward A, surgical ward A, the laboratory department, the emergency OPD, the ICU, the operation room (OR), and the pediatric unit and the maternity unit. Related to the hospital environment, some basic factors were studied like the type of activities carried out in each selected room, time of the day, and the temperature and building conditions were surveyed.

Eight sample plates were collected at morning and afternoon from selected 10 wards totally, 80 sample plates. The air sample was performed using a settle plate sampling method.³ During the sample collection, there was no control of indoor environmental conditions of the wards. The (Titan Biotech Limited, India) 10-cm-sized blood agar plate products were used to collect samples by labeled room number, time, and date of sample collection. Then, the prepared sample plates were transported to already selected rooms. Lid opened plates were placed at 1 m above the ground for 1 h. When the expected sampling time was finished, the sample plates were covered by lids and transported to the laboratory for culture. Control plates were used to ensure cross-contamination during sampling, transportation, and culturing procedures.

Airborne bacterial examination

All blood agar plates were incubated at 37°C for 48 h. The total number of bacterial colonies forming unit per cubic meter was counted and recorded. The bacterial isolates were

characterized morphologically based on the colony size, shape, margin, opacity, elevation, and pigment production. Identical colonies were sub-cultured by nutrient agar and MacConkey agar plates (Hi-Media Company Limited, India) incubating at 37°C for 24 h, and then stored for further examination. Bacterial isolation and characterization conducted as the Buchanan and Gibbons methods.^{12,13} Hence, Gram stain, catalase test, coagulase test, and mannitol fermentation (Titan Biotech Limited, India) were used to differentiate the organisms.¹⁴

Statistical analysis

Bacterial concentration was calculated using cfu/m³ according to standards. SPSS™ version 20 Statistical Software and Microsoft Excel were used for statistical analysis.² Analysis of variance (ANOVA) at $\alpha=0.05$ was conducted to determine sampling time significance, and Tukey's multiple comparisons at 0.05 level test were conducted to compare the differences of mean bacterial concentration among wards. Correlation analysis was performed to determine the relationship between cfu/m³ and other independent variables.

Result

This study was conducted to reveal the distribution pattern and to isolate airborne bacteria for more than 5 months. The hospital had a containing capacity of 450 patient beds with 750 staff who were service givers for more than 89,000 patients per year. Samples were taken simultaneously from the wards in order to determine the load and composition of bioaerosol. Furthermore, airborne bacterial identification was done for each sample plate. Composition analysis and microbial concentration were reported evaluating 80 air samples. After culture enumeration and characterization of indoor bacterial species were done. The density and average bioaerosol concentration were measured based on studied wards. All samples were collected using blood agar and showed bacterial growth except control plates.

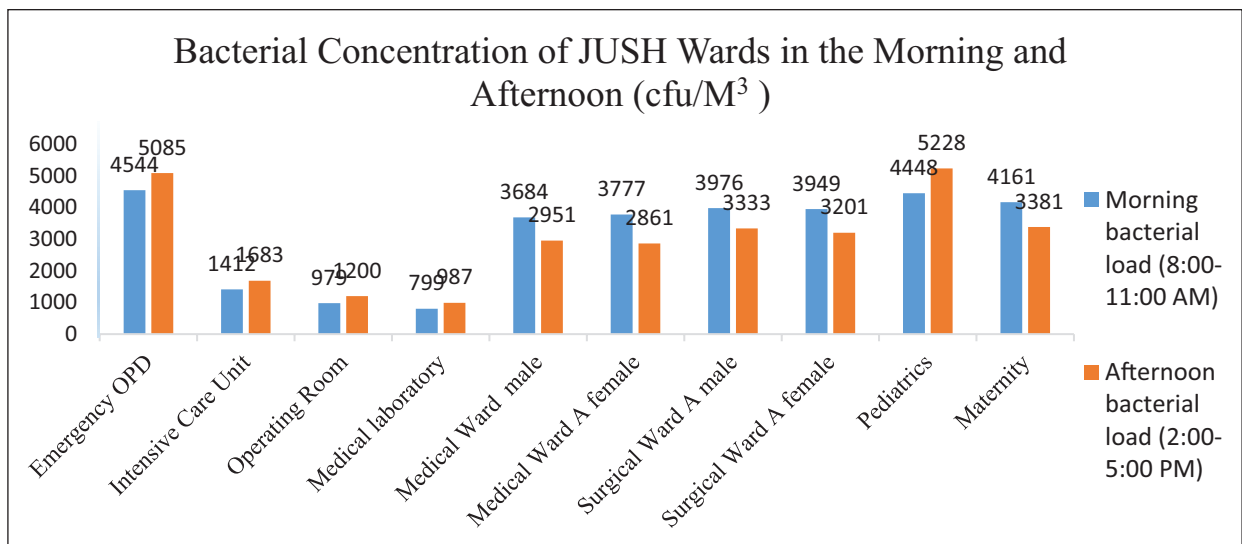
Environmental parameters and building condition of the hospital wards

Environmental parameters such as temperature ($23.75 \pm 2.92^\circ\text{C}$) and ambient relative humidity ($77.7 \pm 7.042 \text{ g/m}^3$) were measured. The mean room temperature and the relative humidity were 23.3°C and 76.35 g/m^3 , respectively. Most of the studied wards were characterized by poor waste management practice and unhygienic house-keeping conditions. Dry sweep was frequently used for all wards which facilitates the spread of bioaerosol into air and compromised the quality of indoor air. Based on the observations, the hospital had been doing housekeeping twice per day. Some of the wards infrequently use disinfectants like chlorine solution for cleansing the contaminated floor bun.

Table 1. Airborne bacterial load in (cfu/plate) all studied wards at Jimma University Specialized Hospital, 2020.

Wards or units	Number of colony forming units per plate in morning (8:00–11:00 a.m.)				Mean of cfu/plate	Number of colony forming units per plate in afternoon (2:00–5:00 p.m.)				Mean of cfu/plate
	MOP1	MOP2	MOP3	MOP4		AFPI	AFP2	AFP3	AFP4	
EOPD	448	416	444	404	428	600	504	412	400	479
ICU	128	148	132	124	133	170	156	148	160	159
OR	100	80	96	93	92	130	110	108	104	113
LAB	75	73	77	76	75	100	84	89	99	93
MEM	340	344	338	366	347	300	264	280	268	278
MEF	382	333	320	388	356	266	264	272	276	270
SURM	355	388	366	389	375	340	288	312	316	314
SURF	380	360	372	376	372	330	288	280	308	302
PED	440	400	424	412	419	450	400	480	640	493
MAT	400	380	392	396	392	350	304	300	320	319

EOPD: emergency outpatient department; ICU: intensive care unit; OR: operating theater; LAB: laboratory; MEM: medical male ward; MEF: medical female ward; SURM: surgical male ward; SURF: surgical female ward; PED: pediatrics; MAT: maternity; MOP: morning plate; AFP: afternoon plate.

**Figure 1.** Bacterial concentration of indoor air of Jimma University Specialized Hospital after 60 min time exposure, 2020.

Observational findings indicated that unlike hospital-acquired infectious diseases standard, ward floors, indoor furniture, and in and around were visibly dirty. The wards have been occupied by the number of beds, healthcare givers, patients and their relatives.

Bacterial load and prevalence in JUSH

A maximum bacterial load 640 cfu/plate was recorded in pediatrics ward at 2:00–5:00 p.m. for 60 min exposure, while 75 cfu/plate was the minimum bacterial concentration that were recorded in the laboratory room in the morning from 8:00 to 11:00 a.m. for 60 min exposure (see Table 1). The bacterial concentration had been determined by cfu/m³, and some variations were observed between wards. The

maximum bacterial load were registered in pediatrics (5228 cfu/m³), followed by the emergency OPD (5080 cfu/m³), which were highly crowded areas. However, ICU and operating room were recorded minimum bacteria load that were relatively characterized less populated areas. The concentration of bacteria in each examined wards were varied during morning and afternoon sample sessions (Figure 1).

Statistical significance test for mean bacterial concentration of wards

One-way ANOVA test was applied to obtain the mean bacterial concentration of wards. The high mean bacterial concentration was found (4814.22 and 4838.11 cfu/m³) in emergency OPD and pediatric wards, respectively. However,

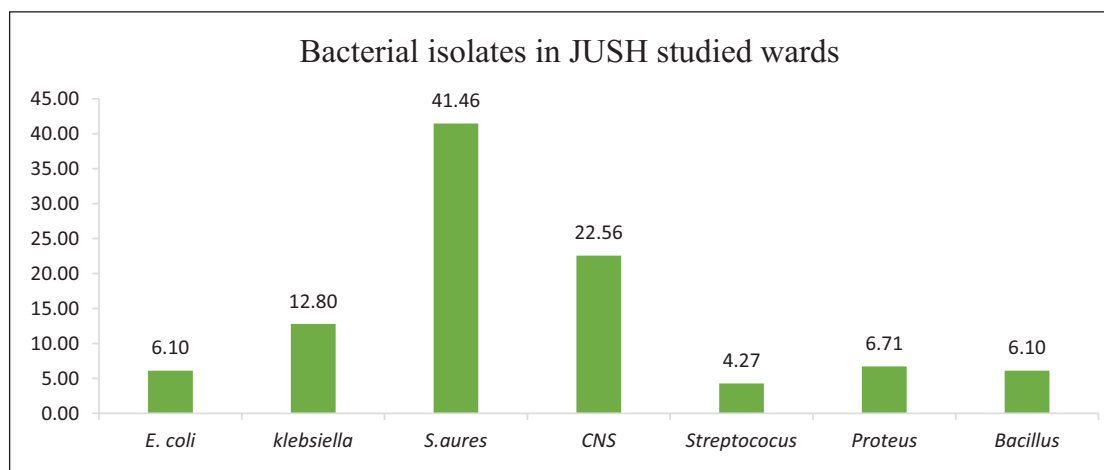


Figure 2. Percentage of detected bacteria as bioaerosols for Jimma University Specialized Hospital studied wards, 2020.

Table 2. The density of total bioaerosols concentration (cfu/m³) in studied hospital wards, Jimma town, 2020.

Hospital	Studied wards								Total average
JUSH	Emergency OPD	Intensive care unit	Operation room	Laboratory	Medical male	Medical female	Pediatrics	Maternity	
Total concentration	5559.99	1816.62	1304.41	1174.1	3825.6	3828.	5127.4	4215.8	3356.5

JUSH: Jimma University Specialized Hospital; OPD: outpatient department.

the minimum (895.05 cfu/m³) concentration was found in the laboratory room with total average concentration of 3081.87 cfu/m³. The ANOVA test result showed that the mean bacterial concentration was significantly different between wards based on data that were collected in morning and afternoon sessions.

Association of bacterial load and the level of indoor air pollution in JUSH

Time for sample collection was not significantly ($p > 0.05$) associated with bacterial load of the JUSH wards. The selected wards' pollution level was evaluated based on sanitary standards of the European commission for non-industrial premises. Based on the standard, the assessment result described that ICU and OR were highly polluted wards, meanwhile the remained eight wards were very highly pollution (>2000 cfu/m³).

Airborne bacterial isolates in JUSH

After morphological and colony characterization, Gram stains were conducted. As a result, 17 Gram-positive rods, 42 Gram-negative rods, and 105 Gram-positive cocci were isolated. The total 80 plates were analyzed for biochemical test, and 7 bacterial species were isolated from the test. *S. aureus* (41.46%) and coagulase-negative spp. (22.56%) were

the most frequently isolated species while *Streptococcus* spp. (4.27%) was the least prevalent Gram-positive species. Through the laboratory experiment, seven different bacterial species were isolated at JUSH wards (see Figure 2).

Total microbial load in wards

The gross density of average bioaerosol concentration in all wards was 3356.49 cfu/m³ in morning and afternoon sessions (see Table 2).

Discussion

The hospital wards had natural and mechanical ventilations in order to exit exhausted air. Indeed, it prevents the excess accumulation of indoor air contaminants in the wards. This encourages the health status of the patients and reduces the health threats of healthcare givers. Likely most hospitals with related conditions have been using similar pollution reduction mechanism as indicated in systematic review.^{15,16}

Studies conducted in northern Nigerian acute care hospital and South Sulawesi, Indonesia, had similar finding with maximum bacteria concentration in pediatric surgical ward (5228 cfu/m³), and the hospitals' indoor environment was contaminated as World Health Organization recommendations not to exceed 1000 cfu/m³ bacterial load.^{17,18} In the morning sampling session, the emergency (4544 cfu/m³) and

the pediatrics (4448 cfu/m³) wards had maximum bacterial concentration in comparison with other wards. In the afternoon sampling session, these wards also registered high bacterial concentration, emergency (5085 cfu/m³) and pediatrics (5228 cfu/m³), similar finding was seen in Ghana teaching hospital.¹⁹ The result of this study indicated that most of the wards were contaminated. Meanwhile, the level of pollution was greater than 2000 cfu/m³, and similar trends were seen in other studies.^{13,19}

The most frequently isolated organisms were *S. aureus*, coagulase-negative spp., and *E. coli* which had similar finding with study conducted in Indonesia.²⁰ In addition to frequent isolation *S. aureus* (41.46%) was highly enumerated species unlike a finding conducted in northwestern Nigeria.²¹ These disparities could be due to the different data collection sessions and periods, and sampling mechanisms. As a limitation, applying an automated equipment (mass spectrometry, molecular biology), drugs sensitivity test, measuring air velocity and surface area of the sample collection rooms, and power calculation for sample size estimation as well as controls selection is important for further studies in this area.

Conclusion

A poor environmental sanitation and hygiene practice in JUSH contributed for high hospital indoor air contamination. Consequently, this study result revealed that the bacterial load was beyond than an acceptable level of World Health Organization for hospital-acquired infections. As finding showed, the distribution pattern of the bacteria in this study will support for further hospital-acquired infectious diseases transmission, monitoring, and evaluation of strategy research works.

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Author contributions

Authors have equal contributions to this manuscript. They drafted, critically reviewed, and approved the final manuscript.

Availability of supporting data

Data will be available upon request.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

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References

- Manisalidis I, Stavropoulou E, Stavropoulos A, et al. Environmental and health impacts of air pollution: a review. *Front Public Health* 2020; 8: 14.
- Omoigberale MNO. Microbiological assessment of hospital indoor air quality in Ekpoma, Edo State, Nigeria. *Global Res J Microbiol* 2014; 4(1): 1–5, <http://www.globalresearchjournals.org/journal/grjm>
- Gizaw Z, Gebrehiwot M and Yenew C. High bacterial load of indoor air in hospital wards : the case of University of Gondar teaching hospital, Northwest Ethiopia. *Multidiscip Respir Med* 2016; 11: 24–27.
- Aliyu AS, Badawi AH, Umar NY, et al. Epidemiological study on hospital acquired infections and infection prevention and control among health care workers in Specialist Hospital Bauchi State, Nigeria. *ARC J Public Health Commun Med* 2020; 5(3): 1–13.
- Obakpororo E and Sandra A. Microbiological quality of indoor air of a general hospital and a health center in Rivers State Nigeria. *Int J Curr Microbiol App Sci* 2014; 3(12): 424–431, <http://www.ijemas.com>
- Naruka K, Charay R and Gaur J. Bioaerosols in healthcare settings: a brief review. *Int J Geol Earth Env Sci* 2017; 4: 59–64, <http://www.cibtech.org/jgee.htm>
- El-Sharkawy MF and Noweir ME. Indoor air quality levels in a University Hospital in the Eastern Province of Saudi Arabia. *J Family Community Med* 2014; 21(1): 39–47.
- Mandal J and Brandl H. Bioaerosols in indoor environment—a review with special reference to residential and occupational locations. *Open Environ Biol Monit J* 2011; 4(1): 83–96.
- Basharia A, Yousef A, Elshareef AAD, et al. Assessment of indoor air quality in medical facilities in Sudan. *Int J Sci Technol Res* 2013; 2(1): 1–4.
- Hoseinzadeh E, Samarghandie MR, Ghiasian SA, et al. Evaluation of bioaerosols in five educational hospitals wards air in Hamedan, during 2011-2012. *Jundishapur J Microbiol* 2013; 6(6): e10704.
- Sudharsanam S, Swaminathan S, Ramalingam A, et al. Characterization of indoor bioaerosols from a hospital ward in a tropical setting. *Afr Health Sci* 2012; 12(2): 217–225.
- Gilbert Y, Veillette M and Duchaine C. Airborne bacteria and antibiotic resistance genes in hospital rooms. *Aerobiologia* 2010; 26: 185–194.
- Shiferaw T, Gebre-silasse L, Mulisa G, et al. Bacterial indoor-air load and its implications for healthcare-acquired infections in a teaching hospital in Ethiopia. *Int J Inf Contr* 2016; 1996: 1–9.
- Cheesbrough M. *District laboratory practice in tropical countries*, vol. II. Cambridge: Microbiology Cambridge, pp. 26–196.

15. Limaylla DC, Silva MO and Fortaleza CMCB. Temperature, humidity, and climate control in hospital units: a clue for understanding the seasonality of healthcare-associated pathogens. *Infect Control Hosp Epidemiol* 2019; 40(7): 829–830.
16. Stockwell RE, Ballard EL, O'Rourke P, et al. Indoor hospital air and the impact of ventilation on bioaerosols: a systematic review. *J Hosp Infect* 2019; 103(2): 175–184.
17. Abubakar U. Point-prevalence survey of hospital acquired infections in three acute care hospitals in Northern Nigeria. *Antimicrobial Resistance and Infection Control* 2020; 9: 63.
18. Kishor Kumar S and Lokesh KS. Comparative study of microbiological air qualities of private and government hospitals in Mysuru city. *Int J Eng Sci Res Technol* 2018; 7(12): 357–365.
19. Larrey EK, Nii J, Laryea A, et al. Microbial load of indoor airborne bacteria and fungi in a teaching hospital in Ghana. *Afr J Microbiol Res* 2020; 14: 100–105.
20. Ikhtiar M, Alzad H and Paramita S. Microbiological assessment of indoor air of Takalar County hospital wards in South Sulawesi, Indonesia. *Science J Public Health* 2017; 5(3): 172–177.
21. Ilyyasu G, Dayyab FM, Abubakar S, et al. Laboratory-confirmed hospital-acquired infections: an analysis of a hospital's surveillance data in Nigeria. *Heliyon* 2018; 4(8): e00720.