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INDOOR AIR BACTERIAL LOAD AND CONTRIBUTING FACTORS IN GOVERNMENT AND PRIVATE HOSPITALS IN HARAR, HARAR TOWN, EASTERN ETHIOPIA

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ACRONYMS AND ABBREVIATIONS

AOR	Adjusted Odds Ratio
CDC	Centers For Disease Control And Prevention
CFU	Colony Forming Unit
CoNS	Coagulase Negative Staphylococci
DALY	Disability Adjusted Life Years
EPA	Environmental Protection Agency
IAQ	Indoor Air Quality
ICU	Intensive Care Unit
LR	Likelihood Ratio
NHMRC	National Health and medical research council
NTM	Non-Tuberculous Mycobacteria
OR	Operational Room

ABSTRACT

Background: Human can be exposed to airborne microorganisms in both residential and hospital indoor environments. This may lead to adverse health effects with major public health impacts. Hospital indoor air may contain a vast number of disease causing agents that could be originate from patients, the staff, visitors, ventilation and outdoors. Hospitalized patients are at a higher risk of infection due to confined spaces that can accumulate microorganisms and create favorable condition for their growth and multiplication.

Objectives: to determine and compare indoor bacterial load, and contributing factors in different wards of the four hospitals in Harar town, 2017.

Methods: A cross sectional study design was used to assess the bacterial load and associated factors in two government hospitals (Police and Jugula), one teaching hospital (Hiwot-Fana) and one private hospital (Yemage) in Harar town. Nine inpatient wards and 96 rooms were taken as a sample to determine the bacterial load. All of the impatient rooms of all wards of these hospitals were included in the study. To determine the bacterial load of these rooms' passive air sampling technique was used. Data was collected using settle plate method by exposing petridish of blood agar media for an hour to the indoor air of the sampled rooms. Observation checklist was used to assess the contributing factors that influence the quality of the indoor air.

Results; Based on our finding, airborne bacteria load ranged from 74.2–14,310 CFU/m^3. The highest bacterial load was found in medical ward and the lowest in OR of Hiwot-Fana specialized teaching hospital. The result of one-way ANOVA showed a significant difference in mean bacterial load among the four hospitals and also the major wards of these four hospitals. In those hospitals, *S.aureus*, *micrococcus* and *CoNS* were among the most common bacteria identified. This study suggests that cleaning frequency, room temperature, a high number of health and medical students as well as number of visitors were found to be determinants that affect bacterial load in the sampled rooms.

Conclusion: High bacterial load was recorded in Jugula, Police & Hiwot-Fana specialized teaching hospitals. The bacterial load of Hiwot-Fana specialized teaching hospital was much higher the other hospitals. Environmental factors play a major role in the increase of bacterial load. Thus, this high bacterial load in those hospitals may lead to high infection risk to the admitted patients.

1. INTRODUCTION

1.1 Background of the study

Clean air is fundamental for the wellbeing of human beings. The quality of air inside homes, offices, schools, day care centers, public buildings, health care facilities where people spend much of their life time is very important to determine the healthy life and for the well-being of the inhabitant (1). The quality of the indoor environment is a major health concern due to the fact that most of the indoor air is a mixture of outside air and microorganisms from different indoor source and additional pollutants emitted from building materials (2).

Human can be exposed to airborne microorganisms in both residential and hospital indoor environments; this may lead to adverse health effects with major public health impacts. Hospital indoor air may contain a vast number of disease causing and non-disease causing agents which could originate from patients, the staff, visitors, ventilation and outdoors. In hospital environment both infected persons and persons at risk congregate, which create a favorable condition for the transmission of the disease especially in crowed room (3).

“Bioaerosol” contaminants are aerosols that contain biological agent such as Viruses, bacteria, allergens and fungi that are found in indoor environments, can cause reactions such as infections, allergies, toxic reactions and others. People inhale significant amount of microorganism called bioaerosols since they spend between 80–95 % of their lives indoors (4).Bio-aerosols contribute to about 5-34% of indoor air pollution. In hospital environment bio-aerosols plays a major role in disease transmission. Since they are extremely tiny in size bioaerosols (<5 μm), can remain suspended and viable in the air for a long time in a confined environment cause high risk of airborne infection. Disease can be transmitted either by droplet (coughing, sneezing and talking) and airborne (dispersion through the air) (5).

Biological contaminants such as bacteria, mold, and viruses can grow on pans of the ventilation system; humid ceiling and floor. Microorganisms, such as *Aspergillus* spores, can become

airborne and infect immune suppressed hospitalized patients. To prevent this problem rooms needs to be cleaned well especially to inhibit mold growth (6).

Among the different causative agents of health care infections, more than 90% accounted by bacteria. The bacterial indoor quality of air can be considered as a mirror image of the hygienic conditions of the hospital rooms. Since, some bacteria can survive for long period of time and resistant to disinfectant, they affect the health of the patients due to their resistance (7, 8).Therefore, determining the indoor bacterial load helps to revise or design appropriate infection control protocol to decrease the occurrence of health care infections.

1.2 Statement of the problem

Hospitalized patients are at a higher risk of infection due to enclosed spaces that can accumulate microorganisms and create favorable condition for their growth and multiplication (9).Hospital housing conditions, such as ventilation, cleaning procedures, number of patients in a room and activities that takes place in the room highly affect the quality of hospital indoor air (10) In addition, poor disinfection practice, cross contamination of hospital materials and equipment favor the growth of these bacteria. Microbial type and load can be an indicator of hospital room cleanliness and its association with patients' health as a means of nosocomial infection (6).

Indoor exposure to air pollutants causes millions of morbidity, mortality and economic burden worldwide every year, especially in developing countries. The problem of indoor air quality associated with several airborne infections, to name the most common disease causing bacterial agents, *Streptococcus pyogenes*, *Neisseria meningitidis*, *Corynebacterium diphtheria* and *Mycobacterium* tuberculosis (11).

The US Environmental Protection Agency (EPA) recently identified that Indoor Air Quality (IAQ) is one of the most crucial environmental health problems (12). Worldwide, 4.3 million deaths were caused by indoor air pollution in 2012 (1); majority of the cases were in developing countries. According to the WHO report 41 million Disability Adjusted Life Years (DALYs) were lost due to indoor air pollution (13).Centers for Disease Control and Prevention (CDC) estimation more than 1.7 million patients a year acquire infections in U.S. hospitals while they are admitted for other health problems (14).

Studies done in Ethiopia showed, high risk of infection due to the high bacterial load in the hospital wards. Researches done in Hawassa, Gonder, Jimma and Adama hospitals concluded that, almost in all of the hospital wards bacterial air quality was above the sanitary standards of European Commission for non industrial premises acceptable values (500-2000 CFU/m^3 as high range) (10, 15-17). Therefore, it is very crucial to assess the contributing factors of this high level of bacteria load within hospitals.

1.3 Rationale and significance of the study

There is, a few data about the air quality in Ethiopia hospitals, as the results of the studies in those hospitals showed the bacterial load is high in most of the hospitals. However, none of them give adequate information about the different environmental factors that contribute for bacteria load such as, temperature, no of windows, cleaning frequency, cleanness of the impatient room, improper use of ventilation systems and overcrowding. In addition, none of these researches showed the difference in bacterial load in government and private hospital.

Strong infection control strategies can play an important role in preventing infections that arising from indoor air microbial aerosols exposure. Prevention of disease is still an important element of the Ethiopia health system policy. Therefore, the significance of assessing indoor air bacterial load and contributing building factors will help the policy makers to design appropriate preventive measure. In addition, it may contribute for indoor air bacterial measurements control and it helps to revise and if necessary, design appropriate hospital infection prevention protocols in an effort to minimize the incidence of hospital acquired infections due to deteriorated indoor air.

2. LITERATURE REVIEW

2.1 Microorganisms and their transmission in hospital environment

Healthcare facilities, such as hospitals, have to pay particular attention to indoor air quality. This is due to the pre-existing health problem of many patients would be more vulnerable to other infectious diseases and biological contaminants that has introduced to the indoor environment (6).

Health care facilities contain a unique group of microorganisms indoor, which are a potential cause of nosocomial infections. Health care acquired infection plays a major role in infection transmission during the hospital stay. Worldwide, the prevalence rate of health care acquired infections is **3.0 -20.7%** and it has an incidence of **5-10 %** (18). In developed countries, from the hospitalized patients 5% to 10% acquire one or more hospital acquired infection. In developing countries the problem of nosocomial infection is much higher. Seven of every 100 admitted patients in developed and 10 in developing countries will acquire at least one health care-acquired infection (1). More than 1.7 million people affected from nosocomial infection and its complications annually in the US only (19).

In sub Saharan countries, hospital acquired infections ranges from 2.5% to 14%, (20, 21).Hospitals in Eastern Mediterranean and South-East Asia Regions had the highest frequencies of nosocomial infections (11.8 and 10.0% respectively) (6). Despite of this problem, there is poor habit to follow infection prevention protocols by the health care providers in developing countries (11).

Indoor biological contaminant in hospital indoor

An estimation of 1 in 10 patients acquires an infection in the hospital stay either through contact or by the airborne route. Evidences showed that some of the hospital-acquired infections are airborne and indoor hospital air could be a potential transmission route of those infectious agents (22). Airborne disease transmission contributes 10-20% of nosocomial infections (23), to name the most common disease causing bacterial agents, *Streptococcus pyogenes*, *Neisseria*

meningitidis, *Corynebacterium diphtheria* and *Mycobacterium* tuberculosis plays an essential role for the transmission of infectious. The problem of Staphylococcus aureus and Streptococcus pyogenes are the major public health problem in the world particularly in developing countries hospital. *S. aureus* is the most known cause of nosocomial infection (24).

Table 2.1 Diseases and the associated indoor bacteria (6).

Disease	**Microbial agent**	**Taxa**
Legionnaires' disease (25)	*Legionella pneumophila*	Bacteria
Pneumonia (26)	*Streptococcus pneumonia*	Bacteria
Pulmonary disease (27)	Non-tuberculous mycobacteria (NTM)	Bacteria
Staphylococcal infection (28)	*Staphylococcus aureus*	Bacteria
Tuberculosis (29)	*Mycobacterium tuberculosis*	Bacteria
Whooping cough (30)	*Bordetella pertussis*	Bacteria

Nevertheless, some of the bacterial infections affect more the susceptible (old age, underlying disease, or chemotherapy) and immuno-compromised hospitalized patients than the healthy groups (31). Indoor air pollution is a major challenge of hospitals due to the increment of immune compromised patients, who has a high risk of airborne bacterial exposure that may lead to an increment in mortality and morbidity (22).

Mode of transmission

Airborne bacteria disperse either long distance far away from the patient room or within a short distance in the room. Droplet (coughing, sneezing and talking) and airborne (dispersion through the air - <5 μm in size of evaporated droplet or dust that contain microorganisms are major mode of transmission (11). Small size bacterial aerosols transmitted to the immediate or the nearby patient. A person could be exposed to a group of bacteria in a single day that may react in a very complex way to cause reparatory inflammation and infection (32).There are different things that determine individual response to any infection to be expressed, the first thing is the type of the microorganism, the intake dose, exposure duration and individual response to the microbes (genetic polymorphisms) (33).

Common acquired infections in the hospital wards

Surgical wounds, urinary tract infections and lower respiratory tract infections are among the common hospital acquired infections. Bacterial load and surgical site infection has a linear relationship. Intensive care units (ICU) and surgical and orthopedic wards are known with the highest prevalence of nosocomial infection rate (15).

Thus, monitoring of bacterial contamination of hospital air wards is very essential particularly, for those infections that an airborne transmission is postulated (34). Infection prevention and bioaerosol monitoring in a hospital environment are crucial approaches that can contribute an important knowledge of bioserosol sources, load, and dispersion and to take quality control measures (35).Airborne bacterial monitoring is found to be an important action to control microbial contamination.

2.2 Major contributors of hospital indoor air quality

Air contamination with microorganism remains without prevention, bacterial contaminants ruminants on hospital surface and equipment; this may cause airborne infection to the patient.

1. **Personal hygiene and hospital room cleanness**

Microbial air quality considered as mirror of the hygienic condition hospital rooms (36). Most of

these hospital-acquired infections are linked with the cleanness of the hospitals. The hospital environment most of the time acts as a favorable place for growth and survival of this particular bacterium. Bacterial agents may contaminate objects, devices, and materials, which consequently contact susceptible body sites of patients. Hospital floors, curtains, patient beds, lockers chairs and tables and other equipment can be reservoir of these bacteria (37).However, Improving the cleaning frequency and increase the number of cleaner plays an important role in minimizing the bacterial load of hospital wards (38).

On the other hand, housekeeping and hygiene contribute a lot for the indoor air quality. Dusts and garbage increase the load of microorganisms in the room. Settled dusts on the floor are enrich with microbes so by their re-suspension they can serve as bioaerosol (39). Moist indoor surfaces can be a breeding site for bacterial growth. Aerosol droplets can release by toilet flushing, the toilet can also a potential source of indoor bioaerosols since feces contain an enormous amount of microorganisms. This may directly lead to diarrheal disease (40).

In addition, common towels, washing basin are possible source of bacteria, which is likely to concentrate on wet surfaces. Bed clothes and dressing are also a potential source of airborne bacteria. Different cleaning activities also contribute to indoor air pollution such as, sweeping of floors and changing of bed sheets lead to suspension of bacteria in to the air (41). Due to the favorable pathogen, host and environment interaction a great deal of health problems occurred in poor hospital setting. Poor disinfection practice also contributes for the high bacterial load in which, contaminating microbes and dust particles suspend and bind with each other then settled on open wound during surgery or during wound dressing that may lead to high risk of infection to the patient (6). For that reason, the patient will be exposed to health care acquired infection that may extend patient admission days and extra financial burden (16).

The human skin and respiratory organs harbor different microorganisms. The Skin dusts and personal clothing during movement release about 1000 per minute bacteria to the air (42). Frequent movement of people in the room contributes to the resuspension of bioaerosoals that had previously settled on flooring. Through breathing and coughing both large and small microorganism could be released to the air (39).

2. Building related factors

In health care facilities, the bacterial load is highly determined by number of occupants, their activity and ventilation status. Ventilation disperses and dilutes the bacterial load thus it reduce the load of the microbes. Source of ventilation affect the diversity and composition of the surrounding microorganisms. Indoor environmental conditions have a strong association with relative humidity, temperature and airborne bacterial load. An increase in microbial dispersal from different sources like, humans, materials or surface can affect the hospitalized patient health through direct effects on microbial population. Studies indicated that there is a strong relationship of allergies and respiratory symptoms with moisture exposure (6). Ventilation methods both mechanically and window-ventilated rooms have a crucial role in reducing the abundance of potentially pathogenic airborne bacteria (43).

Hospital environments, medical equipments and materials are potential source of hospital infections. Indoor air condition of health facilities place patients at greater risk due to enclosed spaces can detain aerosols and them to build up to infectious levels (9).Poor building design, unregulated temperature, humidity, poor ventilation system, overcrowding of the beds and frequent patient, visitor and health care workers movement, internally increase bacterial indoor load can lead to indoor air quality problem (10, 17).

Building dampness will lead to the growth of fungi, mold and bacteria well as the release of volatile organic compounds; and the breakdown of building materials. This also cause different heath problem such as respiratory symptoms, asthma, pneumonitis, rhinosinusitis, bronchitis, and respiratory infections (44).

The Indoor air exchange is the substitution of indoor air with outdoor air. It is important to reduce carbon dioxide amount and other microorganism in the building. Air exchange is very essential to improves indoor air quality. Mode of air exchange could be through infiltration, natural ventilation or mechanical ventilation. For larger particles (3–10 μm in diameter), the deposition loss rate coefficient is much higher, in the range 2–10 per hour. Therefore, deposition for these large particles is crucial to determine the fate of bioaerosols even for buildings with

relatively high air exchange rates (6).

Therefore, to control indoor air pollution identification of potential sources of microorganism, regulating humidity and temperature and use of proper ventilation, air filter in ventilation, use of disinfectant to clean the air and the floor of the room is very important.

Conceptual frame work

The following conceptual framework was developed based on literature review. It depicts the relation of indoor bacterial load with the different contributing factors. It also shows that the effect relationship of the contributing factors with the IAQ. Indoor air quality is highly depend on types of wards and the different medical procedures taken place, building factors, the sanitation of the room and the number of occupant, no of visitors and hospital staffs and their movements in the rooms (10).

The components of this conceptual framework was used to develop the study design and identifying variables.

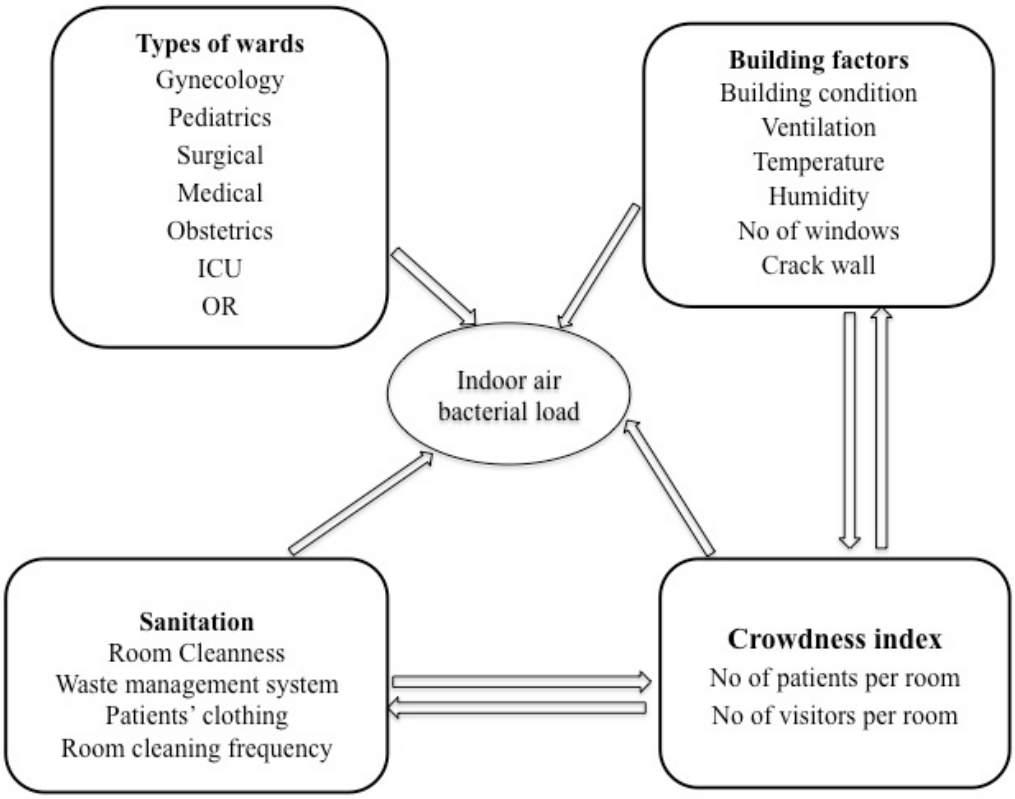


Figure 2.1: The conceptual model shows indoor air bacterial load and its contributing factors (developed by the principal investigator based on literature review).

Research questions

- ☞ Is there a difference in bacterial load among the four hospitals (Hiwot-Fana Specialized teaching Hospital, Police, Jugula hospital & Yemage General Medical Center) in harar?

- ☞ What are the contributing factors for the difference in the bacterial load?

Hypothesis

Bacterial load is different in the four hospitals (Hiwot-Fana Specialized teaching Hospital, Police, Jugula hospital and Yemage General Medical Center) that are found in Harar.

Reason

Since the setting of those four hospitals (private hospital, Specialized teaching Hospital and two are government hospitals) is different determining and comparing the bacterial load will help to assess the contributing factors for the difference.

3. OBJECTIVE

3.1 General objective

The study was designed to determine and compare indoor bacterial load, and contributing factors in different wards of the four hospitals in Harar town, from August 1/2016 to June 5/2017.

3.2 Specific objectives

- To determine the indoor bacterial load in four hospitals
- To compare the indoor bacterial load in the four hospitals
- To identify the dominant type of bacteria in the wards
- To assess the contributing factors for the bacterial load in the four hospitals

4. METHODS

4.1 Study area

Harar town is located 526Kms east of Addis Ababa, Ethiopia. The average temperature of the town is 23^{o}c and 55% humidity. The total population in Harari Region is 188,173 (male 51.6% and 48.4% female). Harari region has the share of 0.24 percent from the Ethiopian total population. There are 3 government (Police and Jugula Hospital & Hiwot-Fana Specialized teaching Hospital) and 2 private hospitals (Yemage General Medical Center and Harar General hospital) in Harar town. Hiwot-Fana Specialized teaching Hospital has a bed capacity of 157 beds with 294 functional room to offer different services of the hospital. The bed capacity of Police, Jugula and Yemage hospital is 80, 88 and 58, respectively. One of governmental hospital (Jugula) is under regional health bureau, The other one is under police & ministry of defense. Hiwot-Fana Specialized teaching Hospital has been serving as a referral hospital to the people of harari region and also for the near by eastern oromia and Ethiopian Somali region. Since july 14,2010,the harari regional health bureau handed over the administration and service provision of the hospital to aramaya university college of health and ,edical sciences and hassince the been named as Hiwot fana specialized university hospital.The two hospitals under the health bureau are referral hospitals (Hiwot-Fana and Jugula) established 50 and 90 years back. These hospitals give various services to the regions population as well as the neighboring population (Oromia, Somali & Dire Dawa).There are also 1 Tuberculosis, 3 health centers, 17 health posts, 1 regional laboratory and 1 nursing school. All these institutions are under regional health Bureau.

4.2 Study design

Cross sectional comparative study was conducted. The study period was from August 1/2016 to June 5/2017.

4.3 Study Setting

Government hospitals: - All wards of Hiwot-Fana Specialized teaching Hospital, Police and Jugula hospital

Private hospitals:-All wards of Yemage General Medical Center

One of those four hospitals is private (Yemage General Medical Center) the other is Hiwot-Fana Specialized teaching Hospital. The rest two are government hospitals namely, Police and Jugula Hospital.

The indoor air microbial load of nine wards of Hiwot-Fana, eight wards of Jugula, seven wards of police and five wards of Yemage hospital were included in the study with a total of 96 rooms used for sample collection (Table 4.1).

Table 4.1: The type of wards included in the study from the four hospitals

Inpatient wards	Hospitals			
	Hiwot-Fana (33 rooms)	Jugula (18 rooms)	Police (21 rooms)	Yemage (24 rooms)
Medical	✓	✓	✓	✓
Surgical	✓	✓	✓	✓
Obstetric	✓	✓	✓	✓
Gynecology	✓	✓	-	-
Delivery	✓	✓	✓	✓
Pediatrics	✓	-	✓	-
ICU	✓	✓	✓	✓
OR	✓	✓	✓	-
Recovery	✓	✓	-	-

4.3.1 Study population

The study population was all inpatient rooms from all wards.

Inclusion criteria

Rooms that are occupied by one or more patients were included in the study. In addition, only inpatient rooms were included.

Exclusion criteria

Outpatient department and staff offices were not included.

4.4 Sampling technique and sample size

All the rooms (96 rooms) from all impatient wards of the four hospitals were included in the sample.

4.5 Data collection tools

4.5.1 Blood agar for indoor air data collection

Blood agar was prepared prior to the data collection day. Sterile blood from Haramaya university sheep farm was taken to prepare the specimen. Follow by the preparation of agar solution and blood agar according to the standard (49) (Figure 4.1). Then the blood agar solution was poured in to petridish, sealed with plastic bag to prevent contamination and stored in the refrigerator one day prior to the data collection day. The laboratory technician was responsible for the preparation of the specimen. The specimens were transported to the sampling rooms using cold box (Figure 4.2). Each petridish were labeled with code and time of the first exposure of the blood agar to the indoor air.



Figure 4.1 : Preparation of blood agar media using sterile blood and agar solution

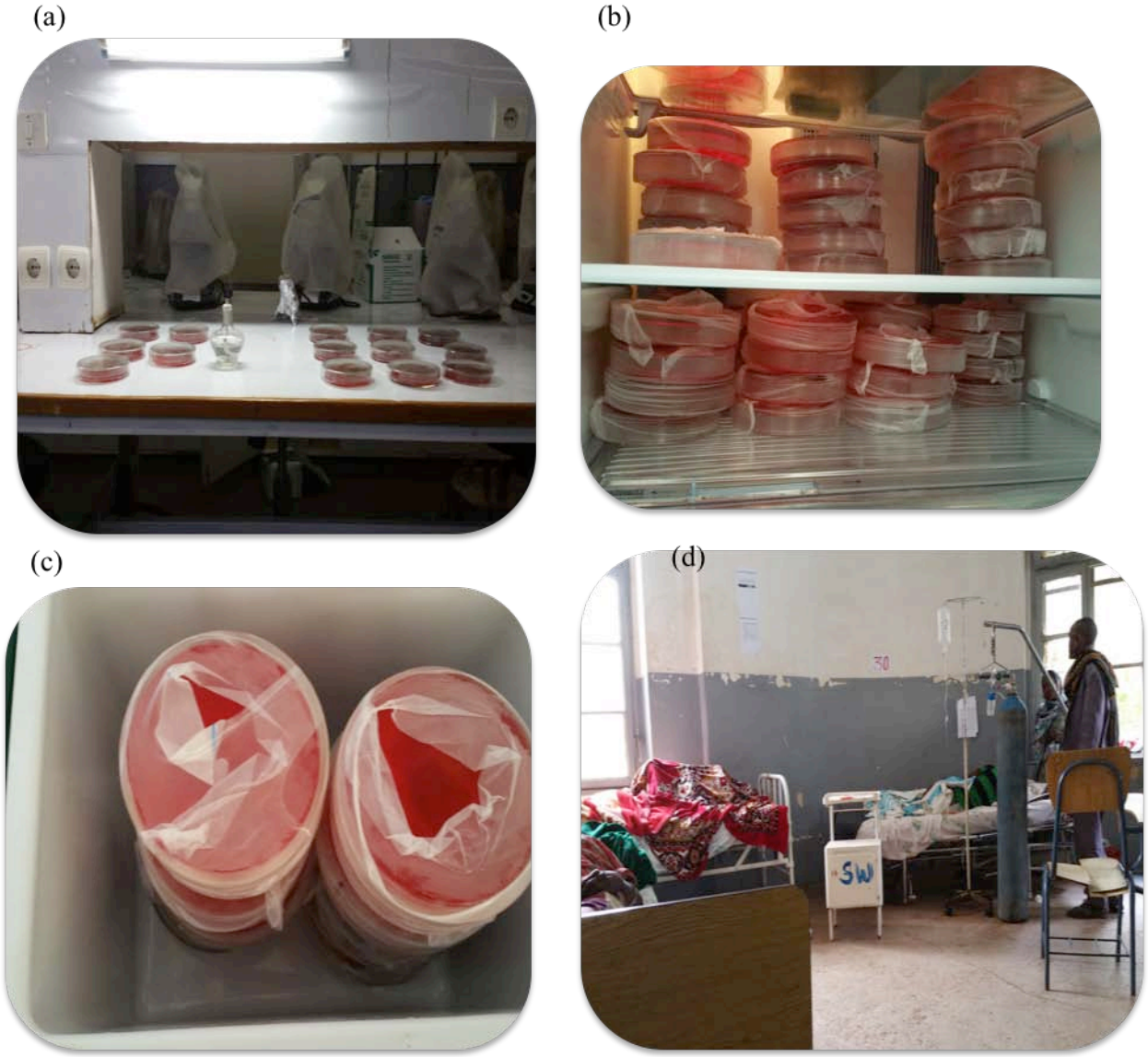


Figure 4. 2: Shows air sample specimen preparation (a) blood agar poured in to the petri dish (b) blood agar containing petri dish sealed with plastic bag and stored in refrigerator (c)transporting the blood agar containing petri dish using cold box for data collection (d) 1 hour air sample exposure of the blood agar containing petri dish in the sampling room.

Media preparation procedures

Blood agar preparation

A 1 L bottle containing deionized water (475 ml) and 11.6g nutrient agar were heated and stirred until the agar dissolved. Followed by, sterilization by autoclaving at 121 ^{o}C for 15 minutes. Then allowed to cool to 50 ^{o}C. After that, 25ml of sterile sheep blood was added aseptically and mix gently. Agar solution of 15-20 ml was dispensed aseptically in to a sterile petri dishes and covered and stored at 4^{o}C (49).

Mannitol salt agar

Mannitol agar was prepared according to the manufacturer's instructions. In a 1L bottle, 500ml of deionized water was mixed with 55.5g MSA, heated and stirred until the agar dissolved. The solution then sterilized by autoclaving at 121 ^{o}C for 15 minutes and cooled to 50–55 ^{o}C, mix well, and 20-25ml dispensed it aseptically in sterile petri dishes. Dated the medium, give it a batch number and Store the plates at 4^{o}C (49).

Catalase test

The test was carried out, by pouring 2-3 ml of hydrogen peroxide solution into a test tube. Then using a glass rod several colonies of the test bacteria were immerse in the hydrogen peroxide solution. Look for immediate bubbling was an indication of positive result (49).

4.5.2 Observational Checklist

Checklist was used to assess the contributing factors such as ventilation system, crowdness, room, cleanness (floor, window, wall, ceiling), no of visitors, frequency of cleaning, proper storage of food and patient staffs, presence of odor and flies, no of windows, room area, floor design and cleanness, temperature, and waste management systems (Annex 3).

4.5.3 Short interview and instrument used

Meter was used to measure the room area to calculate the crowding index. In addition, Interview was made with the patients and the staffs to assess their awareness about waste segregation. Interview also done with the medical directors and environmental health staffs in the hospitals to assess the cleaning frequency of the sampled rooms and presence and strength of infection prevention committee.

Two environmental health professional were hired to assess the contributing factors for the of indoor air quality. In addition, two microbiologists and one laboratory assistance were participated in the sample collection and analysis.

4.6 Data collection procedures

4.6.1 Air sampling to measure bacterial load

Air sample was taken from each room of the inpatient wards in the four hospitals. Passive air sampling technique was used to measure the bacterial load, settle plate method using petri dishes with 9 cm diameter (petri dish of blood agar media). In each of the sampling room the petri dishes was exposed to the indoor air for an hour. The sample was located one meter away the corner of the room (corner away 1m away from door and window to minimize bacterial dilution) with a sampling height will be adjusted at 1m above the floor to estimate the human breathing zone for an hour (45) (Figure 4.2d).The sampling were done in the morning from 10 am-11 am. This time was chosen because high activities of staff, students and visitors were seen during the pre-test.

4.6.2 Data collection using observational checklist and interview

Unique Id number was given for each impatient room, which is similar to the Id on the petridish. The principal investigator exposed the petridish to the indoor air and at the same time the data collectors filled the observational checklist in each room. Short interview was done with at least two patients in each room, one staff member from each ward.

4.7 Study variables

Dependent variables

Indoor bacterial load

Independent variable

Type of wards

Medical, Surgical, Obstetric, Gynecology, delivery, pediatrics, ICU and OR

Building factors

- No of windows
- Ventilation system
- Room temperature
- Proper use of ventilation system
- Room area

Sanitation

- Cleaning frequency
- Cleanness of the room
- Appropriate storage of food and patient medication
- Presence of flies
- Proper waste management
- Proper sealing of waste container

Crowdness

- Traffic density (no of students, medical staffs, visitors) in and near the room
- Number of patients per room
- Number of visitors per room

4.8 Sample quality management

Before the data collection, training and discussion with the data collectors and laboratory technician was undertaken. The prior aim of the training was to introduce the purpose of the data collection and the objective of the research to the data collectors. The other purpose of the training was, to introduce the data collection tools, preparation of the sampling equipment and media as well as the data collection procedure to the data collectors. The microbiologists gave the training for the laboratory sample analysis and the principal investigator for the observational checklist data collection.

In order to keep the quality of the sample every essential procedure was taken starting from collecting to the analysis of these samples such as sterilization of sampling equipment, utilization of personal protective clothes, glove, cold box to bring and take the sample, proper handling of sterilized materials, safe incubation of samples was taken. The location and the duration of the media in the sampling room was monitored by the principal investigator. The way of safe transportation and cross contamination as well as safe analysis in the laboratory was monitored. One contaminated sample, which has showed change in appearance and color was discarded and the resampling was taken place the next day.

Pre-test was also done for both the air sampling and the checklist. The purpose of the pre-test for the air sampling was to decide the media exposure time to the indoor hospital room. During the pretest, the specimen was exposed to the indoor air for 30 minutes, 60 minutes and 90 minutes and it was found that exposure of the specimen more than an hour makes counting difficult since there were a lot of bacterial colonies one on the top of the other. This may cause counting error and duration less than an hour (30 minutes) underestimate the true picture of the load so one hour was selected as a duration time for the specimen exposure. Therefore, the duration of sampling was decided to be one hour after doing the pre-test.

In addition, to determine the kind of data quality procedure needed if there was a need of change in plan and procedure prior to the real data collection day. Moreover, it helped us to see means of contaminations during the equipment preparation, media preparation, transportation, sampling of

air as well as analysis of sample in order to prevent biases and false results. A total of five samples was be used for the pre-test of air sampling. For the checklist the pre-test was used to check the validity of the checklist that means the consistence of the result with the objective of the study and to see familiarity of the data collector with the checklist. A total of ten checklists were used for the observation study. Two of the data collectors each of them filled five checklists for the pretest.

4.9 Operational definition

Indoor air

Its define as air within a building occupied for at least one hour by people of varying states of health. Indoor air quality can be defined as the totality of attributes of indoor air that affect a person's health and wellbeing (46). The load of bacteria in the sampled room measured the indoor air quality in the study.

Cleanliness: Looking at the condition of the floor, wall and window to assess whether it is deep cleaned. Conditions with trash free walkways, mopped floors, stainless floor and wall, organized patients' drawers and table that are free from left items indicate cleanliness.

Soiled: Presence of visible dirt, trace of potential bodily fluids, spots, rust, mold, moist surfaces and stains that appear indicate a lack of sanitation.

Crowding index

The hospital crowding index was defined as the total no of patients per room divided by the room area.

The continuous variable was regrouped in to three distinct categories:

1 <1
2 1-2
3 >2 residents per room

WHO expert group bacterial load standard: Less than 1000 CFU/m^3 is acceptable

European Commission for non-industrial premises sanitary standard for bacterial load

Less than 50 CFU/m^3 as ' very low' bacterial load, 50– 100 CFU/m^3 as ' low' , 100– 500 CFU/m^3 as' intermediate' , 500– 2000 CFU/m^3 as ' high' and above 2000 CFU/m^3 as ' very high' load.

4.10 Data management

4.10.1 Data entry

Raw data from the laboratory result and the observation result was obtained. For the bacterial count both the laboratory technical and the principal investigators count the colony of each sample twice to avoid counting error. Error was checked in each of the sample result in both laboratory and observation checklist. Checking and adjusting the result for consistency was checked to make it ready for coding and storage. Data was coded by the principal investigator and entered in to epidata computer software. Unique Id was given for each of the results collected.

4.10.2 Data cleaning and handling

Data completeness and cleaning was taken place starting from the field on the same day of data collection, preliminary editing by the principal investigator on the field of data collection and controlling of technical matters (the time of specimen exposure to air, incubation temperature and time, bacterial colony counting method) to avoid inconsistence. All of the raw data was checked and edited by principal investigator. Error was checked in all of the data collection steps including, raw data collection, coding and data entry. Unusual and unexpected results were crosschecked with the raw data for their correctness. Missed records, logical inconsistence, miscoding and missing values were checked, running of the descriptive result of the study by using SPSS statistical software version 16.0 package. In addition, Errors and changing of dataset during the analysis was recorded to avoid confusions.

4.11 Data analysis procedures

4.11.1 Air sample analysis procedure

After an hour of exposure the specimen was closed and put back to the cold box and transported to Haramaya university microbiology laboratory and incubated at 37.1^{o}C for 24 hours in non-gas incubator (Figure 4.3a)(Annex 1). After 24 h incubation period, bacterial load was counted as colony forming units (CFU)and CFU/m^3 by using the following formula

$N=5a*104\ (bt)^{-1,}$ (47, 48)

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

b = dish surface (cm^2); and t = exposure time (minutes).

In addition, types of bacteria were identified. Colony forming unit was counted for each sample (Figure 4.3b) and the bacteria with the same colony morphology were cultured separately in to another blood agar and mannitol salt agar (MSA) for the further identification using biochemical tests including catalase activity, blood haemolysis and mannitol fermentation (49) (Figure 4.3c&d) (Annex1). Blood agar culture was used for all bacteria type because it favors the growth and multiplication of most bacteria than the normal agar culture. Three dominant bacteria were identified and Gram stain was done for those cultured bacteria and three of those dominant bacteria species were gram-positive cocci so we used the following procedure (Figure 4.4) to identify the specific bacteria. Since the gram stain of the three identified bacteria were gram-positive, catalase activity was checked to identify whether the bacteria was Staphylococci or streptococci. Three of these bacteria were found to be catalase positive or Staphylococci. In order to identify those bacteria are staphylococcus aureus of CoNS ,those bacteria were inoculate in to MSA.

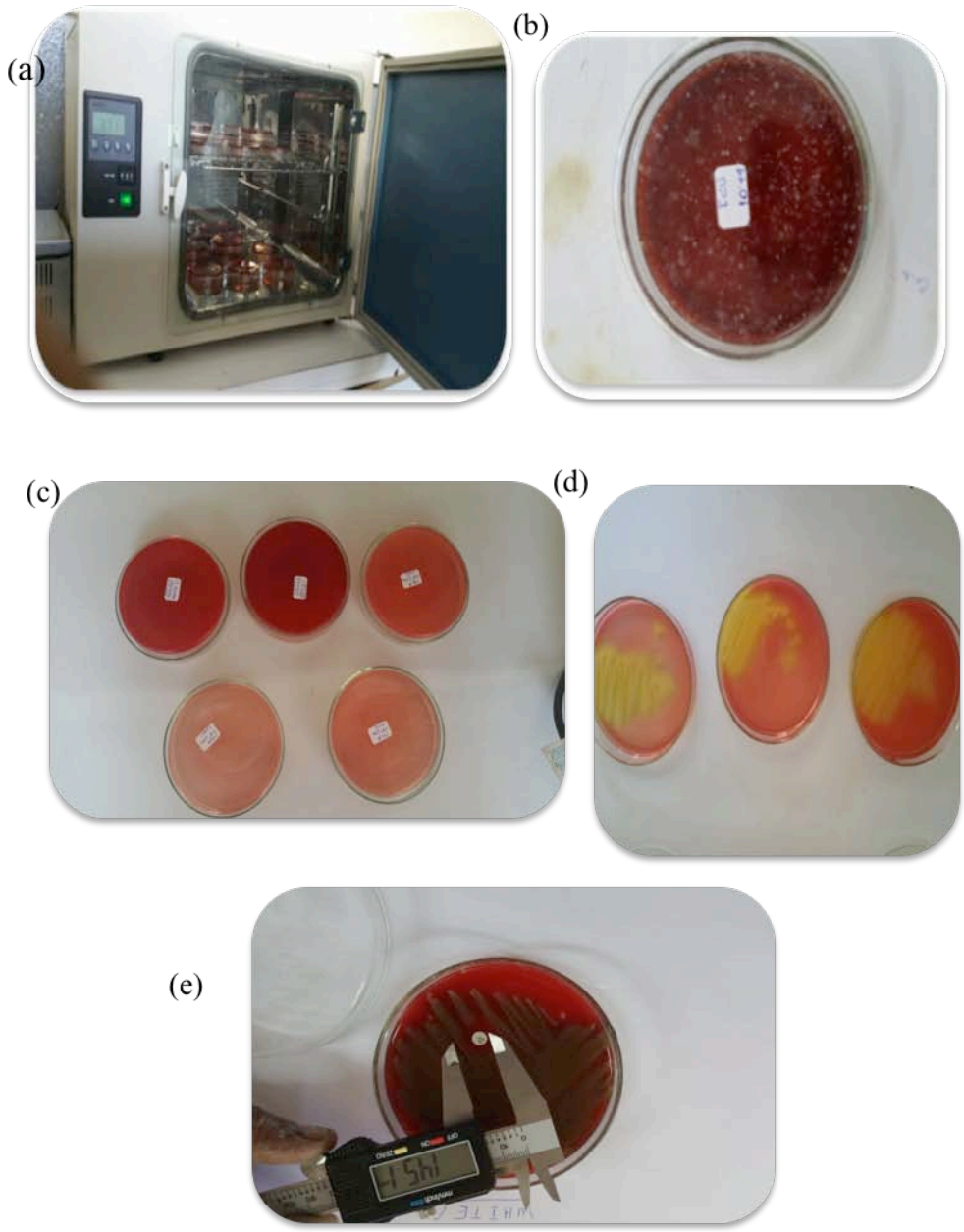


Figure 4.3 Indicates bacteria identification procedure (a) air samples were taken to the laboratory and incubated at 37 °C for 24 hour (b) bacteria colony counted after incubation (c) sample from the bacteria colony were inoculated in to another blood agar and mannitol salt agar plate (MSA) for the identification of the bacteria (d)*Staphylococcus aureus* isolated by MSA (e) Novobiocin antibiotic disk was used to isolate the antimicrobial susceptibility pattern of the bacteria, any zone of inhibition around the disk indicates positive result or effectiveness of the antibiotic.

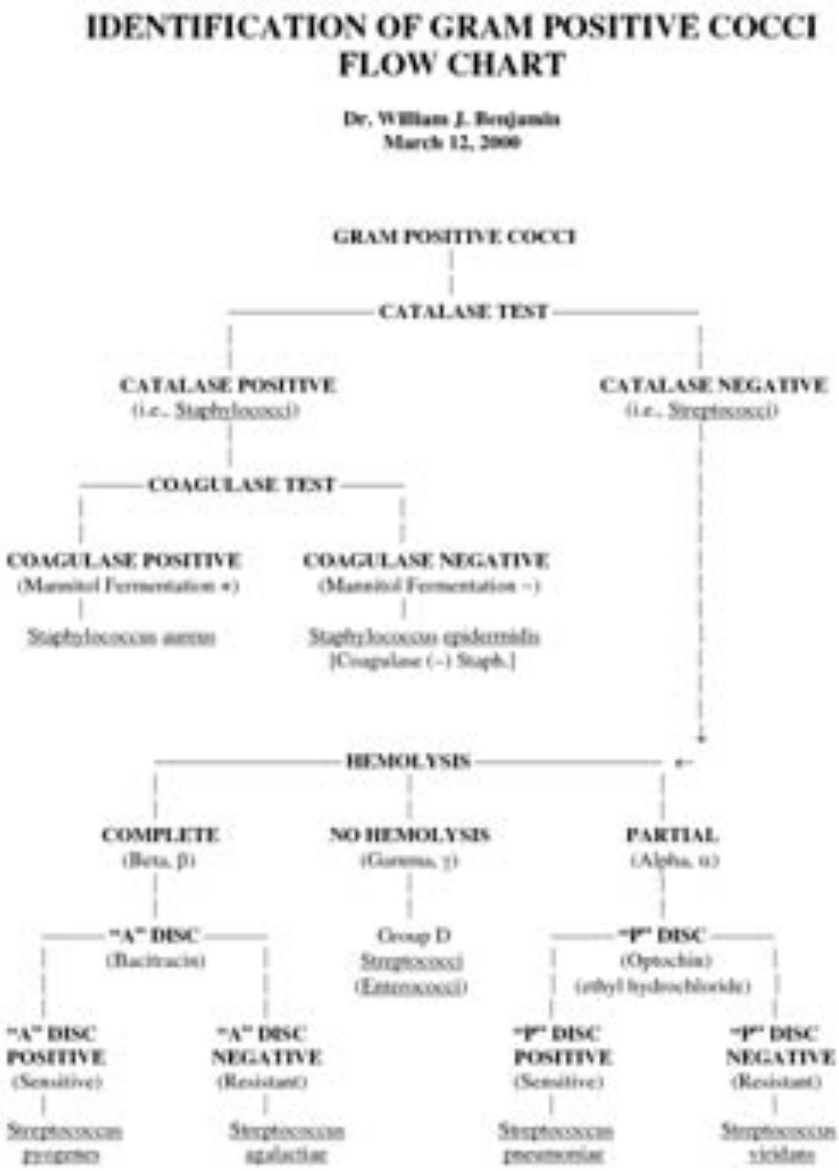


Figure 4.4 Identification of gram-positive cocci flow chart

4.11.2 Statistical Data analysis procedures

Data was entered using Epi-data and exported to SPSS for further analysis. Normality of bacterial load distribution was checked using Kolmogorov-Smirnov test. The bacterial load was normally distributed and it is from independent sample.

Objective	**Data analysis**
Objective 1&3	Descriptive statistics was used to determine the bacterial load (bar chart) and mean of the bacterial count.
Objective 2	One-way ANOVA was used to assess the difference in bacterial load of the four hospitals and the major wards of those hospitals.
Objective 4	➢ Chi-square was used the assesses the difference in bacterial load (grouped based on WHO standard <1000CFU/m^3 and >1000CFU/m^3) with proper usage of ventilation system, appropriate storage of food and patient staffs, no of windows per room, frequency of cleaning, room temperature, no of visitors, room area, no of beds per room, room cleanness, presence of odor and flies and waste management ➢ After the assumption of linear relationship checked, the residuals were examined. Multiple Linear regression was used to identify association between continuous independent variable namely, no of beds per room, no of visitors per room, room area, room temperature, cleaning frequency, no of windows per room and total bacterial load (continuous variable). ➢ A logistic regression model was used for both bivariate & multivariate analysis in order to identify associated categorical independent variables with the indoor bacterial load (grouped based on WHO standard <1000CFU/m^3 and >1000CFU/m^3). Those categorical variables with a significant association ($p<0.05$) with the bacterial load in the binary logistic regression analyses were entered in to multivariate logistic regression analysis model. The findings were expressed in AOD with 95% CIs and significant level was considered at $p<0.05$

4.12 Ethical consideration

Ethical clearance was obtained from Addis Ababa University, public health program ethical review board. Permission letter was taken from each of the hospital administration before sampling collection conducted.

4.13 Dissemination of results

The thesis will be submitted to school of public health as partial fulfillment of the requirements for the master of public health. This finding will also be submitted to peer review journals for publication and after the approval of the abstract committee the abstract of the study will be disseminated to Harar minister of health and sampled hospitals in Harar for intervention action.

5. RESULTS

Objective 1: Indoor bacterial load in the four hospitals

Though the study planned to include the two private hospitals and the three government hospitals, which are found in Harar town, one of the private hospitals refused to be part of the study due to its own reason. Therefore, bacterial load of two government hospitals (Police and Jugula), one specialized teaching hospital (Hiwot-Fana) and one private hospital (Yemage) were included in the study (Figure 5.1). The microbial profile of Hiwot-Fana specialized teaching hospital was much higher than the other hospitals bacterial load.

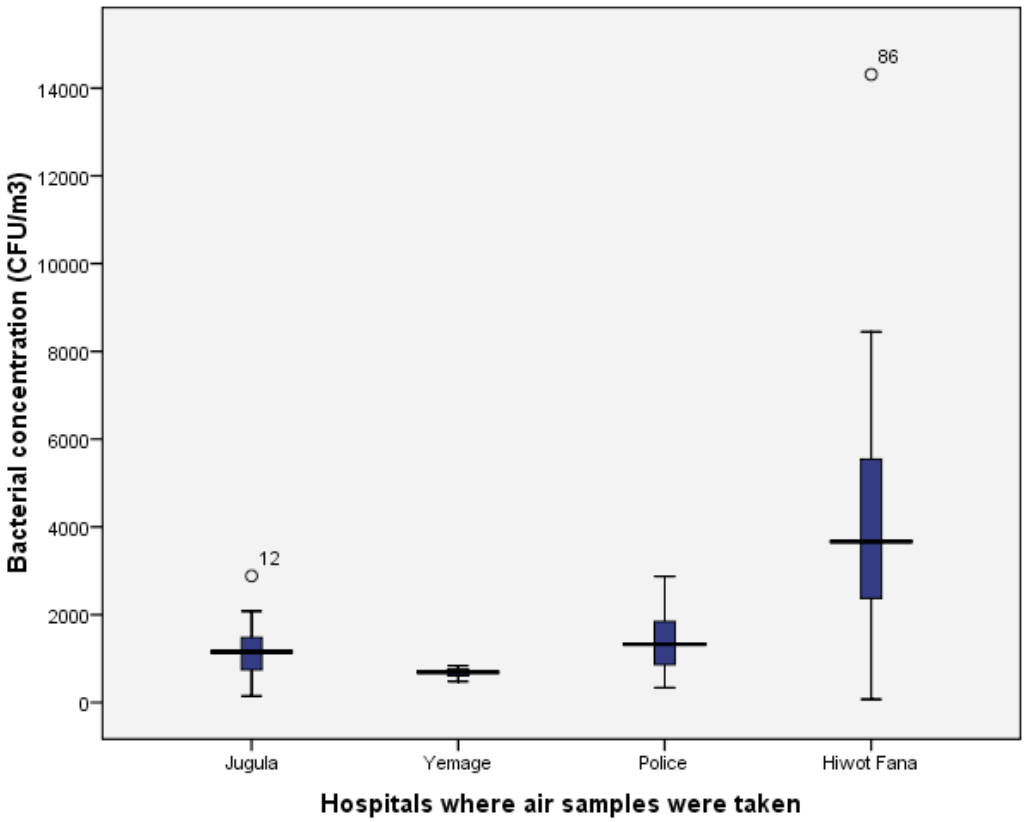


Figure 5.1 Total bacterial load of indoor air in the investigated hospitals after 60 min exposure time, Harar town, Eastern Ethiopia, 2017

Nine different inpatient wards and 96 rooms were taken as a sample to determine the bacterial load. The mean indoor bacterial load in different wards of the investigated hospitals showed in the figure below, highest bacterial load was recorded in Hiwot-Fana specialized teaching hospital (Figure 5.2). Particularly, air samples collected from medical ward, ICU, surgical ward and pediatrics ward of Hiwot-Fana hospital were highly contaminated with different types of microorganisms.

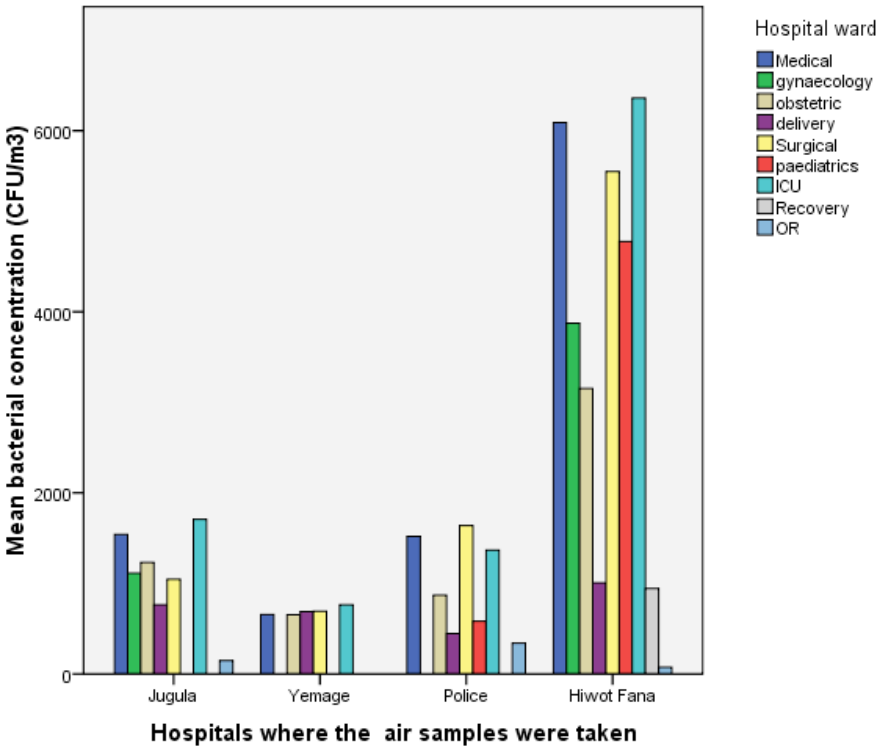


Figure 5.2 Mean bacterial load of indoor air in different wards of the investigated hospitals after 60 min exposure time, Harar town, Eastern Ethiopia, 2017

Airborne bacteria were isolated from different wards of the hospitals at a level ranged from 74.2–14,310 CFU/m3. Fluctuations occurred in airborne bacterial loads in hospitals and in different wards (Figure 5.1& 5.2).

Objective 2: Compare bacterial load in the four hospitals

According to this study, significant difference in mean bacterial load was found among the four hospitals ($F=25.924, p<0.001$). The highest mean bacterial load was found in Hiwot-Fana teaching specialized hospital (4204 CFU/m^3) and the lowest mean bacterial load was registered in Yemage General hospital (672.3 CFU/m^3) (Table 5.1)

Table 5.1: One-Way ANOVA results for mean bacterial load of the four hospitals, 2017.

Hospitals	Mean of bacterial load	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
			Lower Bound	Upper Bound		
Jugula	1.185E3	656.6019	858.324	1511.365	148.4	2883.2
Yemage	672.217	93.2463	632.842	711.591	477.0	837.4
Police	1.380E3	718.1734	1053.110	1706.928	339.2	2872.6
Hiwot-Fana	4.204E3	2758.2348	3226.318	5182.373	74.2	14310.0

Figure 5.3: below showed the mean bacterial load of indoor air in the four hospitals.

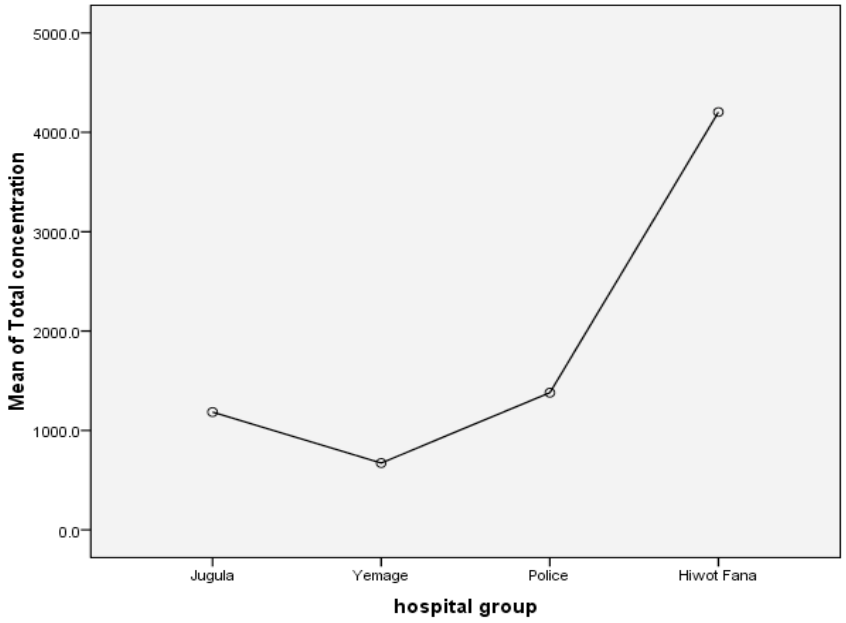


Figure 5.3 Mean bacterial load of indoor air in the investigated hospitals after 60 min exposure time, Harar town, Eastern Ethiopia, 2017.

One-way ANOVA test was used to compare the average bacterial load of wards as depicted below. The highest mean bacterial load (4252 CFU/m3) was found in pediatrics ward and the lowest load (187.3CFU/m3) was found in the OR (Table 5.2). The result showed that there was a significant mean bacterial load difference among major wards of these four hospitals (F=2.62, p=0.04).

Table 5.2: One-Way ANOVA results for mean bacterial load of the different wards in the four hospitals, 2017

Hospital Wards	Mean of bacterial load	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
			Lower Bound	Upper Bound		
Medical	2.013E3	2707.5816	982.629	3042.447	477.0	14310.0
Surgical	2.153E3	2054.3435	1339.914	2965.256	233.2	8183.2
Obs	1.866E3	1616.5631	1251.423	2481.239	445.2	6423.6
OR	187.267	136.7085	-152.336	526.869	74.2	339.2
Pediatrics	4.252E3	2513.0556	2150.958	6352.892	583.0	8448.2

Figure below showed the mean bacterial load in the different wards of the four hospitals in Harar town (Figure 5. 4).

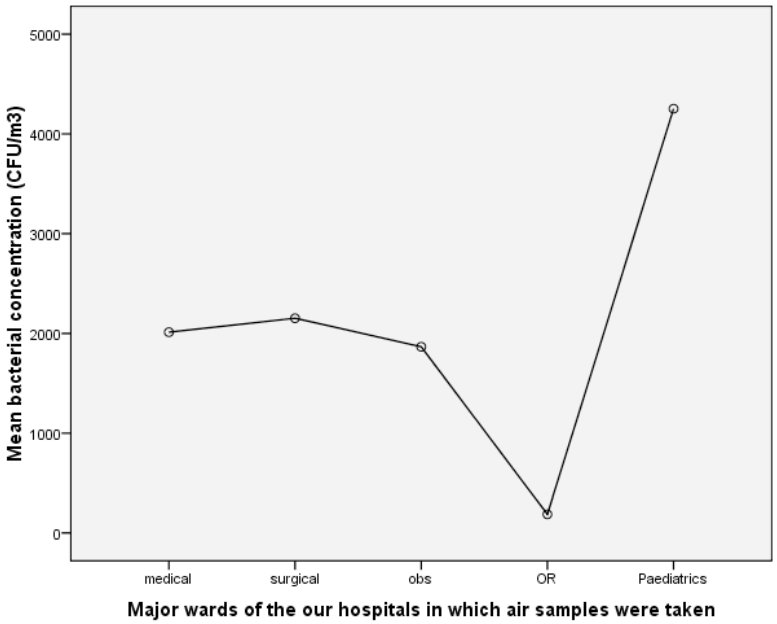


Figure 5. 4: Mean bacterial load of indoor air in different wards of the investigated hospitals after 60 min exposure time, Harar town, Eastern Ethiopia, 2017.

Table below showed the bacterial load ranges of the four hospitals in Harar according to WHO expert group and different scholars.

Table 5.3 Bacterial load ranges of the four hospitals in Harar according to the different scholars.

Hospital name	**Major hospital wards**	**Range of bacterial load (CFU/m3)**				
		Francisco et al., 2000 Cappitelli et al.,2009		WHO expert group		Nevalainen, 1989
		<749 (acceptable)	>750 (limit)	<1000 (acceptable)	>1000 (unacceptable)	4500-10,000 (upper limit)
Hiwot-Fana	Medical				✓	✓
	Surgical					✓
	Obstetric				✓	
	Pediatrics					✓
	OR	✓				
Jugula	Medical				✓	
	Surgical				✓	
	Obstetric				✓	
	OR	✓				
Police	Medical				✓	
	Surgical				✓	
	Obstetric	✓				
	Pediatrics	✓				
	OR	✓				
Yemage	Medical	✓				
	Surgical	✓				
	Obstetric	✓				

The table below depicted the bacterial load of the four hospitals according to the sanitary standards of European Commission for non-industrial premises (Table 5.4).

Table 5.4 Assessment of air quality in the sampling rooms of four hospitals in Harar according to European commission sanitary standards for non-industrial premises

Hospital name	Range of bacterial load (CFU/m3)	Pollution degree	Major hospital wards where air sample was taken					
			Medical	Surgical	Obstetric	Pediatrics	OR	
Hiwot-Fana	<50	Very low						
	50-100	Low						✓
	100-500	Intermediate						
	500-2000	High						
	>2000	Very high	✓	✓	✓	✓		
Jugula	<50	Very low						
	50-100	Low						
	100-500	Intermediate						✓
	500-2000	High	✓	✓	✓			
	>2000	Very high						
Police	<50	Very low						
	50-100	Low						
	100-500	Intermediate						✓
	500-2000	High	✓	✓	✓	✓		
	>2000	Very high						
Yemage	<50	Very low						
	50-100	Low						
	100-500	Intermediate						
	500-2000	High	✓	✓	✓	-	-	
	>2000	Very high						

OBJECTIVE 3: Identify the dominant type of bacteria in the wards

In this study four bacteria species were identified. Out of the four isolated bacteria species, *Staphylococcus aureus* was predominant among isolated bacteria from air samples collected from various wards by passive air method, which accounts for 10,268 (53%) bacterial counts followed by *coagulase negative staphylococci* (CoNS), which accounts for 8138 (42.1%) bacterial count. The third bacteria type with the least bacterial count is *micrococcus*, which accounts for 959 (5%). Environmental Bacillus species was found in the private hospital ICU room with only 5-colony count.

The total load of *Staphylococcus aureus*c oncentration ranged from 31.8 to 8119.6CFU/m^3 and the mean was 1134 CFU/m^3. High mean load of *Staphylococcus aureus* was found in medical and surgical wards of Hiwot-Fana and police hospitals (Figure 5.5).

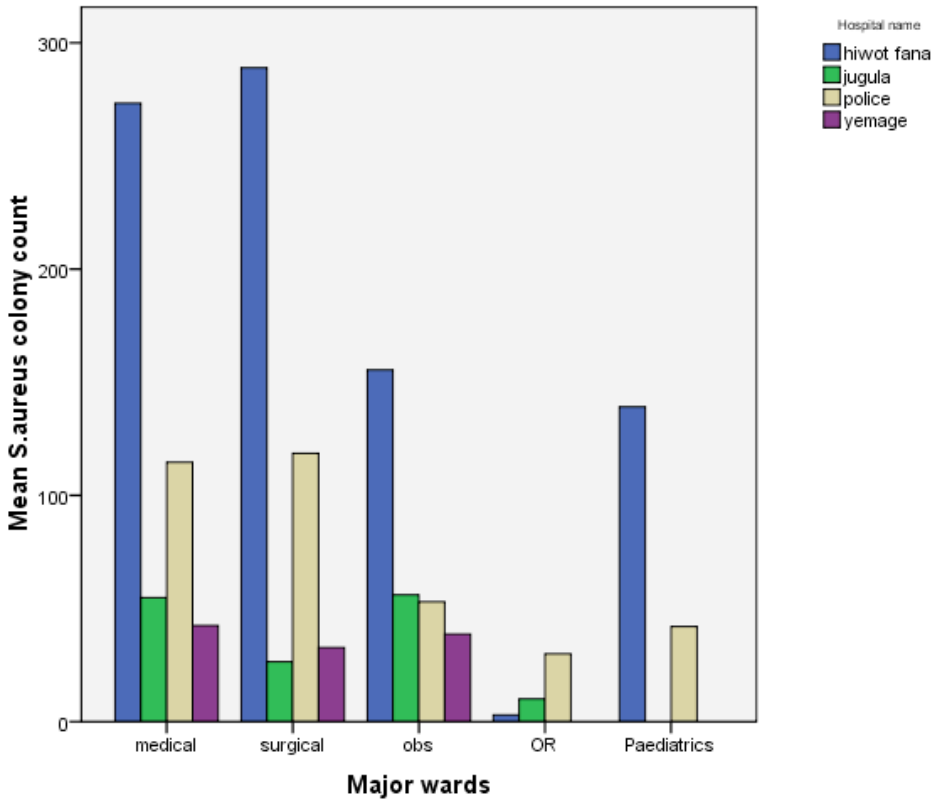


Figure 5.5 Mean *S.aureus* colony count of indoor air in different wards of the investigated hospitals after 60 min exposure time, Harar town, Eastern Ethiopia, 2017

Where as, load of CoNS ranged from 21.2 to 6211.6 CFU/m^3 with an average of 897.7CFU/m^3. Highest mean of CoNS was found in medical and surgical wards of Hiwot-Fana and Jugula Hospitals as well as pediatrics ward of Hiwot-Fana specialized teaching hospital (Figure 5.6).

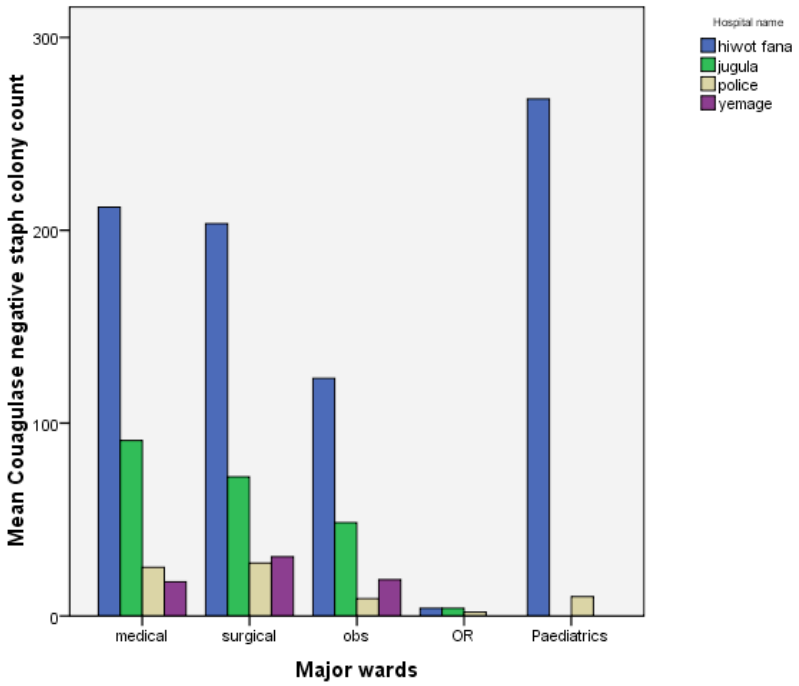


Figure 5.6 Mean *couagulase negative staph* colony count of indoor air in different wards of the investigated hospitals after 60 min exposure time, Harar town, Eastern Ethiopia, 2017

On the other hand, the load of *micrococcus* ranged from 0 to 985.8 CFU/m^3 and an average of 107CFU/m^3. Pediatrics and surgical ward of Hiwot-Fana specialized teaching hospital recorded the highest mean *micrococcus*load (Figure 5.7).

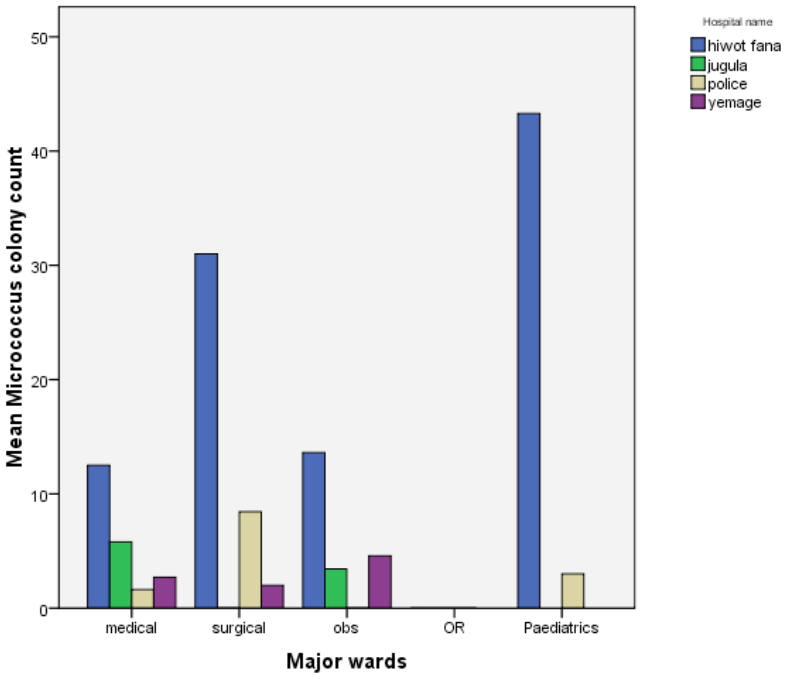


Figure 5.7 Mean *Micrococus*colny count of indoor air in different wards of the investigated hospitals after 60 min exposure time, Harar town, Eastern Ethiopia, 2017.

Objective 4: Contributing factors for the bacterial load

Environmental factors were tested for an association with indoor bacterial loads. The result of this study revealed a negative significant correlation ($P<0.001$) of total bacterial load with cleaning frequency ($r=-0.43$) and a significant positive correlation with temperature ($r=0.55$). However, there was no significance correlation between bacterial load and patient crowding index.

Using the observation survey and the bacterial load data, it was found that most of the environmental factors differs from room to room. Significant differences in bacterial load were also seen for other environmental factors. The table below showed the chi-square result of bacterial load (grouped based on WHO standard $<1000CFU/m^3$ and $>1000CFU/m^3$) and the contributing environmental factor differences in our samples of 96 rooms (Table 5.5).

Table 5.5: Chi-square result of bacterial load with a cut point of $1000CFU/m^3$ and the contributing environmental factors.

Factor	Chi-square value (χ^2)	(df)	p-value
Number of visitors	23.951	3	p<0.001
Proper usage of the windows	13.594	1	p<0.001
Improper storage of food and drugs	15.207	1	p<0.001
Promote bacteria growth	18.383	1	p<0.001
Low floor cleanness	13.523	1	p<0.001
Clean working area	13.523	1	p<0.001
Clean wall	10.685	1	p<0.001
Clean window	9.478	1	p<0.002
Patient clothing	12.709	1	p<0.001
Proper sealed waste container	11.658	1	p<0.001
Awareness of patient with patient disposal	15.709	1	p<0.001
Higher for rooms with flies	17.778	1	p<0.001
Patients use cleaning products	9.140	1	p<0.002
Low traffic density	31.029	2	p<0.001

To conclude there was a significant difference in bacterial load and its contributing factors in the impatient rooms. The bacterial load was higher in rooms with high number of visitors increases, improper usage of the windows that are available in the rooms, with improper storage of food and drugs, rooms with high chance of promoting bacteria growth, low floor cleanness, unclean working area, unclean wall, unclean window, unclean patient clothing, improper sealed waste container, lack of awareness of patient about waste disposal, presence of flies, patient who doesn't use cleaning products and high traffic density. However, there was no significant difference in bacterial load for number of window, number of bed, construction status, floor type, room area, crowding index, waste storage area, presence of heat recovery system, use of consumer chemical use and presence of odor in those hospital rooms.

A multiple linear regression model predicting total indoor bacterial load in the hospitals room was developed (Table 5.6). A Significant association was found for total bacterial loads and increased number of visitors, increased room temperature and frequency of cleaning.

Table 5.6 multiple linear regressions using indoor total bacterial load as dependent variable

	Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
Variable	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
No of beds in the room	-110.390	86.247	-.129	-1.280	.204	-281.761	60.981
No of visitors per room	265.075	72.791	.358	3.642	.000	120.441	409.709
Room area	-23.063	17.732	-.132	-1.301	.197	-58.297	12.171
Room temperature	478.845	152.467	.314	3.141	.002	175.896	781.794
Frequency of cleaning	-826.268	312.612	-.231	-2.643	.010	-1447.420	-205.115
No of window in the room	191.855	216.253	.074	.887	.377	-237.836	621.546

a. Dependent Variable: Total bacterial load

Logistic Regression

Comparing rooms with proper and improper storage of patient staffs, we estimate the odds of higher bacterial load (above the WHO standard >1000CFU/m^3) were 8.9 times higher for rooms with improper storage of food, drug and personal staffs (CI 3.5-22.8) and 4.4 times higher for improper usage of ventilation (CI 1.8-10.5). This clearly shows bacterial load increased by improper storage and improper usage of ventilation like window. Similarly, soiled working area contributed 12.9 times for higher bacterial profile than the clean one (CI 4.6-36.6). Furthermore, un cleaned floor 10.9 times (CI 4.1-28.8), soiled wall 6.2 times (CI 2.5-15.5) soiled window 6.2 times (CI 2.4-15.8), soiled patient cloth 6.6 times (CI 2.4-18), improper sealed waste container 7 times (CI 2.4-20.6), lack of awareness about waste disposal 11 times (CI 2.98-39) and presence of flies 7.5 times contributed for the increment of bacterial load in the sampled rooms (CI 2.95-18.9). Suggestions for remedial action in the hospital rooms with high bacterial load would include installing and repairing the ceiling, walls and floor, adequate ventilation via proper opening of windows and by installing mechanical ventilators, removal of any condition that can promote bacterial growth and controlling the temperature of the room.

Table 5.7: Unadjusted effects of categorical predictors environmental variables on the bacterial load obtained from logistic regression

Categorical predictor	LR Test	OR for survival	95% CI or OR
Appropriate storage	23.21	8.9	3.485-22.763
Proper usage of ventilation	10.787	4.3	1.756-10.466
Cleanness of working area	27.855	12.941	4.581-36.562
Cleanness of floor	26.232	10.85	4.09-28.78
Cleanness of wall	16.239	6.167	2.452-15.511
Cleanness of window	15.657	6.165	2.402-15.823
Patient clothing	14.87	6.558	2.38-18.078
Proper sealed waste container	14.662	7.043	2.409-20.591
Patient awareness about waste disposal	16.967	10.8	2.981-39.134
Presence of flies	19.833	7.468	2.953-18.885
Consumer cleaning product use	11.483	0.133	0.036-0.483

According to the adjusted effects of predictor environmental variable estimated the odds of higher bacterial load (above the WHO standard >1000CFU/m^3) were 2.98 times higher for rooms with soiled wall (CI 0.996-8.963). In rooms with no flies and absence of conditions that promote bacterial growth the bacterial load is relatively low.

Table 5.8: Adjusted effects of categorical predictors environmental variables on the bacterial load obtained from multiple logistic regression

Variables in the Equation

								95.0% C.I.for EXP(B)	
		B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Step 1[a]	Absence of flies	-1.393	.531	6.879	1	.009	.248	.088	.703
	Improper usage of ventilation(1)	.217	.601	.131	1	.718	1.242	.383	4.033
	Absence of condition that promote bacteria growth(1)	-1.283	.588	4.759	1	.029	.277	.088	.878
	Soiled wall(1)	1.095	.560	3.814	1	.041	2.988	.996	8.963
	Constant	1.112	.627	3.144	1	.076	3.039		

a. Variable(s) entered on step 1: FLIES, nnvent, nnpromote, nnwall.

6. DISCUSSION

Bacterial load of the four hospitals

This paper reported the indoor air bacterial load of four hospital inpatient rooms in Harar town. Recent studies done in different Ethiopia hospitals, namely Hawassa university referral hospital 2016, Gondar university teaching hospital 2016, Jimma University specialized hospital 2015 and Adama Hospital Medical College 2016 hospitals revealed high indoor air bacterial load (10, 15-17). Particularly, researches done in Jimma University specialized hospital (2123-9733 CFU/m^3) and wards (480-1468 CFU/m^3) reported a high range of indoor bacterial load (10, 17). In the present study, though the bacterial load of the hospital rooms varies from hospital to hospital as well as from ward to ward, the bacteria load found in Hiwot-Fana specialized teaching university hospital was much higher, which ranged from 74.2-14,310CFU/m^3. Incontrast, if we consider only the two government hospital (Jugula and police hospital) and the private hospital (Yemage General Medical center) the bacteria range was 148.4-2883.3CFU/m^3 which is still higher than the result found in Gondar university teaching hospital wards but much lower than the result found in Jimma University specialized hospital. This high bacterial load in Hiwot-Fana specialized teaching university hospital could be due to low cleaning frequency, overcrowding of medical and health science students and visitors in the rooms, lack of room and personal sanitation.

There is no common guideline or standard for acceptable indoor bacteria load, but different scholars and surveys recommend a cut point for acceptable bacterial load. WHO expert group recommend a total microbial load less than 1000 CFU/m3 (50). Among the four hospital, the mean bacterial load of the two government hospitals namely Jugula (1,185 CFU/m^3) and Police (1,380 CFU/m^3) as well as Hiwot-Fana specialized teaching university hospital (4,204 CFU m^3) were above the acceptable value that WHO expert group suggested, that microbial load should not be above 1000 CFU/m^3 (50).Whereas other researchers suggested a bacterial load should not exceed 750 CFU/m3 (51, 52). Upper limit of airborne bacterial loads ranging from 4500 to 10,000 CFU/m^3 also have been suggested as the upper limit for ubiquitous bacterial aerosols(53). According to these guidelines three of the major wards namely Medical, Surgical and pediatrics

wards of Hiwot-Fana teaching hospital are in the upper bacterial load limit range. Whereas, All wards of the private hospital (Yemage Hospital) are in acceptable ranges according to the study done by Francisco and Cappitelli (51, 52) (Table 5.3).

According to the sanitary standards of European Commission for non industrial premises consider less than 50 CFU/m^3 as ‘ very low’ bacterial load, 50– 100 CFU/m^3 as ‘ low’ , 100–500 CFU/m^3 as‘ intermediate’ , 500– 2000 CFU/m^3 as ‘ high’ and above 2000 CFU/m^3 as ‘ very high’ load (54). Comparing this standards with this study indoor bacterial load, Yemage (477-837.4CFU/m^3) which is the only private hospital in this study is categorized in the high range and the rest three hospitals are found in the very high range namely, Jugula (148.4-2,883.2 CFU/m^3) , Police (339.2-2,872.6 CFU/m^3) and Hiwot-Fana specialized teaching university hospital (74.2-14,310CFU/m^3). On the other hand major wards of Hiwot-Fana teaching hospital is in a very high range of bacterial load. This high bacterial load might be due to the overcrowding and lack of sanitation of the sampling rooms.

Comparing between the four hospitals and their wards

The air quality in terms of bacterial load in Hiwot-Fana specialized teaching hospital was worse than that of the two governmental hospitals and private hospital in all units. The second high microbial load was recorded in jugula hospital followed by police hospital. Yemage, which was the only private hospital, had lowest bacterial load compare to the other three. At the time of sampling there were low activities and one patient in the sampled rooms, which may attribute to the low bacterial count in the private hospital as well as police hospital. The other reasons might be the difference in cleaning frequency, overcrowding, and improper use of ventilation system and sanitation difference of those hospitals. Studies also showed that the indoor air quality is highly dependent on, the number of occupants in the building, their activities and resultant aerosol generation, density of human traffic and the efficiency of ventilation (55).

Medical, ICU, pediatrics and surgical wards showed the highest bacterial growth while the operating theatre was less in microbial burden in all of the hospitals. In this study, higher load of microorganisms was detected in these wards. Particularly, in Hiwot-Fana’s pediatrics ward this could be due to the overcrowding of medical and health science students in these wards as well

as corridors. In addition, children were vomiting here and there that may also contribute for the presence of flies as well as high load of bacteria. An observation that was made in the current study showed the presence of visitors and multiple patients per room have been shown to influence the bacterial load in indoor air. Especially, Hiwot-Fana specialized teaching hospital was overcrowded with a lot of medical students form different health colleges in the town and Haramaya university which exacerbate the activity taken place the wards that highly contribute for the high bacteria load in these wards as well as the hospital as a whole. In addition, the hospital rooms were full of patients there is no even a single bed which is free from patient. Where as in Jugula, police and yemage hospitals there were no medical students around and also there was free beds in the rooms that might play a major role for the decrement of bacterial load in the rooms. Study done in Palestine showed a correlation between low activity and lower bacterial count in the room after patients were discharged at the time of the sampling (56). Furthermore, the cleaning frequency in Hiwot-Fana is less than the rest of the hospitals that might also contributed a lot for the rise of the bacterial load.

Types of bacteria

Due to their ability to stay in the form of aerosol for a long time Gram positive bacteria they are dominate in the air than gram negative bacteria.In those hospitals, *S.aureus, micrococcus* and *CoNS* were among the most common bacteria identified. In our finding also three of the four identified bacteria namely, *Coagulase –negative staphylocooci, Staphylococcus aureus and Micrococccusspp* were gram positive. This result was consistent with previous study done in Ayder Referral hospital in northern Ethiopia 2015 (57) which showed that majority of bacterial findings in the indoor air were Gram-positive bacteria.

Staphylococcus aureus was dominant in our finding, this bacteria can easily live in different part of the human body like the skin, nails, throat and nasopharynx.S.aureus can cause number of infections including respiratory tract infections, bed sore, post-operative infections and food poisoning.Though *Coagulase –negative staphylocooci* are not pathogenic in the normal situation, this bacteria could cause serious infection in immune suppressed patients. Study done in Jordan was showed that from the two hospitals, one private and the other government, *S.aureus, micrococcus and CoNS* were among the dominant bacteria identified (58). Recently, study done

in two hospitals in benincite,Nigeria also reported *that S.aureus ,micrococcus sp*and *bacillus spp* were the common airborne bacteria (59).

In the present study, isolated Gram-negative bacteria environmental Bacillus was found in a very low load count in the ICU room of the private hospital. These bacteria species commonly found in the air, soil, in dusty environment and as a normal flora in human.These genus of bacteria are spore forming and can stay long in the environment. Except, *B.anthracis*and*corynebacterium diphtheria* the *other bacillus spp, coul*d not cause medical problems except for those severely immunocompromosed patients (60).

Associated factors

A number of studies have indicated that biological indoor air pollutants pose potential hazards to patients, medical staffs and visitors in hospitals (61).

It could be hypothesized that decreasing the load of these airborne pathogens in the hospital parts could help lower the risk of infection (62).There are many factors that play a role to keep the lowest possible airborne microorganism levels in hospital parts. Airborne pathogen levels in hospital wards affected by weather conditions, outdoor microbial load and the number of occupants and visitors, staff activities, indoor ventilation system design, cleaning procedures and relative humidity (60).Although airborne microorganisms encountered in hospital wards are apparently nonpathogenic to healthy people, but they can cause adverse health problems in immune-compromised people. Approximately,it is up to 10% of the hospital acquired infections in both healthy and immuno-compromised patients are determined by airborne bacteria (63).

Strategies can be adapted to decrease spreading of microbial contaminants. The quality of indoor air depends on external and internal sources such as cleaning procedures, ventilation and staff activities. These data may be valuable to develop interventions to improve the microbial indoor air quality among different hospital wards also for preventing or decreasing the occurrence of the nosocomial infections.

In the present study, there was a negative linear association between bacterial loads with frequency of cleaning and a positive linear relationship with room temperature. This clearly should that how sanitation and temperature affect the bacterial load in the rooms. The temperature was in a range between 22 to 29.3 ^{o}C. Most of the hospitals wards were in the ranges that are favorable for the survival and reproduction of bacterial growth. Temperature, which is unfavorable for the bacterial growth, ranges between 20 to 22 ^{o}C. This might be one of the reasons for the high bacterial load in our study particularly for Hiwot-Fana specialized teaching hospital.

The human body and patient clothing harbor microbes, the Skin dusts and personal clothing during movement release about 1000 per minute bacteria to the air (42) .Our finding also should significant relationship between patient clothing cleanness, human traffic density and bacterial load in the indoor air.

Environmental factors particularly insufficient ventilation played a crucial role in the increment of bacterial load in the indoor air (43). In this study, there was no significant difference in bacterial load between rooms with different no of windows. However, there was a significant relationship between proper usage of ventilation system and bacterial count. This result showed that, it is not the number that matters but the usage of these windows plays role in the reduction of microbial load.

Generally, this study suggests that the presence of flies like flies, condition that can promote bacterial growth, cleaning frequency, room temperature, number of visitors and unclean wall were found to be the most crucial environmental factors that affect bacterial load of the sampled rooms. These results would suggest that increasing cleaning frequency, adjusting the room temperature and controlling number of visitors might be an effective way of decreasing indoor bacterial load.

7. STRENGTHS AND LIMITATIONS

Strengths

The study merged laboratory result with observation result in order to assess the true picture of the bacterial load and its determinate factors. In addition, the survey involves all the impatient rooms in the four hospitals that are found in Harar town.

Limitations

This study only focuses on impatient rooms of those hospitals; due to financial and time limitation. It doesn't involve the outpatient wards, staff offices and rooms with no patient that might give a better information about the contributing factors of the high bacterial load.

8. CONCLUSIONS

- ✓ The microbial profile of Hiwot-Fana specialized teaching hospital is much higher than the other hospitals bacterial load.

- ✓ The bacterial load of the three of the hospitals namely Jugula, Police and Hiwot-Fana specialized teaching university hospital were above the different indoor biological standards. Especially, Hiwot-Fana specialized teaching hospital was found to be in the upper limit range. Yemage the only private hospital in the study was under acceptable level of bacterial load.

- ✓ Medical, ICU, pediatrics and surgical wards showed the highest bacterial growth while the operating theatre was less in microbial burden in all of the hospitals.

- ✓ Most of the wards of the three government hospitals were heavily contaminated with three common bacteria, namely *S.aureus, micrococcus* and *CoNS* .

- ✓ The major environmental factors that contribute for this high range of bacterial load were low cleaning frequency, presence of flies, soiled walls, high room temperature, a high number of visitors and medical students.

- ✓ To conclude, due to this high bacterial load the patients that are admitted in those three government hospitals are at a high risk of infection. Especially, the bacterial load in Hiwot-Fana hospital may endanger the health of the patients especially, to the vulnerable groups such as the elderly, young children, pregnant women and immuo compromised patients.

9. RECOMMENDATIONS

Jugula, Police and Hiwot-Fana specialized teaching hospital administrations should:

- ✓ Do regular Monitoring and evaluation of bacterial load in these hospitals in order to decrease a risk of infection for the inpatients particularly for the most susceptible patients such as the immune compromised, elderly, children. Besides, there should be regular inspection of each room to assess if there is any condition or situation that may promote bacterial and fungi growth like leakage and any sanitation problem.

- ✓ Improve the sanitation of the inpatient's room especially by increasing cleaning frequency and disinfection of the floor, wall and windows.

- ✓ Restrict number of visitors, and health science students in order to decrease overcrowding in the rooms and corridors of the wards.

- ✓ Facilitate the proper use of windows to mange the temperature of the room and dilution of the bacterial load.

For researchers who are interested in this area of study

- ☞ This research considers the bacterial load and the associated environmental factors in hospital inpatient rooms found in Harar town. So, further studies should be done, by including the outpatient department, radiology department, laboratory department and staff rooms as well as drug suitability test of the identified bacteria. Furthermore, including of different variables like measuring humidity and fungi load will give more information about the room status.

- ✓ It will also be good if this kind of research is done in big cities like Addis Ababa by comparing the private and the government hospitals to understand the bacterial load of those big hospitals.

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ANNEX 1

Air Sampling procedure

BLOOD AGAR preparation

To make about 35 blood agar plates:

Nutritious agar* . . . . . 500 ml

Sterile defibrinated blood** . . . . . 25 ml

Note: Before preparing a batch of blood agar plates, a few plates should be prepared first to make sure the blood is sterile.

1 Prepare the agar medium as instructed by the manufacturer. Sterilize by autoclaving at water bath.

2 When the agar has cooled to 50 ^{o}C, add aseptically the sterile blood and mix gently but well. Avoid forming air bubbles.

Important: The blood must be allowed to warm to room temperature before being added to the molten agar. Dispense aseptically in 15 ml amounts insterile petridishes.Date the medium and give it a batch number, Store the plates at 2–8 ^{o}C.

Mannitol salt agar

Contents: Peptone, Lab-Lemcopowder, mannitol, sodiumchloride, phenol red, agar.Themedium is usually used at a load of11.1 g in every 100 ml distilled water (loadmay vary depending on manufacturer).

1 Prepare the medium as instructed by the manufacturer. Sterilize by autoclaving at 121 ^{o}C for 15 minutes.

2 When the medium has cooled to 50–55 ^{o}C, mix well, and dispense it aseptically in sterile petri dishes. Date the medium and give it a batch number.

3 Store the plates at 2–8 ^{o}C preferably in plastic bags to prevent loss of moisture.

Shelf-life: Several weeks providing there is no change in the appearance of the medium to suggest contamination, deterioration, or alteration of pH.

pH of medium: This should be within the range pH 7.3–7.7 at room temperature.

Catalase test

This test is used to differentiate those bacteria that produce the enzyme catalase, such as staphylococci,from non-catalase producing bacteria such as streptococci.

Principle

Catalase acts as a catalyst in the breakdown of hydrogen peroxide to oxygen and water. An organism is tested for catalase production by bringing it into contact with hydrogen peroxide. Bubbles of oxygen are released if the organism is acatalase producer. The culture should not be more than 24 hours old.

Required

Hydrogen peroxide, 3% H_2O_2 (10 volume solution)

Method

1 Pour 2–3 ml of the hydrogen peroxide solution into a test tube.

2 Using a sterile wooden stick or a glass rod (not a nichrome wire loop), remove several colonies of the test organism and immerse in the hydrogen peroxide solution.

Important: Care must be taken when testing an organism cultured on a medium containing blood because catalase is present in red cells. If any of the blood agar is removed with the organism, a false positive reaction may occur.

3 Look for immediate bubbling as shown in Plate

Results

Active bubbling . . . . . Positive catalase test

No bubbles . . . . . Negative catalase test

Caution: Performing the test on a slide is not recommended because of the risk of contamination from active bubbling. When the rapid slide technique is used, the hydrogen peroxide solution should be added to the organism suspension after placing the slide in a petri dish. The dish should then be covered immediately, and the preparation observed for bubbling through the lid.

Controls

Positive catalase control: Staphylococcus species
Negative catalase control: Streptococcus species

ANNEX 2

Bacterial load analysis procedure

1. Colonies will be counted using a plate counter (the plate counter has a light source and a magnifying glass making colonies easier to see).
2. After, counting the colonies, multiply by the appropriate dilution factor to determine the number of CFU/mL in the original sample.
3. Bacterial load will be counted as colony forming units (CFU) and CFU/$m^3$by using the following formula

   N=5a*104 (bt)−1(47, 48),

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

   b = dish surface (cm^2); and t = exposure time (minutes).

ANNEX 3

Indoor air quality observational checklist

The purpose of this survey is to identify and assess different sources of contaminants and their pathways. Identify different factors including physical, chemical and biological that may be responsible for health of the hospitalized patients. Perform a thorough walk-through survey of different parts of the building and—the building HVAC system. Some or all of the questions and onsite investigation may be completed based on the assessment and judgment of the investigating Health Inspector.We need the full consent and collaboration of the hospital administration in order to pursue this study. If the hospital administrations have any question about this study they are free to contact the principal investigators at any time. The content of this questionnaire is based on AHS-EPH DSOP IAQ - Indoor Air Quality manual,2012(64).

GENERAL INFORMATION ABOUT THE HEALTH FACILITY

Checklist no #: _____Date: _____Time: _____a.m./p.m.

1. Name of the facility: _____
2. Address:_____
3. Telephone:_____
4. Website and e-mail address:_____
5. Total number of beds:_____
6. Hospital occupancy rate in normal situations: _____
7. Ward to be inspected _____
8. Description of the institution (general aspects, institution to which it belongs, type of establishment, population served, area of influence, etc.)

Inspected by	Date
Job title	Signature
Signed off by principal Investigator	Date

This check list is based on the conceptual frame work

1. Hospital capacity, types of wards and Crowdness

Indicate the total number of beds according to the hospital's organization (by department or specialized services):

Department	Number of beds	Number of visitors	Area (m^2)	Observations
General Medicine				
Pediatrics				
General surgery				
Obstetrics				
Gynecology				
Ophthalmology				
General intensive care (ICU)				

1. Building condition

Safety of the structural system and status of the building	Safety level				Observations
	no	low	ave	high	
Condition of the building Low = Deterioration caused by weathering; cracks on the first floor and irregular height of buildings; Average = Deterioration caused only by weathering; High = Good; no deterioration or cracks observed.					
Construction Status Low = Rust with flaking; cracks larger than 3mm; Average = Cracks between 1 and 3 mm or rust powder present; High = Cracks less than 1 mm; no rust.					
Are building materials modern building materials such as gypsum board and ceiling tile that are damaged by water Yes No					
Room condition General: o Temperature/RH o Odors o Vermin Describe any problem:_____					
Floor type Earthen floor Earth floor without vapour barrier o Earth floor without vapour barrier Concrete Preserved wood Crawlspace Concrete floor					
Construction material (e.g., brick, wood frame,					

concrete, cinder blocks, etc.):_____					
Finishes: **Walls/ceilings** Good condition oStained/soiled oMould					
Flooring oGood condition oStained/soiled oMould oWater stains oWet/damp oRecent renovations/painting					
Area carpets oGood condition oStained/soiled oMould oWater stains oWet/damp oOther, specify: _____					
Furnishings - upholstered furniture oSofa oChairs oOther, specify:_____ oNew oGood condition oStained/soiled					
Basement Condition of foundation walls: oStaining oEfflorescence/white crystals Gaps at penetrations in: oSlab oWalls					
Condition and safety of doors and entrances Low =Subject to damage and damage to element(s) would impede the performance of this and other components, systems, or operations; Average = Subject to damage but damage to element(s) would not impede function; High = No or minor potential for damage that would impede the performance of this and other components, systems, or operations.					
Windows/Doors: Insect screens oGeneral condition/operable					
No of windows in the room Low=one average=two high=three or more					
Condition and safety of windows and shutters Low =Subject to damage and damage to element(s) would impede the performance of this and other components, systems, or operations; Average = Subject to damage but damage to element(s) would not impede function; High = No or minor potential for damage that would impede the performance of this and other components, systems, or operations.					
Consumer products used in premise: oChemicals oPaints oCleaners oPesticides oAdhesives oCosmetics oAir fresheners oOther, specify: _____					
Appropriate storage oYes oNo oDon't know Please describe any storage concerns:_____					
Describe any evidence of (note locations, remedial actions, response time and type of wateror pipe involved): Burst pipes:_____ Floods: _____ Roof leaks: _____ Leaks/condensation at windows (air/drafts or					

water):_____ Leaks/condensation at doors (air/drafts or water):_____					
Are there any noticeable odours? If so, describe them.					
Please describe the physical or thermal comfort factors (relative humidity and temperature):_____					
Are there water leaks that could promote growth of biologicagents					
Are damp or wet materials that could promote growth ofbiologic agents promptly dried, replaced, removed,or cleaned?					
Are microbial contaminants removed from ductwork, humidifiers, other HVAC and building system components, and from building surfaces such as carpeting and ceiling tiles when found during regular or emergency maintenance activities or visual inspection?					
When point sources generate airborne loads ofcontaminants above applicable limits, are local exhaustventilation or substitution used to reduce the exposureloads to below the limits?					
Are all areas efficiently light? Yes No					
Are all lights/fittings in good repair? Yes No					
Activities/uses Indicate any processes or activities in the building that may serve as contaminant sources:					

2.1 HVAC systems

Please describe the type of heating, ventilation and air conditioning system

Heating, ventilation, and air-conditioning (HVAC) systems in critical areas	Safety level				Observations
	no	low	ave	high	
Air conditioning system: o Central air o Window unit o Humidifier o Through-wall unit Alterations to the system? o Yes o No o Don't Know If yes, please describe the system and any alterations:					
Does the building have a heat recovery ventilator (HRV)? o Yes o No, If yes, please describe the HRV.					
When the temperature is outside of the range of 68					

to79ºF, is the HVAC system checked and repaired asnecessary to ensure the system is operating properly? Yes No N/A					
Are humidity levels maintained between 30% to 60%relative humidity? Yes No N/A					
When a contaminant is identified in the make-up air supply,is the source of the contaminant eliminated, or are themake-up inlets or exhaust air outlets relocated to avoid entryof the contaminant into the air system? Yes No N/A					
If buildings do not have mechanical ventilation, are windows,doors, vents, stacks, and other portals used for naturalventilation operating properly? Yes No N/A					
Any fixed or portable air conditioning units / fans Low = Poor; Average = Satisfactory; High = Good.					
All equipment clean & in good repair Low = Poor; Average = Satisfactory; High = Good.					
Reservoirs or parts of the HVAC system with standingwater checked visually for microbial growth. Yes No N/A					
Do all areas have a suitable temperature for the patients and visitors					
where extremes of temperatures occur are un blinds, fans, portable heaters available our client group					
Roof: oFlat oSloped, specify approximate slope: _____ Type/construction material: Condition: Potential for water penetration:					
Indicate the frequency of cleaning for each system (e.g., monthly, yearly, etc.). Inspect to assess the cleanliness of each system: Heating system: _____ o Clean o Dirty Cooling system: _____ o Clean o Dirty Filtration system: _____ o Clean o Dirty Humidification system: _____ o Clean o Dirty Exhaust fans: _____ o Clean o Dirty					
Possible contaminant source located near building fresh air intake(s) Yes No If yes, specify type of source: _____ Specify approx. distance and direction: _____					

Use of pesticides or fertilizers: oYes oNo oDon't know If yes, specify type(s): Specify location(s) used:					
Traffic density near premise: oHigh oModerate oLow Vehicle idling area: oYes oNo oDon't know Dump site: Yes No oDon't know Farms(s): Yes No oDon't know Industrial plant(s): oYes oNo oDon't know Radiation source: oYes oNo oDon't know Polluted lake/stream: oYes oNo oDon't know Other hazards: oYes oNo oDon't know Specify: _____					

2. Sanitation

CHECKLIST	Please Tick			Findings & Comments
General Housekeeping	yes	no	N/A	
Are all work areas kept sufficiently clean Are all floor coverings clean & in good repair Are walls and ceilings clean and in good repair Are all windows & glass door panels clean & in good repair				
Ages of occupants **Provide exact ages if possible:** _____ oInfant (0 to 6 months) Toddlers (7 months to 4 years) oChild (5 years to 11 years) oTeen (12 – 19 years) oAdults (20 years to 65 years) oSenior (65+ years)				
Are appropriate washing & sanitary facilities provided and work effectively for; • staff • clients • disabled Persons • public /visitors				
Sleeping arrangements o Mattress with box spring: o Good condition o Elevated off floor o Mattress cover o Mattress without box spring: o Good condition o Elevated off floor o Mattress				

cover o Other, specify: _____				
Bedding/Linen: o Clean o Soiled Stuffed toys: o Clean o Soiled				
Are all goods & materials stored correctly patients' clothing cleanness? Are the bed sheet clean &frequency of change it? Who made the bed and frequency? Frequency of general cleaning duties ?				
Are windows capable of being adjusted • Do windows on ward areas have restricted openings to prevent egress • Do window catches present a problem for the group in clinical areas				
Is there a system in which patients who come in who have signs or symptoms of an infectious disease, will be put in a separate room				
Waste Management				
have all hazardous substances in your department been identified and labeled				
Is there a good Practice of waste disposal procedures for domestic, clinical and confidential waste are waste handling instructions displayed				
are all waste bags/containers properly sealed and labeled				
is waste awaiting collection stored in a suitable, lockable area				
are patients aware of the procedures for collecting special waste such as clinical waste, drugs, blood and sputum				
are staff aware of the procedures for collecting special waste such as clinical waste, fluorescent light fittings and waste electrical equipment (WEE Regulations)				
Are containers marked with accumulation start date?				
Are container labels visible?				
Is the container storing hazardous waste marked withthe words "Hazardous Waste"?				
Are containers segregated according to				

waste type?				
Is the waste disposal unit clean and working correctly				
Is the dishwasher clean and working correctly				
Is the refrigerator clean and working correctly door seal in good repair				
Are all items of equipment clean, working correctly and in good repair				
Are cupboard units clean and in good repair				
Are floors clean and in good repair				
Are the walls and paint work clean and in good repair				
Is the ceiling clean and in good repair				
Are the windows clean and in good repair				
Are the light fittings clean, working correctly and in good repair				
Are all food items within use by dates and stored correctly				
are cleaning materials clearly labeled, stored correctly and securely				
Describe if there appears to be a connection from the garage into the building (i.e. air flows from garage into building)?				

2.1Equipment and material cleanness

Equipments	Safety level				Observations
	no	low	**ave**	**high**	
Medical equipment in operating theaters and recovery rooms Verify that lamps, equipment for anaesthesia, and surgical tables are operational and that table or cart wheels are locked. Low = The equipment is in poor condition or it is not secured; Average = The equipment is in fair condition or not properly secured; High = Equipment is in good condition and is secured.					
Condition and safety of equipment in the sterilization unit Low = The equipment is in poor condition or it is not secured; Average = The equipment is in fair condition or not properly secured; High = Equipment is in good					

condition and is secured.					
Condition and safety of medical equipment in intensive or intermediate care unit Low = The equipment is in poor condition or it is not secured; Average = The equipment is in fair condition or not properly secured; High = Equipment is in good condition and is secured.					
Condition and safety of medical equipment and supplies for burn management Low = The equipment is lacking, is in poor condition, or it is not secured; Average = The equipment is in fair condition or not properly secured; High = Equipment is in good condition and is secured.					
Condition and safety of medical equipment in other services Low = More than 30% of equipment is at risk of material or functional failure and/or equipment puts the entire service's operation at direct or indirect risk; Average = Between 10% and 30% of equipment is at risk of loss; High = Less than 10% of equipment is at risk of loss.					

2.2Water supply system

Water supply system	Safety level				Observations
	no	Low	ave	high	
Water tank has permanent reserve that is sufficient to provide at least 300 liters daily, per bed, for 72 hours Verify that water storage is sufficient to satisfy user demand for three days. Low = Sufficient for 24 hours or less; Average = Sufficient for more than 24 hours but less than 72 hours; High = Guaranteed to cover at least 72 hours.					
Water storage tanks are protected and in secure locations Visit the water tanks to determine the safety of the installations and of the site. Low = The site is susceptible to structural or non-structural failure; Average = Failure would not cause collapse of tank; High = Low possibility of functional failure.					

Alternative water supply to major distribution network Identify the agency or mechanism to supply or restore water service to the hospital should the public water system fail. Low = Provides less than 30% of demand; Average = Provides 30% to 80% of demand; High = Provides more than 80% of daily demand.					
Condition of water distribution system Verify condition and proper performance of water distribution system, including storage tanks, valves, pipes, and connections. Low = Less than 60% are in good operational condition; Average = Between 60% and 80% are in good condition; High = Above 80% are in good condition.					
Supplementary pumping system Identify the existence and operation of the supplementary pumping system in case water Supply is interrupted. Low = There is no back-up pump and operational capacity does not meet daily demand; Average =All pumps are in satisfactory condition; High = All pumps and back-up systems are operational					
Plumbing fixtures – sinks, faucets, drains, pipes Kitchen: o Leaks o Water stains Bathroom: o Leaks o Water stains Toilet: o Good repair o Water stains o Leaks Shower/bathtub: o Good repair o Water stains o Leaks Laundry: o Good repair o Water stains o Leaks o Other, specify: _____					

2.3Environmental phenomena

Epidemics With reference to any past incidents at the hospital and specific pathogens, rate the hospital's exposure to hazards related to epidemics.					
Contamination (systems) With reference to any past incidents involving contamination, rate the hospital, Exposure to hazards from contamination of its systems.					
Infestations With reference to the location and past incidents at the hospital, rate the hospital's exposure to hazards from infestations (flies, fleas, rodents, etc.).					
Others(specify) ..... With reference to any past incidents at the hospital, specify any other					

environmental phenomena not included above that might compromise the level of safety of the hospital.					

3. Infection prevention

Organization of the Hospital infection prevention Committee	Safety level				Observations
	no	low	ave	high	
Infection control Have all staff received basic infection control Training. Yes No Have all staff been made aware of the 'Clean Your Hands Campaign' Yes No					
Committee membership is multi-disciplinary Verify that the positions on the Committee are occupied by personnel from diverse disciplines (for example, hospital director, environmental health, head of emergency services, medical doctor, chief of surgery, chief of laboratory and support services, among others).Low = 0–3 disciplines represented; Average = 4–5 disciplines represented; High = 6 or moredisciplines represented.					
Each member is aware of his/her specific responsibilities Verify that members' assigned responsibilities are in writing, describing their specific roles. Low = Responsibilities not assigned; Average = Responsibilities have been officially assigned; High = All members know and comply with their responsibilities.					

Definitions:

Building systems includes the heating, ventilation and air-conditioning (HVAC) system, the energy management system, and all other systems in a facility that may impact indoor air quality.
Integrated pest management is a sustainable approach to controlling pests by using biological, mechanical, physical, and chemical means in ways that minimize health risks, environmental risks, and cost.

Comments/Corrective action:

Declaration

I, the under signed, declared that this is my original work, has never been presented in this or any other University, and that all the resources and materials used for the dissertation, have been fully acknowledged.

Name: Hiwot Abebe

Signature: _____

Date: _____

Place: _____

Date of submission: _____

This dissertation has been submitted for examination with my approval as University **Supervisor.**

Name: Abera Kumie (PhD)

Signature: _____

Date: _____