Institute of Health Sciences

Faculty of Public Health

Department of Environmental Health Science and Technology

Infection prevention practice, microbial load, and associated factors at Jimma Medical Center, Southwestern Ethiopia

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A thesis submitted to the Department of Environmental Health Sciences and Technology, Faculty of Public Health, Institute of Health, Jimma University, in partial fulfillment of the requirements for the degree of Master of Science (MSc) in Environmental Health.

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Jimma, Ethiopia

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Summary

Background: Hospital environments are a source of healthcare-associated infections, which are mostly caused due to bacteria and fungi. The burden of healthcare-associated infections in low and middle-income countries is much higher and resulted in worse outcomes. It is essential to evaluate the status of infection prevention and control practices and the level of microbial load to design strategies and guidelines to avert the spread of infections related to healthcare.

Objective: The aim of this study is to evaluate the infection prevention practice, microbial load, and associated factors in selected wards at Jimma Medical Center.

Methods: A cross-sectional study was conducted in Jimma Medical Center from April 1 to June 22, 2022. Infection Prevention and control assessment framework tool was used to evaluate compliance with infection prevention and control practices. The settle plate method with a 1/1/1 scheme was used for indoor air sampling and swab samples were taken from inanimate surfaces and medical equipment. A total of 40 indoor air samples, 228 inanimate surfaces, and medical equipment samples were taken from 10 rooms. Multiple linear regression analysis was conducted to find the associated factors with the microbial load in the study area.

Result: From the findings of our study, the infection prevention and control practice score was 456 out of 800, which is an intermediate level. From the total sample, 181 (67.5%) were positive for culture. The mean bacterial and fungal load ranged from 124.4 to 1,607 and 96 to 814.6 CFU/m^3, respectively. A higher indoor air microbial load was detected during the morning time. Crowdedness [β = 2.748 (CI 95%: 1.057 – 4.44)], presence of waste material [β = 1.747 (CI 95%: .213 – 3.282)], and Unclean room [β = 2.505 (CI 95%: .990 – 4.019)] have a significant association with the microbial load.

Conclusion: The findings showed an intermediate level of infection prevention and control compliance at Jimma Medical Center. Almost all wards had intermediate levels of indoor air microbial load. The microbial load of inanimate surfaces and medical equipment was beyond the standard limit which will have an impact on health. Crowdedness, the presence of waste material, and unclean rooms were associated with the microbial load. Periodic infection prevention and control training for workers, and microbial surveillance of the hospital environment should be practiced.

Keywords: Infection prevention and control, Microbial load, Indoor air, Inanimate surfaces, Medical equipment, Jimma Medical Center

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List of Abbreviations and Acronyms

CDC: Center for Disease Control and Prevention

CFU: Colony Forming Unit

CONs: *Coagulase Negative Staphylococcus*

COVID-19: Corona Virus Disease 2019

HCAIs: Healthcare-Associated Infections

HMIS: Hospital Management Information System

IV: Intravenous

IPC: Infection Prevention and Control

IPCAF: Infection Prevention and Control Assessment Framework

JMC: Jimma Medical Center

LMIC: Low and Middle-income countries

LOS**:** Length of Hospital Stay

MICU: Medical Intensive Care Unit

NICU: Neonatal Intensive Care Unit

NIS**:** Nosocomial Infection

OR: Operating Room

PPE: Personal Protective Equipment

SEIPS: Systems Engineering Initiative for Patient Safety

Spp: Species

SPSS: Statistical Package for Social Science

USA: United States of America

WHO: World Health Organization

Chapter One: Introduction

1.1. Background

Infection prevention and control (IPC) is a realistic, evidence-based strategy that guards patients and health workers from being harmed by avoidable infections. Therefore, IPC is a key element in the provision of safe and high-quality services in healthcare facilities (WHO et al., 2016). There is a significant risk of contracting an infection from a contaminated Hospital environment due to inadequate practice of IPC (Biniyam et al., 2018). Healthcare-associated infections (HCAIs) often referred to as Nosocomial infections (NIs), occur within 48 hours or more following Hospitalization or within 30 days following the receipt of medical care (Revelas, 2012).

In a Hospital environment, microorganisms that cause HCAIs include bacteria, viruses, and fungi. However, more than 90% of them are due to bacteria (Jain & Kanwardeep, 2007). The most common organisms causing HCAIs reported are *Staphylococcus aureus (s. aureus), Coagulase-negative staphylococci (CONs*), *Klebsiella* species, *Pseudomonas aeruginosa*, *Escherichia coli (E.coli), and proteus* species that may come from the patient, contaminated instruments, and the environment (Dessie et al., 2016; Gelaw & Gebre-selassie, 2018).

The majority of HCAIs are thought to be spread directly from patient to patient. However, increasing data shows that medical staff and the clinical setting are frequently also sources of infections (Sebre et al., 2020). In modern healthcare, invasive procedures and surgery, indwelling medical devices, and prosthetic devices are linked with these infections (Sikora & Zahra, 2022).

Globally, around 1.4 million people worldwide suffer from a lack of clean and safe healthcare facilities (Jemal et al., 2020). In developed countries, about 5 to 10 percent of patients admitted to hospitals acquire one or more HCAIs. The prevalence of HCAIs is 2 to 20 times higher in developing countries (WHO, 2005). Both the endemic and epidemic burden of HCAIs poses serious threats to public health. However, evidence indicates that between 30 to 70 % of all HCAIs can be avoided (Storr et al., 2017).

Studies on microbial contamination of the Hospital environment in Ethiopia reported high microbial load and the isolated organisms are highly resistant to widely given medications. Even though a considerable number of HCAIs can be prevented with inexpensive and cost-efficient IPC techniques, evidence suggests that Ethiopian healthcare facilities lack effective IPC programs (Sahiledengle et al., 2021).

With the availability of limited data on IPC practice and microbial load status in the study area, this study aimed to determine IPC practice and the degree of microbial contamination from air, inanimate surfaces, and medical equipment samples of selected wards at Jimma Medical Center (JMC).

1.2. Statement of the problem

IPC is a cross-cutting issue in health care. Strong, effective IPC programs can influence the quality of care, improve patient safety and protect all those providing care in the health system, and reduce HCAIs (WHO, 2019). However, adherence to the recommended IPC strategies in low and middle-income countries (LMICs) is generally suboptimal across a wide variety of settings (Weinshel et al., 2015).

A global survey done by WHO in 2019 including 81 countries revealed that the implementation of IPC core components ranges from "inadequate" to "advanced", with significantly lower scores in lower and middle-income countries compared with developed countries (WHO, 2022).

Microbial contamination of the indoor hospital environment, especially in an operating room, intensive care unit, and other specialized wards continued to escalate the burden of HCAIs. which resulted in high morbidity and mortality rate for patients (Napoli et al., 2012).

Out of every 100 Hospitalized patients, 15 patients in LMICs and 7 patients in developed countries acquire at least one HCAI. According to (Magill et al., 2021; Suetens et al., 2018)**,** HCAIs affect 3.2% of all Hospitalized patients in the United States and 6.5% in the European Union/European Economic Area**.** In low-income countries prevalence of HCAIs varies from 5.7% to 19.1%. In Ethiopia, the pooled prevalence of HCAIs was 16.96% (Alemu et al., 2020), and 19.41% in Jimma (Ali et al., 2018).

An international study showed that the overall hospital mortality rate of patients with HCAIs was doubled (30%) versus those without HCAIs 15% (Vincent et al., 2009). A national study in the United States of America (USA) estimated that HCAIs-related death was 98,987 (Klevens et al., 2007)**.** According to European Centre for Disease Prevention and Control (CDC), 91,310 deaths were estimated to have occurred in acute-care Hospitals (Cassini et al., 2016).

The additional length of Hospital stay (LOS) in patients with and without HCAIs was 26.3 and 5.69 days in USA Hospitals, respectively (Shepard et al., 2020). The additional LOS due to HCAIs in developing countries was reported between 5 to 21 days (Ling et al., 2015)**.**

According to the United States (US) Centers for Disease Control and Prevention, the overall annual direct medical costs of HCAIs to Hospitals in the USA alone range from US$ 35.7 to 45 billion, while the annual economic impact in Europe was as high as € 7 billion (Storr et al., 2017).

Studies on the microbial quality of wards of healthcare facilities in Ethiopia are scarce, but the few available ones documented unacceptably high bacterial load (Fekadu & Getachewu, 2015; Genet et al., 2011; Kayta et al., 2022). National IPC guideline has been developed for healthcare facilities in Ethiopia. However, the obedience of the healthcare providers to the protocol is quite limited (Shiferaw et al., 2016). This may play a significant role in poor microbiological quality in different wards of Hospitals (Abdollahi & Sanam, 2012).

The microbial load in healthcare facilities is affected by several factors including poor ventilation, occupants, their activity, high dusting, overcrowded, across spread through sneezing and coughing, the outdoor microbial load, and poor IPC practices (Gola et al., 2019; Weber et al., 2013).

In Jimma, no study was conducted on fungal load from a sample of medical equipment and inanimate surfaces; it was done from an indoor air sample. There is also a difference in the tool used to assess IPC practice in this study from the previous studies in Jimma. In this study, the core components of the current WHO IPC practice were assessed. Whereas, the other study used the systems Engineering Initiative for Patient Safety (SEIPS) model tool to assess IPC practice. The previous studies were also conducted on the old Hospital building. Where, currently the Hospital has moved to a new building that has multiple OR rooms, ICU, and wards. Therefore, this study was carried out to determine the level of infection prevention practice, microbial load, and associated factors in JMC.

1.3. Significance of the study

The finding of this study will help to evaluate infection prevention measures under implementation, microbial contamination, and associated factors with microbial load at JMC and indicative of other similar settings. It will be supportive evidence for implementing evidence-based decisions for the Hospital, give insight and equip health professionals, policymakers, and health planners to develop innovative, culturally sound interventions. It will also be additional information for those who would like to conduct further study in other areas.

Chapter two: Literature review

2.1. Infection prevention and control practice

A global survey by WHO among 81 countries revealed the median IPCAF score of 657.5 (advanced level) in high-income countries (Tomczyk et al., 2022). A national survey in Germany showed a median score of 690 among 736 Hospitals which is an advanced-level IPC implementation (Aghdassi et al., 2019). Similarly, in a survey 65 of Austrian Hospitals, the median IPCAF score was 620 which is an advanced level of IPC (Johannes et al., 2020).

A cross-sectional study in India showed a median IPCAF score of 620 among 32 tertiary care Hospitals, 28% had intermediate and 59% had advanced IPC practices, the results indicated that the multimodal strategies, workload, staffing, and bed occupancy components were the weakest (Rupali, 2021). A cross-sectional survey in Islamabad showed an IPCAF score of less than 200 among all 5 public Hospitals included, with a median score of 117.5 indicating an inadequate level of IPC practice (Savul et al., 2019).

A survey by WHO showed significantly lower scores of IPCAF implementation in low and middle-income countries, in low-income 385 (279.7-442.9) and lower-middle-income countries 500.4 (345.0-657.5). Only 15·2%, 588 of 3873 facilities met all IPCAF minimum requirements (Tomczyk et al., 2022).

A cross-sectional study conducted in Ghana (five of the WHO IPCAF components were used) reported 41.1% basic and 32.1% Intermediate level of IPC practice in 56 acute healthcare facilities. From surveyed facilities, 50% had IPC programs that were not clearly defined and understood by healthcare workers, 64.3% do not have annual training related to updated IPC guidelines, only 21 facilities had a dedicated budget for IPC activities, Only 24 facilities had water services available every day and of sufficient quantity and materials like detergents, running water and personal protective equipment was not properly supplied (Oppong et al., 2020). A quasi-experimental study in Nigeria showed the IPC compliance score climbed from 318.5 to 545 after three months of IPC education and training. The least improvement was recorded in the built environment, materials, and equipment for IPC components, and also, surveillance on HCAIs was sub-optimal both before and after the intervention (Ilesanmi et al., 2020).

A cross-sectional study among eight Hospitals in sub-Saharan Africa revealed a WHO-IPCAF score of 402.5, 305.7, 542.5, 452.5, 377.5, 687.5, 542.5, and 155 with a median score of 428, which is an "intermediate" overall level of IPC compliance (Aiken et al., 2022). A cross-

sectional study in Uganda Lira University Hospital showed the overall IPC compliance score was 225/800 (28.5%). which is a basic IPC compliance level. The identified gaps were no established IPC committee, IPC team, budget, training was rarely/never given, no surveillance and personal protective equipment were not sufficient (Opollo et al., 2021).

A meta-analysis of ten studies from different regions of Ethiopia with an aggregate study sample of 3,510 participants showed the pooled prevalence of safe IPC practice among healthcare workers in Ethiopia was 52.2%. The highest safe practice was observed in Addis Ababa 66.2% (Sahiledengle et al., 2021). A Hospital-based cross-sectional study in southeast Ethiopia showed 21.6% of 660 health professionals in public Hospitals had good compliance with IPC measures (Zenbaba et al., 2021). A qualitative study conducted at Jimma medical center in 2017 reported Irregular/inadequate IPC training, shortages of personal protective equipment (PPE), and high workload were major barriers to IPC implementation (Kenzie et al., 2017). A Cross-sectional study in Jimma showed 35.09% of 231 Nurses have poor adherence to IPC measures (Bekele et al., 2018).

2.2. Microbial load in different hospital units

In a study conducted in Greece, a tertiary university Hospital among 101 air samples, the highest mean total microbial load was observed in internal medicine (689 CFU/m^3), followed by the surgical ward (596 CFU/m^3), neonatal unit (509 CFU/m^3) and ICU (353 CFU/m^3). Also 158 Gram-positive and 44 Gram-negative bacteria were isolated, the majority of Gram-positives were Staphylococcus spp, and the highest *Staphylococcus* load was detected in ICU (Tselebonis et al., 2020).

A study in South Korea showed the mean level of airborne bacteria was (7.2×10^2 CFU/m^3), gram-negative (1.7×10 CFU/m^3), and fungi (7.7×10 CFU/m^3) (Park et al., 2013). A prospective study in Portugal revealed emergency service's highest airborne microbial load of 240 -736 CFU/m^3 and a fungal load of 27-933 CFU/m^3). Bacterial load in the surgical ward 99-495 CFU/m^3) and the operating theatre 12-170 CFU/m^3 (Cabo Verde et al., 2015).

A study in Mexico detected gram-negative bacteria and fungi from indoor air, the predominant bacteria were; *Klebsiella spp, Pseudomonas spp,* and *E. coli spp*. The identified fungi were; *Cladosporium spp, Microsporum canis, Aspergillus spp*, and *Penicillium spp* (Garcia-Cruz et al., 2012). In Nepal, out of 16 indoor air samples, 47.18% of *S. aureus* and 1.82% *Pseudomonas* spp were detected (Kunwar et al., 2019). In a three months cross

sectional study in India, indoor air bacterial load range from 65.52 CFU/ m^3 to 1179 CFU/ m^3 (Kotgire et al., 2020).

A study conducted in Sokoto Hospital North-Western Nigeria among 160 inanimate samples showed a total of 258 bacteria were identified, *S. aureus* 30.2%, *Proteus vulgaris* 17.8%, *P. aeruginosa* 12.%, *E. coli* 11.6%, *Bacillus cereus* 11.6%, *Klebsiella species* 5%, *Salmonella species* 4.3%, *Shigella species* 4%, and *Proteus mirabilis* 3.5% (Muhammad et al., 2013). Another study in Nigera hospital with 201 surface swab samples showed 70% contamination rate. *S. aureus* was the commonly isolated at *39.4%* and *Pseudomonas aeruginosa* has the lowest frequency 1.3% (Saka et al., 2016).

A cross-sectional study in Uganda among operating theatres on both surface and air samples showed 23.9% *Pseudomonas spp,* 17.5% *Bacillus spp,* and 15.8% *Aspergillus spp.* Overall, OR air sample was more contaminated than the surfaces, *S. aureus,* and *CoNs* were high (Matinyi et al., 2018). Another cross-sectional study in Uganda among 138 medical equipment and work surface showed 44.2 % contamination rate. *S. aureus* and *Klebsiella pneumoniae* accounted for the highest bacterial contaminants constituting of 75.4% and 11.5% respectively (Sserwadda et al., 2018).

A cross-sectional study in Bahir Dar among 356 surface and air samples showed 39.6% had bacterial growth. The mean bacteria load of indoor air ranged from 135.8 CFU/dm^2 to 721 CFU/dm^2 and for surface samples from 14.8 CFU/cm^2 to 48.8 CFU/cm^2. Gram-positive isolates were 81.6%, while the gram negatives were (18.4%). The main isolates were *CONs* 44%, *S. aureus* 37.4%, and *Klebsiella spp* 11.6% (Getachew et al., 2018). A study in Gondar from 14 randomly selected wards showed that bacterial load ranged from 583.5 - 1271 (Gizaw et al., 2016). A recent cross-sectional study in Arba Minch among 240 air samples showed the mean bacterial load was 1914 ± 1081.4 CFU/m^3 and fungi load was 1533.7 ± 858 CFU/ m^3. Gram-positive bacteria were the predominant type 56.7%, particularly the isolates of *S. aureus* 20.1%. While predominant fungal isolates were *Aspergillus spp* 38% (Kayta et al., 2022).

A cross sectional study in Hawassa among 120 air samples showed *S. aureus* 30% and *CONs* 28.3% were the predominant species (Mengistu et al., 2016). A cross-sectional study among 72 indoor air samples in Dilla reported the mean bacterial concentration ranges from 450-1585.83 CFU/m^3. A high indoor air bacterial load was found in 80.6% of the samples. Gram-positive bacteria were the most common 71%. Also, Fungal growth was found in 90.3% of the samples (Ashuro et al., 2022). A cross-sectional study in Wolaita Sodo university teaching

and referral Hospital among 216 air samples showed 90.2% culture positive. *CONs* 29.6%, *S. aureus* 26.3%, *Enterococci* species, *Enterococcus faecalis* and *Enterococcus faecium* 16.5%, *Acinetobacter* spp 9.5%, *E. coli* 5.8% and 5.3% were commonly isolated (Solomon et al., 2017).

Another cross-sectional study in Hawassa among 229 samples from medical equipment, inanimate surfaces, and air reported microbial contamination of 74.7%. The most prevalent bacteria were *Micrococcus spp* 41.3%, *Acinetobacter spp* 13.7%, and *Klebsiella pneumonia* 10.2% (Bitew et al., 2021). A cross-sectional study in Arba Minch among 99 inanimate objects and patient-care equipment reported a 71.7 % level of contamination. The prevalent bacteria were *CoNs* 52.2%, followed by *S. aureus* 47.7%, whereas, common Gram-negative bacteria were *Acinetobacter spp* 28.5% and *Klebsiella spp* 23.8% (Birru et al., 2021). A study in Tikur Anbessa Specialized Referral Hospitals, Addis Ababa among 136 medical devices found to be 60.3% contamination, and 84.7% gram positive bacteria, 4.5% were gram negative bacteria and 10.8% were fungi (Dabsu et al., 2014). Similarly, another study using 164 swabbed samples 86% were culture positive. 56.3% were gram- positive bacteria. *S. aureus* 34.4%, *CoNs* 15.3%, and *Bacillus spp* 3.3% were the dominant isolates (Sebre et al., 2020). In Mekelle a study among 130 swab samples showed 88.5% were culture positive. *CONs* 34.9%, *S. aureus* 26.3%, *Citrobacter freundii* 9.2% and *Klebsiella pneumoniae* 8% were the most commonly isolated bacteria (Darge et al., 2019).

A cross-sectional study among 108 air samples from ORs and the surgical ward in Jimma showed the indoor air bacterial load ranged from 28 CFU/hr. to 465 CFU/hr. *S. aureus* was the most frequently isolated species (Genet et al., 2011). Another cross-sectional study in Jimma among 84 air samples reported bacteria and fungi loads ranged between 2123–9733 CFU/m^3 (Fekadu & Getachewu, 2015).

2.3. Factors affecting microbial load

An observational study among 4 different ORs in a large academic hospital in the United States was conducted to identify factors influencing microbial load in the OR. the results showed microbial load was affected by the time of year, and physical movement of people in the same area but not with the number of door openings and the number of people in the OR (Taaffe et al., 2018).

A prospective observational study in 28 ORs of a medical center in Taiwan showed that the type of surgery, the site of the procedure, the number of indoor staff, the stage of surgical

procedure, and the temperature had a significant influence on bacterial count (Shaw et al., 2018).

A study in an Iran hospital equipped with advanced heating, ventilating, and air conditioning system showed Pearson's correlation Temperatures, relative humidity, Working shifts, and season had no significant impact on bacterial load (Mousavi et al., 2019).

A cross-sectional study in Harar, Ethiopia showed that the odds of higher bacterial load were 8.9 times higher for rooms with improper storage of food, drug, and personal staff and 4.4 times higher for improper usage of ventilation, 12.9 times for soiled working areas, 7 times for improperly sealed waste container, 7.5 times presence of flies (Abebe & Kumie, 2017). A cross-sectional study done in Arba Minch, Ethiopia showed that intense room traffic, as well as inappropriate storage of food and drug items and unclean environment around the wards, raised the indoor air microbial load level by 9.6, 7.5, and 5.8 times respectively (Kayta et al., 2022).

2.4. Conceptual framework

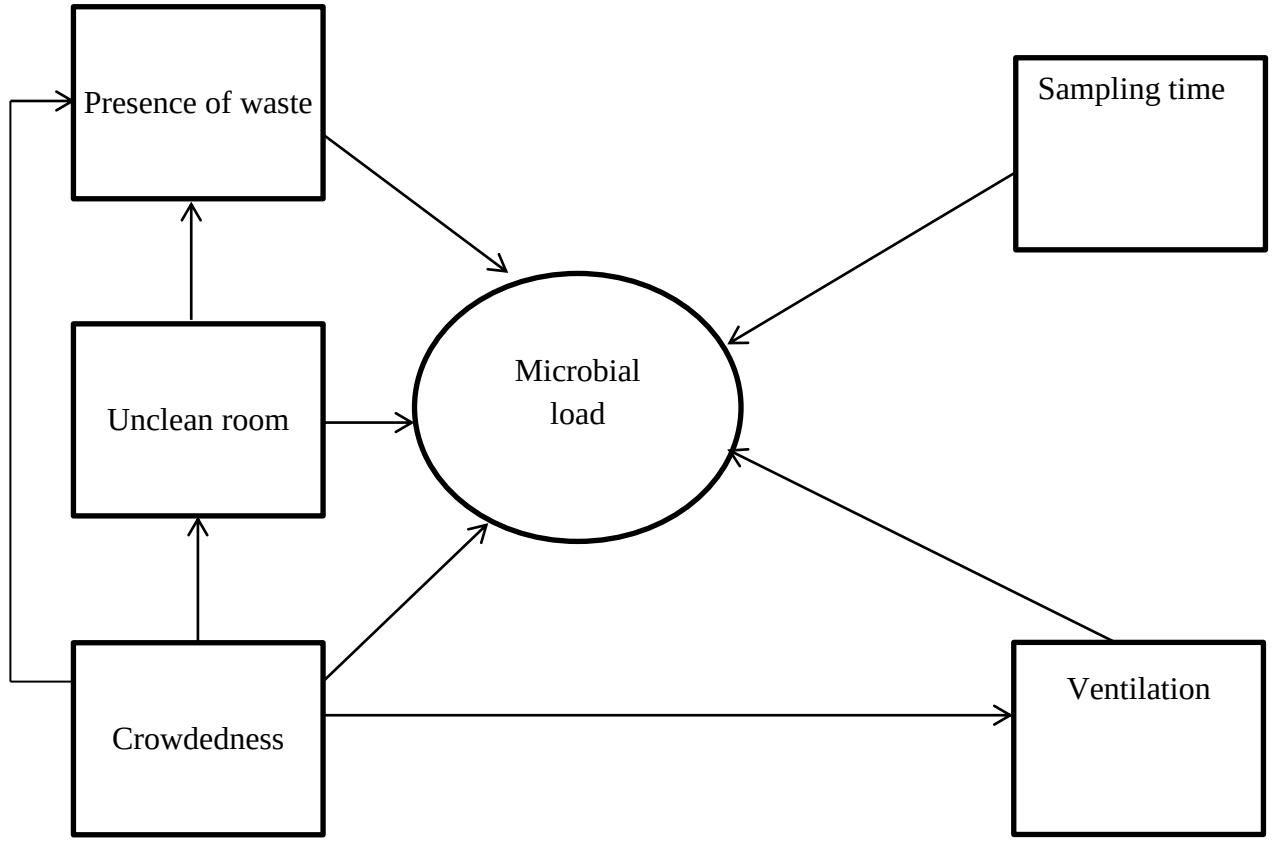

Figure 1. Conceptual framework.

Chapter Three: Objectives

3.1. General Objective

- To evaluate IPC practice, microbial load, and associated factors in selected wards of Jimma Medical Center (JMC).

3.2. Specific Objectives

- To determine IPC practices at Jimma Medical Center.
- To determine microbial load using selected indicator organisms at selected wards of Jimma Medical Center.
- To assess factors affecting microbial load at the selected wards of Jimma Medical Center.

Research questions

- What is the current status of IPC practice in JMC?
- What is the microbial load status of wards in the new building of JMC?
- What are the contributing factors for the difference in microbial load?

Chapter Four: Methods and materials

4.1. Study area

The study was conducted in the Oromia region, Jimma zone, Jimma city, at Jimma Medical Centre (JMC). JMC is 354 km from the capital Addis Ababa in the southwest of Ethiopia (Tilahun et al., 2022). It is one of the teaching and referral Hospitals in the country, with a total 800-bed capacity. JMC is a tertiary-level referral Hospital that provides inpatient, outpatient, and emergency and chronic clinic follow-up services for an estimated 15 million people annually in the southwest part of the country (HMIS data, 2022).

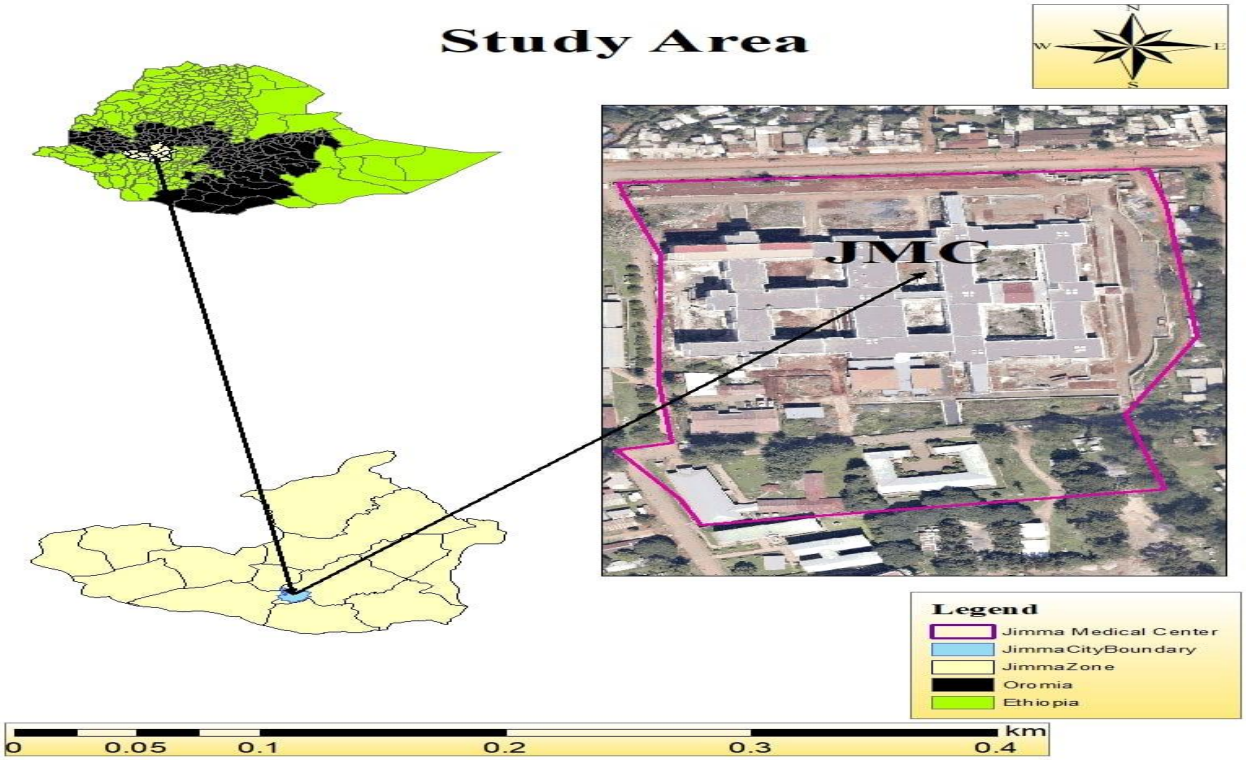

Figure 2. Map of study area.

4.2. Study design and period

A cross-sectional study was conducted from April 1 to June 22, 2022.

4.3. Population

4.3.1. Source population

To assess IPC practice the hospital IPC unit was interviewed. It contains two occupational health and safety professionals, and one reproductive health professional. To detect microbial load the pediatric ward, intensive care units (ICU), and operation rooms (OR) were selected purposively by considering the high-risk nature of the patients admitted to these wards due to

their weak immunity and open wounds from operation (Demissie et al., 2009; Endalafer et al., 2011). JMC has 7 pediatric ward rooms. 4 intensive care units (ICU) which are: 1 Pediatric ICU (PICU), 1 medical ICU (MICU), 1 Surgical ICU (SICU), and 3 Neonatal ICU (NICU) rooms, and 9 operating rooms (OR) of which 7 were functional during the study period.

4.3.2. Sample population

For the determination of microbial load, we have collected samples from indoor air, inanimate surface, and medical equipment of the pediatric ward, MICU, NICU, and OR. The samples were selected by considering different factors like their representativeness of the environment targeted and the study objective. A total of 10 rooms were selected randomly using the lottery method from our source population. Which were 3 pediatric ward rooms, 3 OR, and 2 ICU units from the four units which were MICU and NICU. The MICU had 1 room while NICU had 3 rooms.

4.4. Study variables

Dependent variables

- Microbial load
- IPC practice

Independent variable

- Sampling time
- Ventilation
- Unclean room
- Presence of waste
- Crowdedness (number of occupants/room area)

4.5. Sample size and sampling technique

4.5.1. The sample size for indoor air

The sample size was determined by taking into account the factors such as sampling site, and time (Pasquarella et al., 2000). Two indoor air samples were collected per day from each room with 2 reputations which are (2*10*2 = 40) air samples.

4.5.2. The sample size for inanimate surfaces and medical equipment

Samples of inanimate surfaces and medical equipment were taken from those which have frequent contact with patients and healthcare providers. (175) inanimate surfaces and (53)

medical equipment such as (floor, walls, sink, IV stand, operation tables, cylinder, incubator, and trolley) were included. Accordingly, a total of 228 samples were taken.

4.5.3. Sampling technique

The sampling techniques used for this study were purposive sampling to select the wards followed by simple random sampling.

4.6. Sample collection and analysis

4.6.1. Indoor air sampling and analysis

Indoor air samples were collected by the Settle Plate Method, according to the 1/1/1 scheme (for 1 hour, 1 meter above the floor, about 1 meter away from the walls or any major obstacles) (Pasquarella et al., 2000). A Petri dish containing 5% sheep blood agar and Sabouroad dextrose agar was used for total bacterial and fungal load count. For gram-negative and gram-positive bacteria isolation, MacConkey agar, and Mannitol salt agar were used. Sampling was done in the morning (10:00-11:00 am) and the afternoon (3:00-4:00 pm). Culture media were prepared according to the manufacturer's instructions, and sterility was confirmed by incubating at 37°C for 24 hours and observing for growth.

After sampling all samples were labeled properly and transported to the medical microbiology laboratory at Jimma University using an ice box. Each plate was incubated for 24 hours at 37°C under aerobic conditions for bacterial growth and while the fungal culture plates were incubated at 28 °C for 3-5 days (Ekhaise et al., 2010). Colony-forming units (CFUs) were counted using a colony counter. After counting the CFU/m^3 was calculated using Omeliansky's equation (Kayta et al., 2022).

$N=5a\times10^4\ (bt)^{-1}$

Where N = microbial CFU/m^3 of indoor air a = number of colonies per petri dish

b = dish surface area (cm^2) t = exposure time (minutes)

Gram staining was performed on a sample taken from culture after overnight incubation using Crystal violet (as an initial stain), Gram's iodine (as a mordant or binding agent), acetone alcohol (as a decolorizer), and Safranin (as a counter stain) to identify gram-positive and gram-negative bacteria. Then confirmatory tests for *S. aureus, CONs,* and *Klebsiella* species (Cheesbrough, 2006), and *Aspergillus species of* fungi were conducted.

4.6.2. Swab Sampling and analysis

Sterile cotton-tipped applicator sticks, moistened with sterile normal saline, was used to collect swab specimen (Garcia-Cruz et al., 2012). A 10x10 cm^2 area was used for sampling and for smaller surfaces or equipment the surface area was approximated and the whole area was swabbed. High-touch areas of different inanimate surfaces and medical equipment were sampled in this study. The swabs were rotated with firm pressure over the target areas and then repeated at perpendicular angles for maximum recovery. One swab was used for each surface. Samples were taken in the morning and afternoon sections. Samples were labeled properly and transported to the medical microbiology laboratory at Jimma University using an ice box within 30 minutes and processed immediately (Saka et al., 2016). For a more accurate count samples were vortexed to release the microbes from the swab. A total of 100 µL of the original swab suspension and 100 µL of the two dilutions were then inoculated on nutrient agar and Sabouroad dextrose agar for total bacterial and fungal colony count. Mannitol salt agar, and MacConkey agar for gram-positive and gram-negative bacteria isolation using a sterile spreader. Samples were incubated at 37 ^{0}C for 24 hours for bacteria and 28°C for 3-5 days for fungi (Garcia-Cruz et al., 2012). The number of colonies was counted from the plate dilution with the most countable number and multiplied by the appropriate dilution factor, and then divided by the area swabbed (100 cm^2) to express the colony count as CFU/cm^2 (Public Health England, 2017).

Gram staining was performed on a sample taken from culture after overnight incubation using Crystal violet (as an initial stain), Gram's iodine (as a mordant or binding agent), acetone alcohol (as a decolorizer), and Safranin (as a counter stain) to identify gram-positive and gram-negative bacteria. Then confirmatory tests for *s. aureus, CONs, E. coli, Klebsiella* species, *Pseudomonas aeruginosa (P. aeruginosa)* (Cheesbrough, 2006) and *Aspergillus species of fungi* was conducted.

4.6.3. Biochemical tests

For both air and swab samples, confirmatory tests were conducted for the selected microorganisms. *S. aureus and CONs.* were identified by catalase and coagulase test. Identification of Gram-negative bacteria was performed for pure colonies sub-cultured on nutrient agar for final identification of the isolates (Cheesbrough, 2006). Identification was based on their characteristics or reaction on Kligler's Iron Agar, indole, H_2S production, citrate agar, lysine decarboxylase agar, and oxidase after 24-hour incubation. Indole test for

E.coli, oxidase test for *Pseudomonas aeruginosa*, and citrate utilization test for *Klebsiella* species identification of bacteria were performed (Cheesbrough, 2006).

The identification of fungal colonies (*Aspergillus spp)* was conducted by visual and microscopic examinations. Visual emergence of fungal colonies arises on the 3^{rd} to 5^{th} days, from the incubation 28 °C. A compound microscope was used to determine the colonial feature and morphological structure of *Aspergillus spp*, morphology was determined by mounting the material in Lacto phenol and cotton blue.

4.6.4. Data collection for IPC and factors associated with microbial load

4.6.4.1. Data collection for IPC

The infection prevention and control assessment framework (IPCAF) is a close-formatted and structured questionnaire to which a scoring system has been assigned. The IPCAF has been structured in tandem with the World Health Organization (WHO) guidelines regarding the core components of IPC programs at the health facility. The tool has eight core components:

Core component 1: IPC program

Core component 2: IPC guidelines

Core component 3: IPC education and training

Core component 4: Healthcare-associated infection (HAI) surveillance

Core component 5: Multimodal strategies for implementation of IPC interventions

Core component 6: Monitors, and audits of IPC practices and feedback

Core component 7: Workload, staffing, and bed occupancy

Core component 8: Built environment, materials and equipment for IPC at the facility level.

Points are allocated to individual questions depending on their importance in the context of the component being assessed. The overall score for all components is 800. The overall score obtained across the eight subsections is therefore used to assign the health facility to one of the four levels of IPC practice (WHO, 2018):

- Inadequate (scores 0-200) implies that IPC core components implementation is deficient. Significant improvement is required.
- Basic (scores 201 -400) means that some aspects of the IPC core components are in place but not sufficiently implemented.

- Intermediate (scores 401-600) indicate the proper implementation of most aspects of the IPC core components but there is a need for an improvement in the facility's scope and quality of implementation.
- Advanced (601-800) shows the full implementation of the IPC core components by a health facility in tandem with the WHO's recommendations. (WHO, 2018).

Data were collected by two BSc Environmental health professionals from the 3 IPC unit members of JMC using joint evaluation (Ilesanmi et al., 2020).

4.6.4.2. Observational assessment

A checklist was used to assess the contributing factors such as sampling time, ventilation system (natural or mechanical), crowdedness, unclean room, and presence of waste material in the room. Data were collected during each sampling time in all selected rooms (Abebe & Kumie, 2017; Kayta et al., 2022).

4.7. Operational definition

Indoor air: The air inside the rooms of the pediatric, MICU, NICU, and OR.

Inanimate surface: items like bed rails, tabletops, trolley, OR lamps, OR tables, walls, floors, locker, light switches, chairs, tables, sink, and door handles.

Medical equipment: Items involved in patient care, like Patient monitors, IVs, incubators, radiant warmers, phototherapy machines, cylinders, Suction machines, and anesthesia machines.

Crowdedness: Number of occupants per room area (m^2) (Abebe & Kumie, 2017).

Unclean room: Condition with soiled floor and wall, drawers, and table that have left items indicate the unclean room.

European Commission for non-industrial premises sanitary standard for the bacterial load (Wanner, H.U., & Gravesen, 1993)**:** A bacterial load of less than 50 CFU/m^3 is considered “Very low,” 50 to 100 CFU/m^3 is “Low,” 100 to 500 CFU/m^3 is “intermediate,” 500 to 2000 CFU/m^3 is “High,” and more than 2000 CFU/m^3 is “Very high”..

For the surface sample acceptable limits of microbial load, at < 5 CFU/cm^2 (Dancer, 2004).

4.8. Data analyses procedure

Data were coded by assigning a unique identification number. The Data were entered into Epi-data version 3.1 then cleaned and exported to Statistical Package for Social Sciences (SPSS) version 26 for further analysis. The generated data were compiled and presented using

descriptive statistics. All variables were transformed to log (x + 1) to fit the multiple linear regression model that was used to determine factors affecting the microbial load.

For the multiple linear regression model $p < 0.05$ was considered a significant association with the microbial load.

4.9. Data Quality management

Before the actual sample collection, training, and discussion with sample collectors and laboratory professionals were organized by the principal investigator. To keep the quality of the samples starting from the preparation of media, sample collection to analysis, aseptic techniques including sterilization of sampling equipment, culture media preparation following manufacturer's instructions, and media sterility was confirmed by incubating at 37°C for 24 hours and observing for growth, use of controls during sample collection from randomly selected rooms, personal protective clothing, gloves, facemask, sample label, and ice box to transport the sample was used.

4.10. Ethical Consideration

Ethical clearance was initially obtained from the Institutional Review Board (IRB) of Jimma University with IRB. No 440/22. Approval to conduct the study was also obtained from the Hospital administration.

4.11. Dissemination of the study

The findings of this study will be presented to Jimma University Institute of Health Science Department of Environmental Health Science and Technology. In addition, efforts will be made to publish the results in national and international journals.

4.12. Limitations of the study

Shortcomings of our work include the inability to identify additional bacterial and fungal species due to resource limitations.

Chapter five: Results

5.1. Infection prevention and control practice

The overall IPC compliance score was 456 out of 800, which equates to an 'intermediate' level of compliance. For the individual components of IPCAF, scores ranged from 25 to 90. The highest and lowest compliance was observed in the "Infection prevention and control guideline and healthcare-associated infection surveillance components respectively (figure 3).

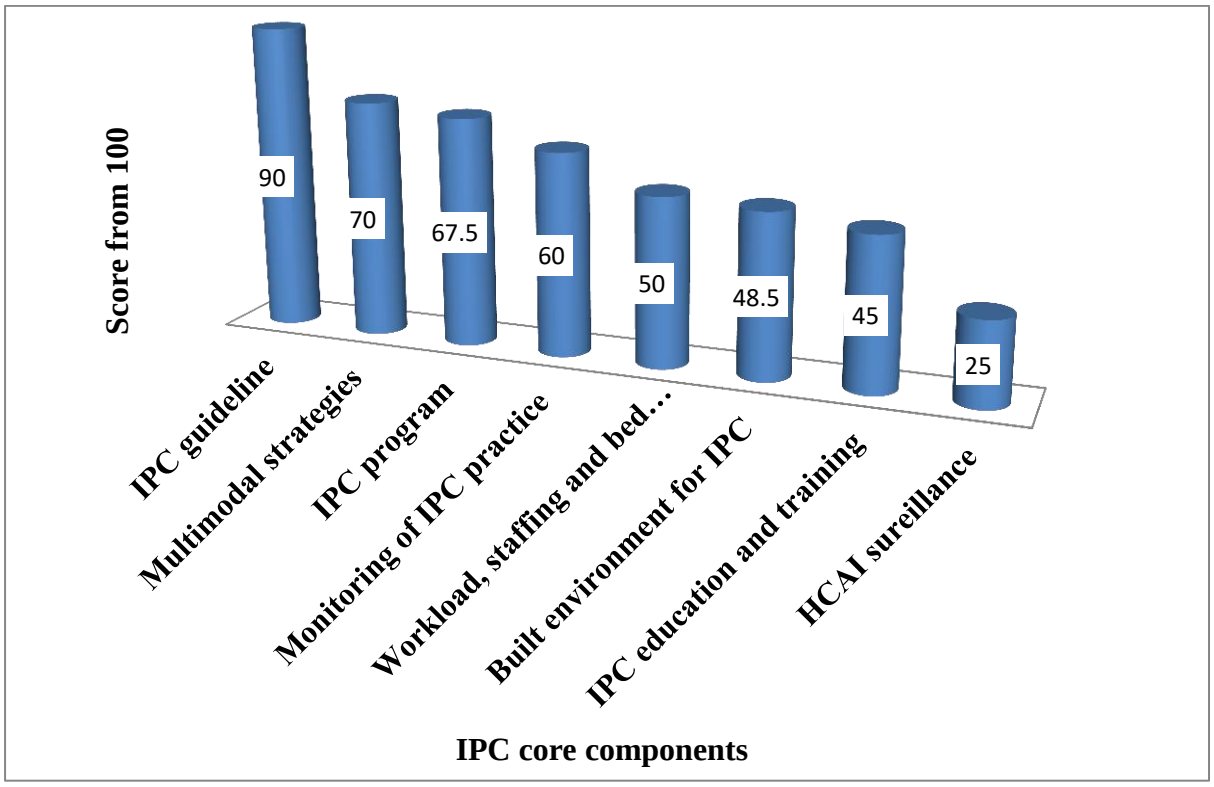

Figure 3. IPCAF result of JMC, 2022.

JMC has an IPC program with clearly defined objectives. The facility IPC team comprised 3 IPC personnel supporting IPC programs in the facility. However, there is shortage of dedicated budget for IPC-related activities. Identified strengths and gaps are described in table 1.

Table 1. Strength and gaps in IPC according to the IPCAF tool at JMC, 2022

Variables	Strength	Gap
IPC program	• Availability of IPC team • IPC committee • Clearly defined objectives and annual activity plan	• No clear commitment and support for the IPC program by senior facility leadership
IPC Guidelines	• Availability of guidelines that are consistent with national/international guidelines	• Healthcare workers have not received training related to new or updated IPC guidelines introduced in the facility
IPC education and training	• Personnel with IPC expertise to lead the training and additional non-IPC personnel with adequate skills to serve as trainers and mentors (link nurses or doctors, champions) present • Some personnel are trained using interactive training sessions (e.g., simulation, and bedside training)	• Annual training for health care workers but not mediatory • Only new employee orientation for other personnel • No IPC training for administrative and managerial staff • IPC training is not integrated with the clinical practice and training of other specialties • No specific IPC training for patients or family members • No periodic evaluation of the effectiveness of training programs • No ongoing development/educational program is offered for IPC staff
Healthcare-associated infection surveillance	• Surveillance is a defined component of the IPC program • Surveillance for surgical infections • Reliable surveillance case definitions according to international	• No personnel responsible for surveillance activities • Prioritization hasn't been done to determine the HCAIs to be targeted for surveillance according to the local context

	standards	• No, surveillance for (device-associated infections catheter-associated UTI, central line-associated bloodstream infections, ventilator-associated pneumonia), • Infection caused by multi-drug resistant pathogens • Infections in vulnerable populations (neonates, intensive care unit, immune compromised, burn patients), infections that affect healthcare workers (Hep B or C, HIV, influenza) • No adequate microbiology and laboratory capacity to support surveillance Information analysis and dissemination • Surveillance data not used to make facility-based plans for improving IPC
Multimodal Strategies	• Multimodal strategies are used to implement IPC interventions • Intervention to ensure the necessary infrastructure and continuous availability of supplies are in place • Education a d training through written information and /or oral instruction • Audits of hand hygiene • Awareness-raising tools to promote intervention (posters)	• Safety climate and culture change elements not included in multimodal strategies

Monitoring/audit of IPC	• A trained person for monitoring/audit of IPC • Well-defined monitoring plan • Feedback on the audit report to the IPC team and committee	• No assessment for safety cultural factors at the facility
Work load, staffing, and bed occupancy	• A system in place to act on results of staffing needs assessment when staffing levels are deemed to be low • One patient per bed	• The ratio of health care workers to patients is maintained in less than 50% of units • Patients placed in beds standing in the corridor outside of the room more frequently than twice a week • Bed spacing of 1 meter is maintained only in certain departments and no system is in place to assess and respond when adequate bed capacity is exceeded.
Built environment, materials, and equipment for IPC	• Water service is available and of sufficient quantity for all uses more than 5 days per week • Presence of hand hygiene stations • Presence of improved latrine • Availability of sufficient power/energy for all uses day and night • Availability of materials for cleaning • Single patient room available for cohorting patients with similar pathogens	• Unreliability of supplies for hand hygiene station • Cleaning materials not well maintained • PPE is not continuously available in sufficient quantities • No pit or other disposal method is used for non-infectious waste • Incinerator is present but not functional • No wastewater treatment system

5.2. Microbial load

5.2.1. Microbial load from indoor air

Out of 40 air samples, 37 (92.5%) were culture-positive. The distribution of bacterial and fungi load in indoor air in terms of CFU/m^3 is presented in Table 2. The highest bacterial and fungal load was 1607 CFU/m^3, and 814 CFU/m^3 respectively reported in the pediatric ward. In the investigated rooms the highest mean bacterial CFUs were recorded in the morning (10:00-11:00 am) compared with the afternoon (3:00-4:00 pm) Table 2.

Table 2. The microbial load of indoor air in studied rooms at JMC, 2022.

Type of ward	Time	Bacteria (CFU/m^3)	Fungi (CFU/m^3)
Pediatric ward	10-11 am	1607	814.6
	3-4 pm	1348.8	570.5
MICU	10-11 am	340.7	321
	3-4 pm	235.9	307.6
NICU	10-11 am	467.3	476
	3-4 pm	310.3	287.4
OR	10-11 am	146.3	206
	3-4 pm	124.4	96

According to the European standards for non-industrial premises, the pediatric ward showed a high level of microbial load. While the remaining wards showed an intermediate level.

Table 3. Microbial contamination level of studied rooms at JMC according to the European standards for non-industrial premises, 2022.

Microbe	Range of values (CFU/m^3)	Pollution degree	Type of ward and time			
			Pediatric ward	MICU	NICU	OR
Bacteria	< 50	Very Low				
	50-100	Low				
	100-500	Intermediate		√	√	√
	500-2000	High	√			
	>2000	Very high				

Fungi	< 25	Very Low				
	25-100	Low				
	100-500	Intermediate		√	√	√
	500-2000	High	√			
	>2000	Very high				

5.2.2. Microbial load from inanimate surfaces and medical equipment

The mean aerobic colony count (ACC) from surfaces in the Hospital was higher than the acceptable limits, at < 5 CFU/cm^2 (Dancer, 2004). The mean total aerobic colony counts from all inanimate surfaces and medical equipment in the investigated wards were 43.3, 28.8,32,18 CFU/ cm^2 for the pediatric ward, MICU, NICU, and OR respectively. The highest mean bacterial colony number was reported in pediatric wards at 43.3 CFU/cm^2 and the least was in OR at 18 CFU/cm^2 as shown in table 4.

Table 4. The microbial load of inanimate surfaces and medical equipment at JMC, 2022.

Type of ward	Bacterial colonies in CFU/cm^2	Fungal colonies in CFU/cm^2
Pediatric	43.3	32.3
MICU	28.8	22.5
NICU	32	20.2
OR	18	5.25

Based on the distribution of specimens 212 microbial isolates were recovered from inanimate surfaces and medical equipment, the highest microbial growth was documented from floors accounting for 37 (17.5%). Details of microbial distribution on the inanimate surfaces and medical equipment are shown in (Table 5).

Table 5. Types of microbes isolate inanimate surfaces and medical equipment in studied rooms at JMC, 2022.

Type and number of screened inanimate surfaces and medical equipment	Identified Species						
	S. aureus	*CONs*	*Klebsiela spp*	*P. aeruginosa*	*E. coli*	*Aspergillus spp*	Total
Floor (n=36)	13	10	6	4	2	2	37
Wall (n=36)	4	13	1	-	-	-	18
Bed rails (n=17)	8	6	3	1	1	1	20
Door handles (n=13)	5	6	2	1	-	-	14
Locker (n=12)	7	3	-	-	2	1	13
Light switch (n=13)	5	6	2	1	-	1	15
Chair (n=14)	6	2	3	2	-	-	13
Table (n=6)	1	1	1	2	-	-	5
Sink (n=13)	5	5	1	2	1	1	15
Trolley (n=6)	-	4	-	-	-	-	4
OR table(n=3)	2	1	-	1	-	-	4
OR lamp (n=3)	1	-	-	-	-	1	2
Iv stand (n=17)	5	1	6	1	-	3	16
Cylinder(n=17)	8	2	2	1	-	-	13
Patient monitor (n=6)	2	1	1	2	-	-	6
Suction machine (n=3)	2	1	-	-	-	-	3
Radiant warmer (n=5)	2	2	-	-	-	-	4
Incubator (n=3)	-	2	1	-	-	1	4
Phototherapy machine (n=2)	1	-	-	-	-	-	1
Anesthesia machine (n=3)	2	2	-	-	-	1	5
Total = 228	79 (37.3)	68 (32)	29 (13.7)	18 (8.5)	6 (2.8)	12 (5.7)	212

5.3. Microbial isolates at selected wards in JMC

A total of 268 samples (175 swabs from inanimate surfaces and 53 from medical equipment, and 40 indoor air samples) were collected from 4 different wards and processed during the study period. Of all processed samples, 181 (67.5%) yielded growth of a total of 270 microbial isolates. Of which 249 bacteria and 21 were fungal isolates. Gram-positive bacteria isolates predominate at 193 (77.5%) followed by gram- negatives bacteria at 56 (22.5%). The majority of the isolated microbes at 212 (78.5%) were recovered from inanimate surfaces and medical equipment samples and the rest 58 (21.5%) were from indoor air (Figure 4).

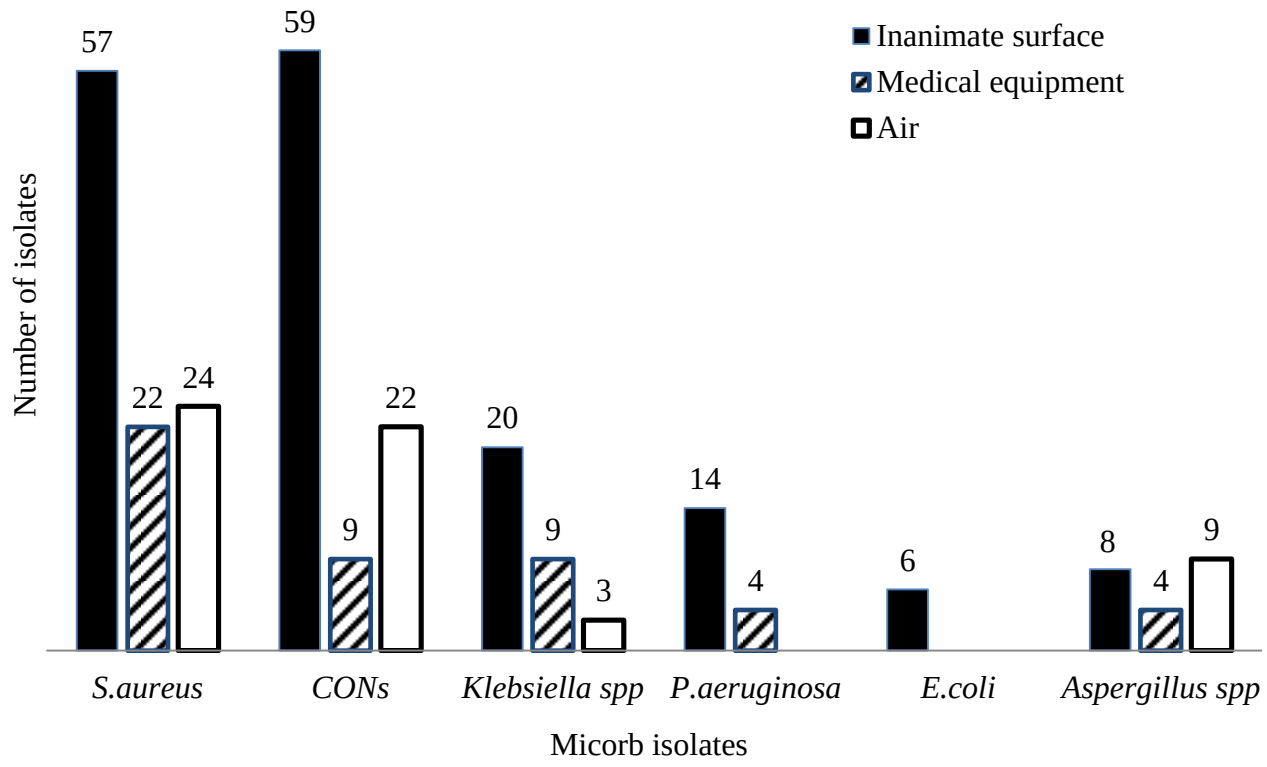

Figure 4. Types of microbes isolated from inanimate surfaces, medical equipment, and indoor air at JMC, 2022.

When we look at the distribution of isolates from different wards, the highest microbial isolate were recovered from the pediatric ward at 111 (41.1%) followed by NICU with 69 (25.6%), OR at 55 (20.3%), and MICU at 35 (13%). *S. aureus* was the dominant bacteria isolate from all wards 103 (38%).

Table 6. Microbial distribution in studied rooms at JMC, 2022.

Type of ward	Total sample collected	*S.aureus*	*CONs*	*Klebsiella spp*	*P.aeruginosa*	*E. coli*	*Aspergillus spp*	Total
Pediatric ward	93	41	34	17	5	4	10	111
MICU	36	13	12	-	5	1	4	35
NICU	68	25	24	11	4	1	4	69
OR	71	24	20	4	4	-	3	55
Total	268	103	90	32	18	6	21	270

5.4. Factors associated with microbial load in JMC

In this study independent variables which were:- sampling time, open windows/ doors, crowdedness of the room, presence of waste material in the room, and unclean room were analyzed using a multiple linear regression model to find any probable association with the microbial load.

The final multiple linear regression model explained about 20.8% of the variation in microbial load. Three variables were identified as positive predictors of microbial load; which were crowdedness [β = 2.748 (CI 95%: 1.057 – 4.44)], presence of waste material [β = 1.747 (CI 95%: .213 – 3.282)], and Unclean room [β = 2.505 (CI 95%: .990 – 4.019)] (Table 8).

Table 8. Multiple linear regressions of independent variables associated with microbial load in JMC (n = 268)

Variables	Unstandardized Coefficients		Standardized Coefficient Beta	T	P value	95% confidence interval for beta	
	Beta	Std. Error				Lower bound	Upper bound
Constant	-1.091	.484		-2.255	.025	-2.044	-.139
Sampling time	.835	.665	.072	1.256	.210	-.474	2.144
Open windows/ doors	.355	.436	.052	.814	.416	-.504	1.214

Crowdedness	2.748	.859	.235	3.199	.002**	1.057	4.440
Presence of waste material	1.747	.779	.150	2.242	.026**	.213	3.282
Unclean room	2.505	.769	.216	3.257	.001**	.990	4.019

Note: ** significant at 0.05 level.

The results also showed that the level of microbial load varied between the type of wards. For air, inanimate surface, and medical equipment samples, the pediatric ward had the highest level of microbial load Figures 5 and 6.

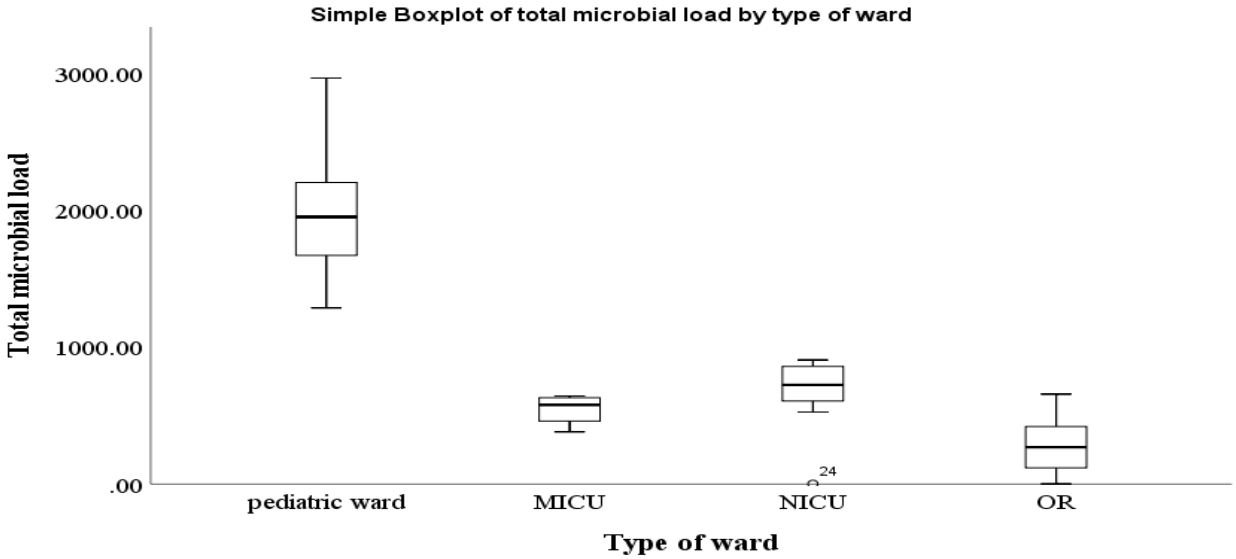

Figure 5. Indoor air microbial load distribution in different wards in JMC.

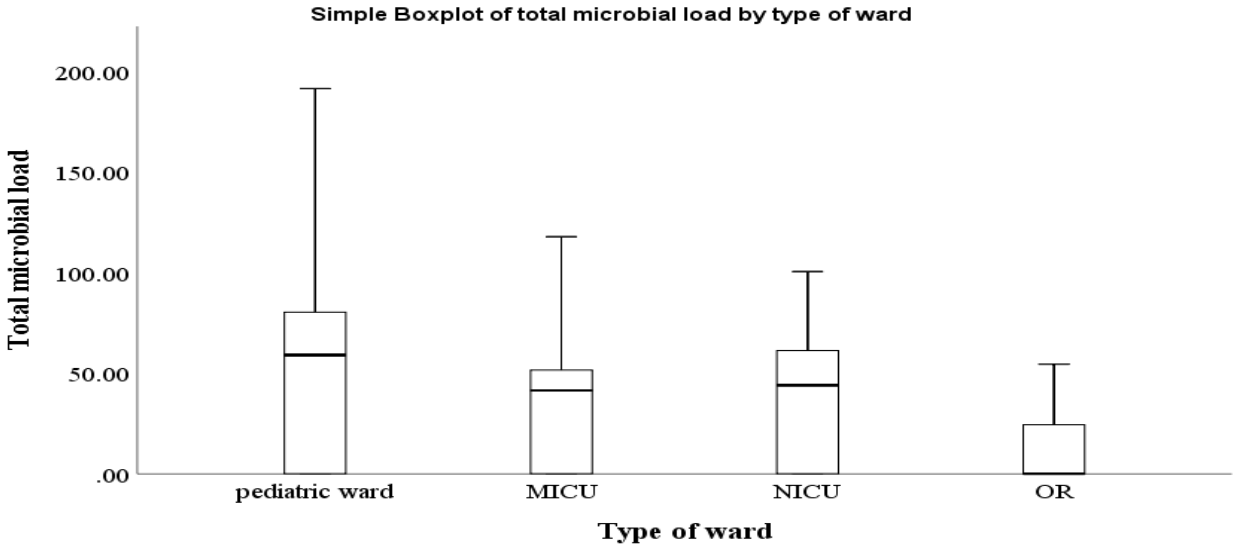

Figure 6. The microbial load of inanimate surfaces and medical equipment in different wards of JMC.

Chapter six: Discussion

The infection prevention and control (IPC) implementation level in this study was 456 from 800 (intermediate) level. this result was lower than results reported in developed states which showed an advanced level but a modest comparative difference with a similar level of IPC compliance was observed with: lower-middle-income countries 500.4 (Tomczyk et al., 2022). In Nigeria Federal Medical Centre 545 (Ilesanmi et al., 2020). Sub-Saharan Africa 428 (Aiken et al., 2022). Hiwot Fana comprehensive Specialized Hospital 542.5 (Aiken et al., 2022). On the other hand, the result was lower compared to studies from Germany, Australia, and India, where 84.5%, 58%, and 59% of Hospitals showed an overall advanced level of IPC compliance respectively (Aghdassi et al., 2019; Johannes et al., 2020; Rupali, 2021). This difference might be due to management and senior support, and the high quality of health care in the above countries. Whereas the resource limitations in this study setting compared to theirs is other factors.

However, the study finding was higher than studies in Uganda and Pakistan which showed a basic and inadequate level of IPC compliance (Opollo et al., 2021; Savul et al., 2019). The authors attributed the low result to the absence of IPC guidelines, HCAIs surveillance, and multimodal strategies in the Hospitals, which are established in JMC even though with constraints.

Lower scores for IPC compliance out of the eight core components were found in HCAIs surveillance (25/100), IPC education and training (45/100), built environment, materials, and equipment (48.5/100), and bed occupancy, staffing, and workload (50/100). Comparable to this result, HCAIs surveillance and workload components were found to be low in sub-Saharan Africa (Aiken et al., 2022). The reason for the low HCAIs surveillance might be due to the absence of a responsible person for continuous surveillance activity in JMC. Irregular/inadequate IPC training, shortage of Personal protective equipment (PPE), and high workload are still unresolved issues at JMC which were also reported by a previous qualitative study (Kenzie et al., 2017). This could be mainly due to a shortage of budget: even though not enough there is high number of staff and a large number of medical students who require PPE. However, there are improvements in areas like the availability of an isolation room, a dedicated IPC team, and a water supply in the facility.

The overall microbial contamination rate of this study was 181(67.5%). which is in line with a study by (Maryam et al., 2014) in Nigeria which showed 65.7% contamination rate. Lower results were reported from Iraq 17.8%; (Nasser et al., 2013), and Bahir Dar, Ethiopia 39.6% (Getachew et al., 2018). However, higher microbial contamination rates have been reported 88.4% from Tigray, Ethiopia (Darge et al., 2019), and 74.7% Hawassa, Ethiopia (Bitew et al., 2021). This variation might be attributed to a difference in the number of people in the hospital community and the period of sample collection, as temperature and humidity could affect the rate of microbial isolation.

From the total culture positive plates (181), about 77.5% of the isolates were gram-positive and 22.5% were gram-negative. This finding was in line with a previous study done in Dilla where 71% were gram-positive bacteria (Ashuro et al., 2022) and Bahir Dar Ethiopia was 81.6% gram-positive and 18.4% gram-negative (Getachew et al., 2018). However, it differs from those reported in Tigray, Ethiopia, where the proportions were 68.4% and 31.6%, respectively (Darge et al., 2019). Hawassa Ethiopia, 51.1% gram-positive and 48.9% gram-negative bacteria were detected (Bitew et al., 2021). However, in all cases gram-positive bacteria were predominant. This might be due to their lower susceptibility to adverse environmental conditions than gram-negative.

In the present study, 103 (38.1%) *S.aureus*, and 90 (33.3%) *CONs* were the predominant isolates. This finding was found to be consistent with the findings of studies from Nigeria and Ethiopia (Hailemariam et al., 2016; Hammuel et al., 2014; Sebre et al., 2020). This may be due to *S. aureus* constitute part of the normal human flora, inhabiting the skin, mucous membranes and regularly being shed onto the Hospital environment by patients and medical personnel, whereupon they persist. These isolates were also indicators of inadequate clinical sanitation.

The mean indoor air bacterial load of this study was found to be 124.4 - 1,607 CFU/ m^3. The results were comparable to a study in Dilla which showed bacterial load range from 450 – 1585.8 CFU/m^3 (Ashuro et al., 2022). However, the results were much lower than that reported from Jimma, Ethiopia 3106 - 9733 CFU/m^3 (Fekadu & Getachewu, 2015), Harar, Ethiopia 148.4 - 2,883.2 CFU/m^3, (Abebe & Kumie, 2017), Hawassa, Ethiopia 4420 CFU/m^3 (Hailemariam et al., 2018), and Arba Minch, Ethiopia 1914±1081.4 CFU/m^3 . The disparity

could be attributed to the difference in IPC practice, length of plate exposure time, period of sample collection, and hospital settings (general or referral).

The mean indoor air fungal load that was observed in this study ranged from 96 - 814.6 CFU/m^3. These results were higher than the values of previous studies done in India (0 to 262 CFU/m^3) and Nigeria (6 to 44.7 CFU/m^3) (Ekhaise et al., 2010; Kotgire et al., 2020). The variations could be attributed to the differences in the length of plate exposure time, and period of sample collection. But this result was lower than a previous study done at Jimma hospital 2123 CFU/m^3 to 4168 CFU/m^3 (Fekadu & Getachewu, 2015), and a study in Arba Minch, Ethiopia 1533.7 ± 858.8 CFU/m^3 (Kayta et al., 2022).

The finding showed lower results compared to the previous study done at the hospital which showed a high microbial load among the wards (Fekadu & Getachewu, 2015; Genet et al., 2011). This might be due to the absence of an IPC team at the time as reported by another study in the hospital (Kenzie et al., 2017) and currently, the hospital has moved to a new and bigger building. However, the findings still imply that the Hospital needs a closer follow-up by the IPC team to improve the level of IPC compliance found in this study. Short-term interventions that aim to optimize the practice of IPC among the health professionals in the Hospital could be useful. But, the lack of consistent support for the IPC program by senior facility leadership could have an impact so it requires management support.

Of the total (40) Hospital indoor air samples processed during the study period, 37(92.5%) showed microbial growth. This implies that many pathogenic microbes are remaining suspended in the air. The finding was comparable with studies done in Hawasa and Sodo, Ethiopia where the recovery rate was 96.9% and 90.2%, respectively (Leta et al., 2016; Solomon et al., 2017). The microbial isolated from the indoor air sample were 24 (41.4%) *S.aureus*, 22 (38%) *CoNs*, 9 (15.5%) *Aspergillus* spp, and 3 (5.2%) *Klebsiella* spp. All these microbes are known infectious pathogens, especially among immune-compromised patients admitted to the Hospital. The result was in line with studies done in Bahir Dar, Ethiopia (Getachew et al., 2018), Hawasa (Mengistu et al., 2016), and Jimma (Genet et al., 2011). The reason for high *S. aureus* could be due to the inability of gram-negative bacteria to survive in an aerosolized state for a long period because of the inability to resist conditions like drying.

On top of this highest mean indoor air microbial load was recorded in the morning session which was similar to findings from Bahr Dar, and Hawasa (Getachew et al., 2018)

(Hailemariam et al., 2016). The possible reasons might be due to the high trafficking of visitors and health science students in the Hospital.

The mean bacterial and fungal load of inanimate surfaces and medical equipment from the pediatric ward, MICU, NICU, and OR, were (43.3 and 32.3 CFU/cm^2), (28.8 and 22.5 CFU/cm^2), (32, and 20.2 CFU/cm^2), and (18, and 5.25 CFU/cm^2), respectively. This finding was beyond the acceptable standard limits set by Dancer, which states that the mean aerobic count from surfaces should be < 5 CFU/cm^2 (Dancer, 2004). The findings of bacterial load in NICU & OR were comparable to the result from Bahir Dar Hospital, which determined 27 CFU/cm^2 and 14 CFU/cm^2, respectively (Getachew et al., 2018). This result could have occurred because of some of the berries to IPC practice implementation within the Hospital like non-mandatory annual training for workers, no specific IPC training for patients or family members, insufficiency of personal protective equipment, and unreliable supplies for hand hygiene stations.

Of the total 228 inanimate surfaces and medical equipment samples, 144 (63.2%) contamination rate was detected in this study. This was in line with Black Lion Hospital, Ethiopia (60.3%), (Dabsu et al., 2014). On the other hand, a study conducted in Uganda reported a contamination rate of 44.2% (Sserwadda et al., 2018), in Bahir Dar and Hawassa Ethiopia reported 26.3% (Getachew et al., 2018), and 50.4% (Bitew et al., 2021) respectively, which was lower than this study. Higher results have also been reported from 70% from Nigeria (Saka et al., 2016), 71.7 % from Arba Minch (Birru et al., 2021), and 88.5% Tigray, Ethiopia (Darge et al., 2019). The discrepancies in contamination rates observed might be due to differences in hand hygiene, the frequency of decontamination, and the nature of the medical equipment and inanimate surfaces.

Among the analyzed factors multiple linear regression model showed that higher crowdedness was found more prone to be contaminated with the high microbial load. A study in Arba Minch also showed crowding index contributed to a high microbial load by 12.5 times (Kayta et al., 2022).

As per this study presence of waste in the room had a significant association with the microbial load. This result was contrary to a study in Arba Minch where the presence of waste did not have a significant association with the microbial load.

In this study, unclean rooms were associated with a higher microbial load. The finding was comparable to a study in Harar which showed soiled working areas have a bacterial load 12.9 times higher than cleaner ones (Abebe & Kumie, 2017). Another study in Arba Minch also indicated unclean environment around the wards affected the microbial load by 5.8 times (Kayta et al., 2022).

This study is difficult to generalize to a larger area because of the single study area used. However, the study could imply the need for further large-scale studies in Ethiopia targeting microbial load and IPC practice in tertiary care Hospitals to strengthen this finding by the use of a larger sample size and multiple locations in Ethiopia.

Chapter seven: Conclusion and recommendation

7.1. Conclusion

Overall the findings revealed an intermediate level of IPC compliance score in the study area and almost all wards had an intermediate level of indoor air microbial load. The mean aerobic colony count from inanimate surfaces and medical equipment was higher than the acceptable limit. *S. aureus* was the major identified isolate. Crowdedness, the presence of waste, and the unclean room had a significant association with the microbial load. The microbial load found in this study might be a potential risk factor for the spread of healthcare-associated infection in the Hospital.

7.2. Recommendation

Based on the findings of the study, the following recommendations were forwarded:

To JMC IPC team

- Should strengthen the current IPC status to reach an advanced level by working on the identified gaps and developing long-term plans for the sustenance and promotion of the existing IPC program activities.
- Organize mandatory IPC training sessions for workers and periodic evaluation of the effectiveness of training programs.

To JMC

- The Hospital should support the IPC team consistently, for efficient implementation of the IPC practices in the facility.
- Encourage periodic hospital-wide microbial surveillance to identify and minimize/eliminate sources of microbial contamination.

To researchers

- Further studies should be done on additional types of bacterial and fungal species and their antimicrobial resistance pattern in all wards of the hospital.

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ANNEXES

I. Sample collection format

1. Collection day _____/_____/_____E.C. at _____ (time)
2. Ward _____ Room no_____
3. Code number _____
4. Sampling time _____
5. Type of sample collected
   a. Air samples
   b. inanimate surface
   c. medical equipment
6. List of inanimate surface and medical equipment sampled

- Floor
- Wall
- Bed
- Door knob
- Locker
- Light switch
- Chair
- Table
- Sink
- Trolly
- OR lamp
- OR table
- Iv stand
- Cylinder
- Patient Monitor
- Suction machine
- Radiant warmer
- Incubator
- Phototherapy machine
- Anesthesia machine

II. laboratory result

7. Culture result
   a. Positive
   b. Negative
8. The number of colonies counted on the petri dish

_____

9. Number of colonies in CFU/m^3 for air samples and CFU /cm^2 for surface

_____

10. Bacterial species identified

III. Observational checklist

1. Type of ward _____
2. Sampling time _____
3. Sample code number _____
4. Number of people in the room during sampling? _____
5. Room area? _____m^2
6. Room volume? _____m^3
7. Presence of mechanical ventilator?
   a. Yes
   b. No
8. If yes is it functional?
   a. Yes
   b. No
9. Were the windows/doors open during sampling?
   a. Yes
   b. No
10. Window area _____ m^2
11. Door area _____ m^2
12. Presence of waste matter in the room (on the floor, open waste bin)
    a. Yes
    b. No
13. Cleanness of the room (see if the wall and floor are soiled and spider webs)
    a. Yes
    b. No

IV. Air specimen collection procedure used using the settle plate method

1. The plates were examined for contamination before use.
2. The code number was written on the base of the plate.
3. The plates were transported from the medical microbiology laboratory of Jimma university to the site of sample collection using an ice box.
4. The plates were placed one meter above the floor (using alcohol-cleaned chairs which are 1 meter long) and one meter away from the wall with the lids still on.
5. During transporting and placing the plates in their appropriate site of sample collection, sterile surgical gloves, surgical clothing (when collecting in ORs), and face masks were used.
6. Lids were raised to expose the surface of the medium. The plates will be supervised for the whole collection time (1 hour).
7. After 1 hour of exposure, the lids of the plates were closed and transported to the medical microbiology laboratory of Jimma university laboratory using an ice box.

V. Specimen collection procedure used for high touch areas surfaces using swabs

1. The swab and the test tube were assembled with a code number written on each tube.

2. The surface of the sample collection site was checked to make sure that they are dry and free of any liquids.

3. Clean plastic with a hollow area of $10cm^2$ was placed on the surface to be Sampled.

4. The sample collection cotton swab was moistened with sterile normal saline.

5. The swab was rubbed by rotating it in the predetermined surface area.

6. The swab was inserted back into the test tube.

7. Then the samples were transported to the medical microbiology laboratory.

VI. Biochemical test procedures

Identification of gram-positive bacteria: were identified based on their Gram reaction, catalase, and coagulase test results.

Catalase test: This test is used to differentiate staphylococci (+ve) from streptococci (-ve) Procedure.

1. The test organism was taken using a sterile wire loop and added to the slide.
2. A drop of 3% hydrogen peroxide was added to a slide and looked for immediate bubbling.
3. Interpretation: Active bubbling---- positive test and No release of bubbles---- negative test.

Coagulase test: This test is used to differentiate staphylococcus aureus from other *staphylococcus spp*.

Procedure

1. A drop of physiological saline was placed on two separate slides.
2. The test organism was emulsified in each drop to make a suspension.
3. One drop of plasma was added to one of the suspensions and mix gently. It was looked for clumping of the organism within 10 seconds.
4. Interpretation-: Clumping within 10 seconds ----------S. aureus

   No clumping within 10 seconds ----------other staphylococcus species

Identification of gram-negative bacteria will be based on their test result with a series of biochemical tests.

Procedure

1. A loop full of the bacterial suspension is inoculated into indole, citrate agar, lysine decarboxylase agar
2. Incubated at 35-37oc for 24 hours.
3. Looked for color change (turbidity or motility) of the medium.
4. Then, the test organism is identified by considering the results of the biochemical tests.

VII. WHO IPCAF evaluation toll

Core component 1: Infection Prevention and Control (IPC) program		
Question	Answer	Score
1. Do you have an IPC program? Choose one answer	☐ No	0
	☐ Yes, without clearly defined objectives	5
	☐ Yes, with clearly defined objectives and an annual activity plan	10
2. Is the IPC program supported by an IPC team comprising of IPC professionals? Choose one answer	☐ No	0
	☐ Not a team, *only* an IPC focal person	5
	☐ Yes	10
3. Does the IPC team have at least one full-time IPC professional or equivalent (nurse or doctor working 100% in IPC) available? Choose one answer	☐ No IPC professional available	0
	☐ No, *only* a part-time IPC professional available	2.5
	☐ Yes, one per > 250 beds	5
	☐ Yes, one per ≤ 250 beds	10
4. Does the IPC team or focal person have dedicated time for IPC activities?	☐ No	0
	☐ Yes	10
5. Does the IPC team include both doctors and nurses?	☐ No	0
	☐ Yes	10
6. Do you have an IPC committee actively supporting the IPC team?	☐ No	0
	☐ Yes	10

7. Are any of the following professional groups represented/included in the IPC committee?

Senior facility leadership (for example, administrative director, chief executive officer [CEO], medical director)	No	0
	Yes	5
Senior clinical staff (for example, physician, nurse)	No	0
	Yes	2.5
Facility management (for example, biosafety, waste, and those tasked with addressing water, sanitation, and hygiene [WASH])	No	0
	Yes	2.5
8. Do you have clearly defined IPC objectives (that is, in specific critical areas)? Choose one answer	☐ No	0
	☐ Yes, IPC objectives *only*	2.5
	☐ Yes, IPC objectives and measurable outcome indicators (that is, adequate measures for improvement)	5

	☐ Yes, IPC objectives, measurable outcome indicators, and set future targets	10

9. Does the senior facility leadership show clear commitment and support for the IPC program:

By an allocated budget specifically for the IPC program (that is, covering IPC activities, including salaries)?	☐ No	0
	☐ Yes	5
By demonstrable support for IPC objectives and indicators within the facility (for example, at executive level meetings, executive rounds, participation in morbidity and mortality meetings)?	☐ No	0
	☐ Yes	5
10. Does your facility have microbiological laboratory support (either present on or off-site) for routine day-to-day use? Choose one answer	☐ No	0
	☐ Yes, but not delivering results reliably (timely and of sufficient quality)	5
	☐ Yes, and delivering results reliably (timely and of sufficient quality)	10
Subtotal score		**/100**

Core component 2: Infection Prevention and Control (IPC) guidelines

Question	**Answer**	**Score**
1. Does your facility have the expertise (in IPC and/or infectious diseases) for developing or adapting guidelines**?**	☐ No	0
	☐ Yes	7.5
2. Does your facility have guidelines available for:		
Standard precautions?	☐ No	0
	☐Yes	2.5
Hand hygiene?	☐ No	0
	☐ Yes	2.5
Transmission-based precautions?	☐ No	0
	☐ Yes	2.5
Outbreak management and preparedness?	☐ No	0
	Yes	2.5
Prevention of surgical site infection?	☐ No	0
	☐ Yes	2.5
	No	0

Prevention of vascular catheter-associated bloodstream infections?	☐ Yes	2.5
Prevention of Hospital-acquired pneumonia ([HAP]; all types of HAP, including (but not exclusively) ventilator-associated pneumonia)?	☐ No	0
	☐ Yes	2.5
Prevention of catheter-associated urinary tract infections?	☐ No	0
	☐ Yes	2.5
Prevention of transmission of multidrug-resistant (MDR) pathogens?	☐ No	0
	☐Yes	2.5
Disinfection and sterilization?	☐ No	0
	☐ Yes	2.5
Health care worker protection and safety	☐ No	0
	☐ Yes	2.5
Injection safety?	☐ No	0
	☐ Yes	2.5
Waste management?	☐No	0
	☐ Yes	2.5
Antibiotic stewardship?	☐ No	0
	☐ Yes	2.5
3. Are the guidelines in your facility consistent with national/international guidelines (if they exist)?	☐ No	0
	☐ Yes	10
4. Is implementation of the guidelines adapted according to the local needs and resources while maintaining key IPC standards?	☐ No	0
	☐ Yes	10
5. Are frontline health care workers involved in <u>both</u> planning and executing the implementation of IPC guidelines in addition to IPC personnel?	☐ No	0
	☐Yes	10
6. Are relevant stakeholders (for example, lead doctors and nurses, Hospital managers, quality management) involved in the development and adaptation of the IPC guidelines in addition to IPC personnel?	☐ No	0
	☐ Yes	7.5
7. Do health care workers receive specific training related to new or updated IPC guidelines introduced in the facility?	☐ No	0
	☐ Yes	10
8. Do you regularly monitor the	☐ No	0

implementation of at least some of the IPC guidelines in your facility?	☐ Yes	10
Subtotal score		**/100**
Core component 3: Infection Prevention and Control (IPC) education and training		
Question	**Answer**	**Score**
1. Are there personnel with the IPC expertise (in IPC and/or infectious diseases) to lead IPC training?	☐ No	0
	☐ Yes	10
2. Are there additional non-IPC personnel with adequate skills to serve as trainers and mentors (for example, link nurses or doctors, champions)? Choose one answer	☐ No	0
	☐ Yes	10
3. How frequently do health care workers receive training regarding IPC in your facility? Choose one answer	☐ Never or rarely	0
	☐ New employee orientation *only* for health care workers	5
	☐ New employee orientation and regular (at least annually) IPC training for health care workers offered but not mandatory	10
	☐ New employee orientation and regular (at least annually) mandatory IPC training for all health care workers	15
4. How frequently do cleaners and other personnel directly involved in patient care receive training regarding IPC in your facility? Choose one answer	☐ Never or rarely	0
	☐ New employee orientation *only* for other personnel	5
	☐ New employee orientation and regular (at least annually) training for other personnel offered but not mandatory	10
	☐ New employee orientation and regular (at least annually) mandatory IPC training for other personnel	15
5. Does administrative and managerial staff receive general training regarding IPC in your facility? Choose one answer	☐ No	0
	☐ Yes	5
6. How are health care workers and other personnel trained? Choose one answer	☐ No training available	0
	☐ Using written information and/or oral	5

	instruction and/ore-learning *only*	
	☐ Includes *additional* interactive training sessions (for example, simulation and/or bedside training)	10
7. Are there periodic evaluations of the effectiveness of training programmes (for example, hand hygiene audits, other checks onknowledge)? Choose one answer	☐ No	0
	☐ Yes, but not regularly	5
	☐ Yes, regularly (at least annually)	10
8. Is IPC training integrated in the clinical practice and training of other specialties (for example, training of surgeons involves aspects of IPC)? Choose one answer	☐ No	0
	☐ Yes, in some disciplines	5
	☐ Yes, in all disciplines	10
9. Is there specific IPC training for patients or family membersto minimize the potential for health care-associated infections (for example, immunosuppressed patients, patients with invasivedevices, patients with multidrug-resistant infections)?	☐ No	0
	☐ Yes	5
10. Is ongoing development/education offered for IPC staff (for example, by regularly attending conferences, courses)?	☐ No	0
	☐ Yes	10
Subtotal score		**/100**

Core component 4: Health care-associated infection (HCAIs) surveillance

Question	**Answer**	**Score**
1. Is surveillance a defined component of your IPC programme?	☐ No	0
	☐ Yes	5
2. Do you have personnel responsible for surveillance activities?	No	0
	Yes	5
3. Have the professionals responsible for surveillance activities been trained in basic epidemiology, surveillance and IPC (that is,capacity to oversee surveillance methods, data management andinterpretation)?	☐ No	0
	☐ Yes	5
4. Do you have informatics/IT support to conduct your surveillance(for example, equipment, mobile	No	0
	Yes	5

technologies, electronic health records)?		

Priorities for surveillance - defined according to the scope of care

5. Do you go through a prioritization exercise to determine the HCAIsto be targeted for surveillance according to the local context (that is, identifying infections that are major causes of morbidity and mortality in the facility)?	☐ No	0
	☐ Yes	5

6. In your facility is surveillance conducted for:

Surgical site infections?	No	0
	☐ Yes	2.5
Device-associated infections (for example, catheter-associated urinary tract infections, central line-associated bloodstream infections, peripheral-line associated bloodstream infections, ventilator-associatedpneumonia)?	☐ No	0
	Yes	2.5
Clinically-defined infections (for example, definitions based only on clinical signs or symptoms in the absence of microbiological testing)?	☐ No	0
	☐ Yes	2.5
Colonization or infections caused by multidrug-resistant pathogens according to your local epidemiological situation?	☐ No	0
	☐ Yes	2.5
Local priority epidemic-prone infections (for example, norovirus, influenza, tuberculosis [TB], severe acute respiratory syndrome [SARS], Ebola, Lassa fever)?	☐ No	0
	☐ Yes	2.5
Infections in vulnerable populations (for example, neonates, intensivecare unit, immunocompromised, burn patients)?[14]	☐ No	0
	☐ Yes	2.5
Infections that may affect health care workers in clinical, laboratory, or other settings (for example, hepatitis B or C, human immunodeficiency virus [HIV], influenza)?	☐ No	0
	☐ Yes	2.5
7. Do you regularly evaluate if your surveillance is in line with thecurrent	☐ No	0
	☐ Yes	5

needs and priorities of your facility?		

Methods of surveillance

8. Do you use reliable surveillance case definitions (defined numerator and denominator according to international definitions [e.g. CDC NHSN/ECDC] or if adapted, through an evidence-based adaptation process and expert consultation?	☐ No	0
	☐ Yes	5
9. Do you use standardized data collection methods (for example, active prospective surveillance) according to international surveillance protocols (for example, CDC NHSN/ECDC) or if adapted, through an evidence-based adaptation process and expert consultation?	☐ No	0
	☐ Yes	5
10. Do you have processes in place to regularly review data quality (for example, assessment of case report forms, review of microbiology results, denominator determination, etc.)?	☐ No	0
	☐ Yes	5
11. Do you have adequate microbiology and laboratory capacity to support surveillance? Choose one answer	☐ No	0
	☐ Yes, can differentiate gram-positive/negative strains <u>but</u> cannot identify pathogens	2.5
	Yes, can reliably identify pathogens (for example, isolate identification) in a timely manner	5

Information analysis and dissemination/data use, linkage, and governance

12. Are surveillance data used to make tailored unit/facility-based plans for the improvement of IPC practices?	☐ No	0
	☐ Yes	5
13. Do you analyze antimicrobial drug resistance on a regular basis (for example, quarterly/half-yearly/annually)?	No	0
	☐ Yes	5
14. Do you regularly (for example, quarterly/half-yearly/annually) feedback up-to-date surveillance information to:		
Frontline health care workers (doctors/nurses)?	☐ No	0
	☐ Yes	2.5
Clinical leaders/heads of department	☐ No	0

	☐ Yes	2.5
IPC committee	☐ No	0
	Yes	2.5
Non-clinical management/administration (chief executive officer/chief financial officer)?	☐ No	0
	☐ Yes	2.5
15. How do you feedback up-to-date surveillance information? (at least annually) Choose one answer	☐ No feedback	0
	☐ By written/oral information *only*	2.5
	☐ By presentation and interactive problem-orientated solution finding	7.5
Subtotal score		**/100**
Core component 5: Multimodal strategies for implementation of infection prevention and control (IPC) interventions		
Question	**Answer**	**Score**
1. Do you use multimodal strategies[16] to implement IPC interventions?	☐ No	0
	☐ Yes	15
2. Do your multimodal strategies include any or all of the following elements: Choose one answer (the most accurate) per element	**System change**	0
	☐ Element not included in multimodal strategies	0
	☐ Interventions to ensure the necessary infrastructure and continuous availability of supplies are in place	5
	☐ Interventions to ensure the necessary infrastructure and continuous availability of supplies are in place and addressing ergonomics and accessibility, such as the best placement of central venous catheter set and tray	10
	Education and training	
	☐ Element not included in multimodal strategies	0
	☐ Written information and/or oral instruction and/or e-learning *only*	5
	☐ *Additional* interactive training sessions (includes simulation and/or bedside training)	10
	Monitoring and feedback	
	☐ Element not included in multimodal strategies	0

	☐ Monitoring compliance with process or outcome indicators (for example, audits of hand hygiene or catheter practices)	5
	☐ Monitoring compliance and providing timely feedback of monitoring results to health care workers and key players	10
	Communications and reminders	
	Element not included in multimodal strategies	0
	☐ Reminders, posters, or other advocacy/awareness-raising tools to promote the intervention	5
	☐ *Additional* methods/initiatives to improve team communication across units and disciplines (for example, by establishing regular case conferences and feedback rounds)	10
	Safety climate and culture change	
	Element not included in multimodal strategies	0
	☐ Managers/leaders show visible support and act as champions and role models, promoting an adaptive approach[18] and strengthening a culture that supports IPC, patient safety and quality	5
	☐ *Additionally*, teams and individuals are empowered so that they perceive ownership of the intervention (for example, by participatory feedback rounds)	10
3. Is a multidisciplinary team used to implement IPC multimodal strategies?	☐ No	0
	☐ Yes	15
4. Do you regularly link to colleagues from quality improvement and patient safety to develop and promote IPC multimodal strategies?	☐ No	0
	☐ Yes	10
5. Do these strategies include bundles or checklists?	☐ No	0
	☐ Yes	10
Subtotal score	**/100**	

Core component 6: Monitoring/audit of IPC practices and feedback		
Question	**Answer**	**Score**
1. Do you have trained personnel responsible for monitoring/audit of IPC practices and feedback?	☐ No	0
	☐ Yes	10
2. Do you have a well-defined monitoring plan with clear goals, targets and activities (including tools to collect data in a systematic way)?	☐ No	0
	☐ Yes	7.5
3. Which processes and indicators do you monitor in your facility? Tick all that apply	None	0
	☐ Hand hygiene compliance (using the WHO hand hygiene observation tool[20] or equivalent)	5
	☐ Intravascular catheter insertion and/or care	5
	Wound dressing change	5
	☐ Transmission-based precautions and isolation to prevent the spread of multidrug resistant organisms (MDRO)	5
	☐ Cleaning of the ward environment	5
	Disinfection and sterilization of medical equipment/instruments	5
	☐ Consumption/usage of alcohol-based handrub or soap	5
	Consumption/usage of antimicrobial agents	5
	☐ Waste management	5
4. How frequently is the *WHO Hand Hygiene Self-Assessment Framework Survey* undertaken? Choose one answer	☐ Never	0
	Periodically, but no regular schedule	2.5
	☐ At least annually	5
5. Do you feedback auditing reports (for example, feedback on hand hygiene compliance data or other processes) on the state of the IPC activities/performance? Tick all that apply	No reporting	0
	☐ Yes, within the IPC team	2.5
	Yes, to department leaders and managers in the areas being audited	2.5
	☐ Yes, to frontline health care workers	2.5
	☐ Yes, to the IPC committee or quality of care committees or equivalent	2.5
	Yes, to Hospital management and senior administration	2.5
6. Is the reporting of monitoring data	☐ No	0

undertaken regularly (at least annually)?	☐ Yes	10
7. Are monitoring and feedback of IPC processes and indicators performed in a "blame-free" institutional culture aimed at improvement and behavioral change?	☐ No	0
	☐ Yes	5
8. Do you assess safety cultural factors in your facility (for example, by using other surveys such as HSOPSC, SAQ, PSCHO, HSC)	☐ No	0
	☐ Yes	5
Subtotal score		**/100**

Core component 7: Workload, staffing and bed occupancy		
Question	**Answer**	**Score**

Staffing

1. Are appropriate staffing levels assessed in your facility according to patient workload using national standards or a standard staffing needs assessment tool such as the *WHO Workload indicators of staffing need* method?	☐ No	0
	☐ Yes	5
2. Is an agreed (that is, WHO or national) ratio of health care workers to patients maintained across your facility? Choose one answer	☐ No	0
	☐ Yes, for staff in less than 50% of units	5
	☐ Yes, for staff in more than 50% of units	10
	☐ Yes, for all health care workers in the facility	15
3. Is a system in place in your facility to act on the results of the staffing needs assessments when staffing levels are deemed to be too low?	☐ No	0
	☐ Yes	10

Bed occupancy

4. Is the design of wards in your facility in accordance with international standards[26] regarding bed capacity? Choose one answer	☐ No	0
	Yes, but *only* in certain departments	5
	☐ Yes, for all departments (including emergency department and pediatrics)	15
5. Is bed occupancy in your facility kept to one patient per bed? Choose one answer	☐ No	0
	☐ Yes, but *only* in certain departments	5
	☐ Yes, for all units (including emergency departments and pediatrics)	15

6. Are patients in your facility placed in beds standing in the corridor outside of the room (including beds in the emergency department)? Choose one answer	☐ Yes, more frequently than twice a week	0
	☐ Yes, less frequently than twice a week	5
	No	15
7. Is adequate spacing of > 1 meter between patient beds ensured in your facility? Choose one answer	☐ No	0
	☐ Yes, but *only* in certain departments	5
	☐ Yes, for all departments (including emergency department and pediatrics)	15
8. Is a system in place in your facility to assess and respond when adequate bed capacity is exceeded? Choose one answer	☐ No	0
	☐ Yes, this is the responsibility of the head of department	5
	☐ Yes, this is the responsibility of the Hospital administration/ management	10
Subtotal score		**/100**
Core component 8: built environment, materials and equipment for IPC at the facility		
Question	**Answer**	**Score**

Water

1. Are water services available at all times and of sufficient quantity for all uses (for example, hand washing, drinking, personal hygiene, medical activities, sterilization, decontamination, cleaning and laundry)? Choose one answer	☐ No, available on average < 5 days per week	0
	☐ Yes, available on average ≥ 5 days per week or every day but not of sufficient quantity	2.5
	☐ Yes, every day and of sufficient quantity	7.5
2. Is a reliable safe drinking water station present and accessible for staff, patients and families at all times and in all locations/wards? Choose one answer	☐ No, not available	0
	☐ Sometimes, or only in some places or not available for all users	2.5
	☐ Yes, accessible at all times and for all wards/groups	7.5

Hand hygiene and sanitation facilities

3. Are functioning hand hygiene stations (that is, alcohol-based hand rub solution or soap and water and clean single-use towels) available at all points of care? Choose one answer	☐ No, not present	0
	☐ Yes, stations present, but supplies are not reliably available	2.5
	☐ Yes, with reliably available supplies	7.5
4. In your facility, are ≥ 4 toilets or	Less than required number of toilets or latrines available and functioning	0

improved latrines[28] available for outpatient settings or ≥ 1 per 20 users for inpatient settings? Choose one answer	☐ Sufficient number present but not all functioning	2.5
	☐ Sufficient number present and functioning	7.5

Power supply, ventilation and cleaning

5. In your health care facility, is sufficient energy/power supply available at day and night for all uses (for example, pumping and boiling water, sterilization and decontamination, incineration or alternative treatment technologies, electronic medical devices, general lighting of areas where health care procedures are performed to ensure safe provision of health care and lighting of toilet facilities and showers)? Choose one answer	☐ No	0
	☐ Yes, sometimes or only in some of the mentioned areas	2.5
	☐ Yes, always and in all mentioned areas	5
6. Is functioning environmental ventilation (natural or mechanical) available in patient care areas?	☐ No	0
	☐ Yes	5
7. For floors and horizontal work surfaces, is there an accessible record of cleaning, signed by the cleaners each day? Choose one answer	☐ No record of floors and surfaces being cleaned	0
	Record exists, but is not completed and signed daily or is outdated	2.5
	☐ Yes, record completed and signed daily	5
8. Are appropriate and well-maintained materials for cleaning (for example, detergent, mops, buckets, etc.) available? Choose one answer	☐ No materials available	0
	☐ Yes, available but not well maintained	2.5
	☐ Yes, available and well-maintained	5

Patient placement and personal protective equipment (PPE) in health care settings

9. Do you have single patient rooms or rooms for cohorting patients with similar pathogens if the number of isolation rooms is insufficient (for example, TB, measles, cholera, Ebola, SARS)? Choose one answer	☐ No	0
	No single rooms but rather rooms suitable for patient cohorting available	2.5
	☐ Yes, single rooms are available	7.5
10. Is PPE available at all times and in sufficient quantity for all uses for all health care workers? Choose one answer	☐ No	0
	☐ Yes, but not continuously available in sufficient quantities	2.5
	☐ Yes, continuously available in sufficient	7.5

	quantities	

Medical waste management and sewage

11. Do you have functional waste collection containers for non-infectious (general) waste, infectious waste and, sharps waste in close proximity to all waste generation points? Choose one answer	☐ No bins or separate sharps disposal	0
	☐ Separate bins present <u>but</u> lids missing or more than 3/4 full; <u>only</u> two bins (instead of three); <u>or</u> bins at some but not all waste generation points	2.5
	☐ Yes	5
12. Is a functional burial pit/fenced waste dump <u>or</u> municipal pick-up available for disposal of non-infectious (non-hazardous/ general waste)? Choose one answer	☐ No pit or other disposal method used	0
	☐ Pit in facility <u>but</u> insufficient dimensions; pits/dumps overfilled or not fenced/locked; <u>or</u> irregular municipal waste pick up	2.5
	☐ Yes	5
13. Is an incinerator or alternative treatment technology for the treatment of infectious and sharp waste (for example, an autoclave) present (either present on or off site and operated by a licensed waste management service), functional and of a sufficient capacity? Choose one answer	☐ No, none present	0
	☐ Present, <u>but</u> not functional	1
	☐ Yes	5
14. Is a wastewater treatment system (for example, septic tank followed by drainage pit) present (either on or off site) and functioning reliably? Choose one answer	☐ No, not present	0
	☐ Yes, <u>but</u> not functioning reliably	2.5
	☐ Yes <u>and</u> functioning reliably	5

Decontamination and sterilization

15. Does your health care facility provide a dedicated decontamination area and/or sterile supply department (either present on or off site and operated by a licensed decontamination management service) for the decontamination and sterilization of medical devices and other items/equipment? Choose one answer	☐ No, not present	0
	☐ Yes, but not functioning reliably	2.5
	☐ Yes and functioning reliably	5
16. Do you reliably have sterile and disinfected equipment ready for use? Choose one answer	☐ No, available on average < five days per week	0
	Yes, available on average ≥ five days per week or every day, <u>but</u> not of sufficient quantity	2.5

	☐ Yes, available every day and of sufficient quantity	5
17. Are disposable items available when necessary? (for example, injection safety devices, examination gloves) Choose one answer	☐ No, not available	0
	☐ Yes, but *only* sometimes available	2.5
	☐ Yes, continuously available	5
Subtotal score		**/100**

Interpretation of IPCAF score

1. Add up your points

	Score
Section (Core component)	**Subtotals**
1. IPC program	
2. IPC guidelines	
3. IPC education and training	
4. HCAIS surveillance	
5. Multimodal strategies	
6. Monitoring/audits of IPC practices and feedback	
7. Workload, staffing and bed occupancy	
8. Built environment, materials and equipment for IPC at the facility level	
Final total score	**/ 800**

2. Determine the assigned "IPC level" in the facility using the total score from Step 1

Total score (range)	**IPC level**
0–200	Inadequate
201–400	Basic
401–600	Intermediate
601–800	Advanced

VIII. Figures of laboratory

Stiring swab sample

Dillution

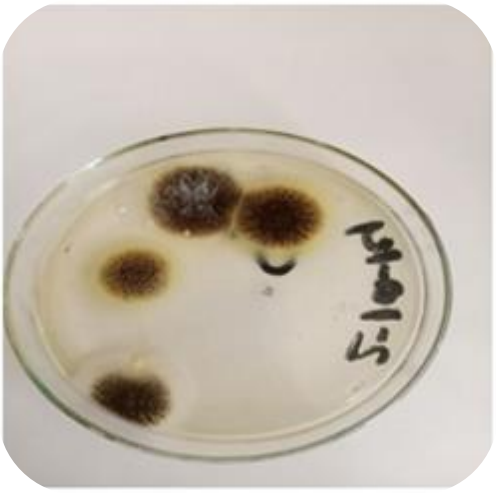
Spreed plate

Microbial load count

s.aureus and *CONs* identification

Microbial inoculation for biochemical test

Biochemical test results



Aspergillus niger

Aspergillus sydowii

DECLARATION

I, the undersigned, declare that this thesis is my original work, has not been presented for a degree in this or any other university, and that all sources of materials used for the thesis have been fully acknowledged.

Name: _____

Signature: _____

Name of the institution: _____

Date of submission: _____

This thesis has been submitted for examination with my approval as a University advisor

Name advisor _____

Date _____ Signature _____

Approval of The examiner

Name of examiner_____

Date _____ Signature _____