MICROBIAL LOAD AND INDOOR AIR QUALITY OF OPERATING THEATRES IN THE UNIVERSITY COLLEGE HOSPITAL, IBADAN

BY

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MATRIC NO: 128016

A DISSERTATION SUBMITTED TO THE UNIVERSITY OF IBADAN
IN PARTIAL FULFILLMENT OF THE RQUIREMENTS FOR THE AWARD OF
MASTERS OF PUBLIC HEALTH (ENVIRONMENTAL HEALTH) DEGREE

DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCES,
FACULTY OF PUBLIC HEALTH, COLLEGE OF MEDICINE
UNIVERSITY OF IBADAN,
IBADAN, NIGERIA.

JULY, 2015

ATTESTATION STATEMENT

We certify that this dissertation on Microbial Load and Indoor Air Quality of Operating Theatres in the University College Hospital, Ibadan was carried out by **OGUNDARE, Johnson Oluwaseun** of the department of Environmental Health Sciences in the Faculty of Public Health, College of Medicine, University of Ibadan, Ibadan, Nigeria.

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DEDICATION

This work is dedicated to Almighty God, and to my late elder brother Dr. James Olusegun OGUNDARE (MBBS, Ibadan).

AKNOWLEDGEMENTS

With sincerity of heart full of immeasurable gratitude, I appreciate the Ancient of Days, the Almighty Jehovah for His mercies upon me throughout the course of this research work.

My profound gratitude goes to my supervisor Dr. O. M. Bolaji, who has indeed been a father, mentor, teacher and guardian for his time, support, professional advice in ensuring that I come out as gold purified by fire with evidence- based study. Thank you Sir, may the Lord Almighty enlarge your coast and reward you greatly.

My appreciation also goes to the UI/UCH Ethical review committee for corrections and suggestions on my research protocol towards the success of this work. Also, I am indebted to all UCH Theatre nurses, Surgeons, Anaesthetists and the Head and all members of Infection Control Unit of the Medical Microbiology Department, UCH, Ibadan.

I will not forget to appreciate my research assistants -Mr. Fakunle Greg, Miss Alege Adenike and Miss Isumede Loveth (Department of Environmental Health Sciences) for contributing to the body of knowledge through their supports.

My appreciation also goes to the entire academic and non-academic staff of the Department of Environmental Health Sciences for their support most especially Dr. G. Ana (HOD), Prof. M.K.C Sridhar, Dr. E. Oloruntoba, Dr. O. Okareh, Mr. Morakinyo and Mr. Ahmed and all the laboratory and administrative staff of Medical Microbiology Department.

I will not be fulfilled if I do not appreciate my wife- Omolara Mary Ogundare, you have been so supportive.

Big thanks to Prof. J. A. Otegbayo (CMAC), Prof. Layi Shittu (Head of Surgery), Dr. Pat. Onianwa (Former Head of Clinical Nursing and DDN wards), Mrs. F. Adegoke (DDN Theatres, ICU, Radiology and CSSD), Prof. O. Olayemi, Prof. A. Oni (HOD, Medical Microbiology), Mrs. Ewete & Mrs. Gbaja (ICN), Dr. Oluremi Olufajo and all the Assistant Director of Nursing, (Emergency Theatre, Main Theatre and Gynae Theatre), of the University College Hospital (UCH), Ibadan.

Finally, I appreciate everybody whom I came across during the period of this research work. I say thank you.

ABSTRACT

Microbial contamination of indoor air of operating theatres is one of the risk factors for the development of Surgical Site Infections (SSI). Operating theatre environment, including personnel, can become contaminated with microorganisms capable of causing SSI, morbidity, prolong hospitalization of patients or even death. Studies on indoor air quality particularly the air-borne microbes that are associated with SSI have not been adequately investigated. This study was therefore designed to determine the air-borne microbial load and indoor air quality of operating theatres in the University College Hospital, Ibadan.

A descriptive cross-sectional design which involved purposive selection of seven operating theatres viz: main (T1, T2, T3, T4, T5), gynaecology (T6) and emergency (T7) theatres was adopted. Temperature and Relative Humidity (RH) of the indoor environments of the theatres were measured three times a week before and after surgery using multi-tester N21FR. Values obtained were compared with the Association of peri-Operative Registered Nurses (AORN) guideline limits of 22.0ºC and 55.0% respectively. Particulate matter (PM_{10}) concentrations in the indoor environments were measured using Met-one particle counter and compared with the World Health Organisation Guideline Limits (WHOGLs) of 50µg/m³. Air-borne microbial samples were collected using non-volumetric method. Total Bacterial Counts (TBC) and Total Fungal Counts (TFC) per cubic-metre were determined and compared with the American Industrial Hygiene Association (AIHA) guideline limit of 50 cfu/m^3. Data were analysed using descriptive statistics, ANOVA and Spearman's rank correlation at 5% level of significance.

Indoor temperature and Relative Humidity across the seven theatres were significantly higher after surgery (29.9±1.5ºC and 62.1±7.0%) than before surgery (27.6±1.1ºC and 61.2±8.2%) and were not within AORN guideline limits. Indoor PM_{10} after surgery (60.2±21.2µg/m³) was higher than before surgery (47.8±18.3µg/m³) and the WHOGLs. Indoor TBC after surgery was $2.1x10^2$ cfu/m^3 and then was higher than before ($0.5x10^2$ cfu/m^3). Similarly, indoor TFC across the theatres after surgery ($0.17x10^2$ cfu/m^3) was higher than before ($0.03x10^2$ cfu/m^3) but lower than the AIHA guideline limits. *Streptococcus spp., Staphylococcus spp. and Aspergillus spp.* were among the organisms isolated from the indoor air environment before and after surgery. Emergency theatre T7 recorded the highest RH (61.9±8.0%), PM_{10} (69.1±25.3µg/m³), TBC ($1.52x10^2$ cfu/m^3) and TFC ($0.16x10^2$cfu/m^3). A significantly positive correlation was observed between indoor TFC and RH (r = 0.124) and indoor TBC and PM_{10} (r = 0.099).

Microbial load in the selected operating theatres was higher than the internationally recommended values for an ideal and safe operating theatre. Therefore, operating techniques and environmental conditions should be properly monitored to ensure compliance with recommended standards.

Keywords: Operating theatre, Indoor air quality, Microbial load, surgical site infection, University College Hospital

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INTRODUCTION

1.1 BACKGROUND INFORMATION

Surgical operations and interventional procedures are performed in areas with various levels of microbiological control of the ventilation. Microbial contamination of indoor air of operating theatres is one of the risk factors for the development of Surgical Site Infections (SSI). Operating theatre environment, including personnel, can become contaminated with microorganisms capable of causing SSI, morbidity, prolong hospitalization of patients or even death.

Microorganisms that cause infections in healthcare facilities include bacteria, fungi and viruses and are commonly found in the patient's own endogenous flora, but can also originate from health care personnel and from environmental sources (Sehulster and Chinn, 2003). In particular, the environmental matrices (water, air and surfaces) play a leading role as reservoirs of microorganisms (Sehulster and Chinn, 2003): e.g. Legionella spp. and Pseudomonas aeruginosa are often isolated from water samples in hospital facilities (Napoli *et al.*, 2010); influenza A virus and other viruses from air (Tseng, 2010); spores of filamentous fungi from surfaces in operating theatres (Vescia, 2011). For this reason, hospital environmental control procedures can be an effective support in reducing nosocomial infections. This is particularly true in high risk healthcare departments where patients are more susceptible because of their health conditions, or in operating theatres because of tissue exposure to air (Weiss, 2010).

There is no international consensus on the methods, types of sampling and tolerable limits of bio-burden in operating theatres. The main parameters associated with environmental bio-contamination in operating theatres are discussed with a special emphasis on air quality and its control. Hospital indoor air pollution is associated with inadequate building environments, including building materials, air conditioning systems, ventilation rates, and human factors, such as over-crowding in constrained spaces (Wan *et al.*, 2011).

Evaluations of operating theatre air quality assessed levels of particulate matter (PM), microbial agents, and volatile organic compounds (VOCs) (Edmiston *et al*, 1999).

Environment, surgical personnel and patients are significant sources of airborne microbes in an operating theatre. The patient is the centre point of a functioning OT complex. He / she is in isolation for varying times, away from his near and dear ones and is physically sick. Efforts are directed to maintain vital functions, prevent infections / promote healing with safety, comfort and economy.

1.2 PROBLEM STATEMENT

Operating theatre environment, including personnel, can become contaminated with microorganisms capable of causing surgical site infection (SSI), morbidity, prolong hospitalization of patients in relation to cost-effective analysis or even death. Therefore, in Public Health, it is believed that the environment plays an important part in infection prevention and control and considering the evaluation of operating room ventilation and environmental cleanliness to be an integral part of any infection prevention and control program. For instance, measuring the degree of bacterial contamination of indoor air and the susceptibility pattern of the isolates to commonly used antibiotics in the area will help to select appropriate antibiotics for empirical therapy. This also helps to revise and, if necessary, design appropriate hospital infection prevention protocols in an effort to minimize the incidence of costly SSI. Moreover, it provides the tools needed to localize the source and control the spread of SSI. Therefore, this study was designed to determine the air-borne microbial load and indoor air quality in operating theatres in the University College Hospital, Ibadan with respect to acceptable physico-chemical standards of an ideal Operating room and measure antimicrobial susceptibility pattern of the isolates.Indoor air pollution is responsible for 2.7% of the global burden of disease (Kmucha, 2008). It's over 10 years now since the US Environmental Protection Agency (EPA) ranked indoor air pollution as one of the top five environmental threats to public health and one of the largest remaining health risks in the United States.

From the study site preliminary survey, it could be said that, operating room ventilation and standard operating room infection control practices in the Operating Theatres of the University College Hospital (UCH), Ibadan is not adequate enough to minimize the risk of air-borne microbes and surface contamination of each operating suite of UCH theatres. Use of Standard Precautions along with engineering and work-practice controls will assist perioperative practitioners in reducing the transmission of pathogenic organisms. Perioperativepatient care is based on surgical aseptic principles. Careful adherence to these principles supports infection prevention and control, ultimately improving surgical patient safety and outcomes. Each member of the surgical team must demonstrate the highest integrity in the application of this knowledge.

1.3 JUSTIFICATION FOR THIS STUDY

Over the past decades, the role of air as a vehicle of infection and surface contamination has been the subject of much interest and debate. Institute of Medicine, Board on Health Care Services reported that, Consumer demand for public reporting of healthcare quality data has increased since the 1999 publication of the Institute of Medicine's *To Err is Human: Building a Safer Health System*. The report was based upon analysis of multiple studies by a variety of organizations and concluded that between 44,000 to 98,000 people die each year as a result of preventable events such as medication errors, surgical complications and infections. Subsequently, there was demand for greater transparency and a concerted effort to reduce and eliminate HAIs. The development of an HAI is no longer considered an inevitable consequence of healthcare. This informed the quest for more knowledge on Nigerian situation reports of environmental controls and surgical practices in relation to HAIs, particularly the SSI.

University College Hospital is a tertiary health care facility for quality patient care and qualitative medical and nursing education. This makes room for large population of surgical patients, workers, residents, students and visitors.Because of this many activities that normally go on and sanitary practices in the theatres and surgical wards can affect the indoor air quality of patients' care environment which can as a result have an adverse effect on surgical patients' health outcomes. Hospital-acquired fungal infections are

becoming more and more frequent because of the widespread and irrational use of broad spectrum antibiotics that are mostly ineffective against fungi.

Air biocontamination and related health effects are an emerging public health problem. Air-borne bacteria, fungi and viruses can cause infection in diverse living or working environments. This is particularly relevant in medical facilities where there are susceptible patients and tissues are exposed to the air during surgery. As such, there is a need for various systems to minimize the introduction, generation and retention of particles in these environments (CDC, 2003).In this context, microbiological monitoring of air quality and surface contamination is useful in order to determine the potential exposure of individuals at risk. Following a study by the Medical Research Council showing a correlation between microbial air contamination and SSI incidence in prosthetic joint surgery (Lidwell, 1998),ultraclean operating theatres have been recommended for this type of surgery, while conventional theatres supplied by turbulent airflow systems are recommended for other types of surgery.According to Centres for Disease Control and Prevention (CDC, 2003), guidelines for the design and ventilation of operating theatres have been published, and threshold values have been proposed for both ultraclean andconventional theatres.

However, there is no international consensus on tolerable limits of microbial air contamination, and there are no generally accepted methods and frequencies for air sampling. The patient is the centre point of any functioning OT complex. He / she is in isolation for varying times, away from his near and dear ones and is physically sick. Efforts are directed to maintain vital functions, prevent infections / promote healing with safety, comfort and economy.In Nigeria, few studies have been able to link indoor microbial contamination with the risk of developing surgical site infections. Applying strategies for the prevention of surgical site infection help to reduce surgical patients' morbidity, mortality and length of stay, and save cost for the healthcare institutions. Therefore, this study aimed at assessing the indoor air-borne microbial load and air quality of selected operating theatres in the University College Hospital, Ibadan to serve as a base line information for further research toward ensuring a safe surgery outcomes.

1.4 OBJECTIVES

1.4.1 Broad Objective

The broad objectiveof this researchwas to assess indoor air-borne microbial load and air quality of selected operating theatres in the University College Hospital, Ibadan.

Comment [GF1]: Of this study

1.4.2 Specific Objectives

The specific objectives of this research were to:

1. assess the indoor characteristics of the selected operating theatre in the University College Hospital Ibadan.
2. determine the environmental parameters comprising suspended particulate matters, operating room temperature and relative humidity in the selected operating theatre in the University College Hospital.
3. determine the indoor microbial burdenof the selected operating theatre in the University College Hospital before and after surgery.
4. assess the sanitary conditions in the selected operating theatres in the University College Hospital.
5. identify relationship between the microbial load and environmental parameters(Temp., RH and PM) of the selected operating theatre in the University College Hospital, Ibadan.

Comment [GF2]: determine

Comment [OO3]:

1.5 RESEARCH QUESTIONS

1. What are the indoor characteristics of the operating suites in the selected theatres in the University College Hospital?
2. What are the environmental parameters comprising suspended particulate matters, operating room temperature and relative humidity in the selected operating suites of University College Hospital against standards?
3. What is the indoor microbial load of each operating suite of the selected theatres?
4. What is the particulate burden in the selected theatre?
5. What is the relationship between the microbial load and environmental parameters of selected operating theatres?

1.6 HYPOTHESES

a. **H_0**: There is no association between indoor air quality and microbial load of the operating theatres

b. **H_1**: There is an association between indoor air quality and microbial load of the operating theatres

CHAPTER TWO

LITERATURE REVIEW

2.1 Microbiological commissioning and monitoring of operating theatre suites

Surgical operations and interventional procedures are performed in areas with various levels of microbiological control of the ventilation. The following areas are recognized: (1) Conventionally ventilated operating suites (2) Ultraclean-ventilated (UCV) operating theatres (3) Unventilated theatres (4) Treatment rooms. There is no technical difference between an unventilated theatre and a treatment room. Limited advice exists on conventionally ventilated and UCV theatres in the UK Health Technical Memorandum (HTM) 2025 (NHS, 1994). The HTM gives limits on the microbiological (bacterial and fungal) content of air in empty and working theatres, but states in a margin note 'precise guidance is inappropriate and will depend on local circumstances'.

Surgical site infection (SSI) is the second most common health care associated infection next to hospital acquired urinary tract infection (WHO, 2002). The prevalence of SSI varies from country to country depending on level of adherence to infection prevention practice measures in a given health care setting (Jroundi *et al*, 2007).

Surgical site infection (SSI) is a major complication following surgery and is associated with increased morbidity and mortality, as well as increased costs (Broex *et al.*, 2009). Over the past decades, the role of air as a vehicle of infection and surface contamination has been the subject of much interest and debate. Infectious complications may range from superficial infections to deep and organ-space infections, many of which may be associated with increased mortality (Whitehouse *et al.*, 2002). The prevalence of SSI varies from country to country depending on level of adherence to infection prevention practice measures in a given health care setting (Jroundi, 2007). The infection, which is an important clinical indicator for quality of patient care and infection control (Imai, 2008), is primarily determined by the overall contamination level of hospital environment like indoor air together with the surgeon's technique during the operation, patient's degree of

susceptibility, insertion of foreign material or implants, appropriateness of surgical preparation, adequacy and timing of antimicrobial prophylaxis (Dharan, 2002).

The incidence of SSI in African countries is higher than those in developed countries. In an Algerian study, the cumulative incidence of surgical site infection was reported to be 11.9% in 2001 (Atif *et al*., 2006). In another Tanzanian study, 19.4% of patients developed surgical site infections after surgery (Eriksen, 2003), In a Ugandan study, the overall cumulative incidence of surgical site infection was 10% among surgical patients in general and 9.4% among women who underwent caesarean section (Hodges and Agba, 1997). In Nigeria, the cumulative incidence was 23.6 per 100 operations (Ameh *et al*., 2009).

Surgical site infection is being used as a good index of nosocomial infection. It is a prototype of HAI and constitutes a serious problem. Postoperative Surgical Site Infections remain a major source of illness and a less frequent cause of death in the surgical Patient (Nichols, 1998). The term for infections associated with surgical procedures was changed from surgical wound infection to Surgical Site Infection in 1992 by the Center for Disease Control and Prevention (Horan *et al*., 1992). These infections are classified into incisional, organ, or other organs and spaces manipulated during an operation; incisional infections are further divided into superficial (skin and subcutaneous tissue) and deep (deep soft tissue-muscle and fascia). Detailed criteria for these definitions have been described (Horan *et al*., 1992). These definitions should be followed universally for surveillance, prevention, and control of Surgical Site Infections.

The WHO emphasizes that each hospital should have a surveillance programme on HAI. In that vein, the University College Hospital's HAI programme was started in January 1976 (Montefiore *et al*., 1979)). Periodically, an audit of the programme is worthwhile and had been done to alert the Health Care providers in this region on issues on HAI. The last audit reported the situation between January 1989 and December 1991 (Oni *et al*., 1997), whence the prevalence of HAI was found to be 4.9%.

Use of Standard Precautions along with engineering and work-practice controls assists perioperative practitioners in reducing the transmission of pathogenic organisms. Perioperativepatient care is based on surgical aseptic principles. Careful adherence to these principles supports infection prevention and control, ultimately improving surgical patient safety and outcomes. Each member of the surgical team must demonstrate the highest integrity in the application of this knowledge.

The skin surface is the most common site of *S. epidermidis*. Approximately 30% to 70% of individuals carry staphylococci on their skin. This can lead to contamination of clothing and dispersal of the microorganisms. For no known reason, individuals who are skin carriers of staphylococci differ in the rate at which they shed the microorganisms. There is no obvious difference in hygiene and skin condition between light and heavy shedders and no other contributing factor is apparent. Heavy shedders seem to be in normal good health. *S. aureus* infections in hospitals can lead to prolonged hospital stays and may result in death. *S. aureus* has been found in the nasal passages of 25% to 35% of the adult population (CDC, 2005).

Human nasal and throat cavities are the most important reservoirs that continuallyreplenish the external environment. Among perioperative personnel, *S. aureus* has been found mostcommonly in the respiratory passages. The potential for patient infection increases greatly as thepersonnel carrier rate increases. Nasal carriers also may be skin carriers. Microbes' carriers usually harbor either coagulase-positive (pathogenic) or coagulase-negative (nonpathogenic) staphylococci; seldom are there both types and rarely more than one strain is identified. Because an individual may be a carrier of staphylococci one day and a noncarrier the next, frequent swab testing of the nose as an infection control measure is impractical. Staphylococci survive for long periods in the air, dust, debris, bedding, and clothing. Pathogenic staphylococci grow in the sweat, urine, and tissue and on the skin of humans. They are more difficult to destroy than many other non–spore-forming organisms. Cleanliness of the environment; proper handling and, when appropriate, sterilization of linens and equipment; and adherence to adequate hand

hygiene practices are important controls to prevent transmission of infection (AORN, 2009).

The US Environmental Protection Agency (EPA) recently called Indoor Air Quality (IAQ) one of the most important environmental health problems in the 1990s. IAQ problems generally are caused by two circumstances: (1) poor or inadequate ventilation and (2) exposure to one or more contaminant sources in the building (MS Hospital Consulting, 2001). The operating theatre (OT) needs to be well ventilated such that it prevents any deposition of dust particles. Air circulation with a laminar air flow system through High efficiency particulate air filter (HEPA) (0.3µm) serves the best purpose. As per Association of peri-Operative Registered Nurses (AORN) and US Public Health services minimum requirements for OT air are 25 changes per hour, positive pressure compared with corridors, temperature between 18-24º C and humidity of 50 to 55% (Sehulster *et al.*, 2003).

It is increasingly difficult to ignore the burden posed by surgical site infections (SSIs) on patients' safety in terms of pain, suffering, delayed wound healing, increased use of antibiotics, revision surgery, increased length of hospital stay, mortality, and morbidity, which are also reflected in excess healthcare costs (Harrop *et al*., 2012). Surveillance programs focused on healthcare-associated infections (HAIs), including SSIs, are essential tools to prevent their incidence and reduce their adverse effects, thereby allowing for the reduction of patients' risk of infection. As is widely shown in the literature from high-income countries, including the United States, the incidence of HAI can be reduced by as much as 30%, and by 55% in the case of SSI, through the implementation of an effective surveillance approach (Umscheid *et al*., 2011).

Within the scope of developing countries, several reports of the International Nosocomial Infection Control Consortium (INICC) have also shown that, if surveillance and infection control strategies are applied in limited-resource countries, HAIs can also be reduced significantly (Rosenthal *et al*., 2013; Tao *et al*., 2012 and Rosenthal *et al*., 2012).

According to the World Bank's categorization, 68% of the world countries have low-income and lower-middle-income economies, and they can also be referred to as lower-income or developing countries. Today, lower-income countries comprise more than 75% of the world population. However, far too little attention has been paid to the incidence of SSIs in limited-resource countries, where standard methodological approaches are urgently needed (Aiken *et al*., 2012). The infection, which is an important clinical indicator for quality of patient care and infection control (Imai, 2008), is primarily determined by the overall contamination level of hospital environment like indoor air together with the surgeon's technique during the operation, patient's degree of susceptibility, insertion of foreign material or implants, appropriateness of surgical preparation, adequacy and timing of antimicrobial prophylaxis (Dharan, 2003). Thus to achieve acceptable performance, operating rooms (ORs) and surgical wards (SWs) should accomplish a complex range of infection control measures by considering different contamination risks for SSI because a well implemented infection control program can reduce the incidence of hospital acquired infections (HAIs) by around one-third (though eradication is impossible) (Kallel *et al*, 2005) as it is done in countries like USA (Zimmerman, 2007).

One of the risk factors for the development of SSI is bacterial contamination of indoor air in ORs and SWs (Landrin *et al*., 2005). So, in any hospital which performs different surgical procedures, the hospital ORs and SWs should be well designed interms of ventilation and air-conditioning (Zimmerman, 2007., Dascalaki *et al*., 2009) because such environments are one of the settings which require the highest hygiene standards than other settings in there (Ulger *et al*., 2009). ORs' and SWs' indoor air (which places patients at a greater risk than the outside environment) could be polluted with bacterial pathogens released into it from various sources (Nunes *et al*., 2005).

Environmental surface reservoirs like floors, patients and carrier health personnel, construction activities and delayed maintenance can act as a source for microbiological air pollution through shedding and environmental disturbance during different activities (Suzuki *et al*., 1984 and CDC, 2009). Factors like number of visitors, extent of indoor

traffic, time of day and the amount of materials brought in from outside aggravate the extent of air bacterial flora. In one study, for example, airborne dispersal of *S. aureus* is directly associated with the concentration of the bacterium in the anterior nares. Approximately 10% of healthy carriers will disseminate *S. aureus* into the air. Thus the microbiological quality of air can be considered as a mirror of the hygienic conditions of the operating room (CDC, 2009., Ekhaise *et al.*, 2008 and Kalliokoski, 2003) since reduction of airborne bacteria in the operating room by about 13-fold, for example, would reduce the wound contamination by about 50% (Fleischer *et al.*, 2006).

Most of the infections arising from indoor air could potentially be prevented through adequate application of infection control practices (Wood *et al.*, 2007). For instance, measuring the degree of bacterial contamination of indoor air and the susceptibility pattern of the isolates to commonly used antibiotics in the area will help to select appropriate antibiotics for empirical therapy. This also helps to revise and, if necessary, design appropriate hospital infection prevention protocols in an effort to minimize the incidence of costly SSI. Moreover, it provides the tools needed to localize the source and control the spread of SSI (Runner, 2007). SSIs are among the most common hospital acquired infections comprising 14–16 percent of inpatient infections (Skarzynska *et al*., 2000 and Troilet *et al*.,2001).

A survey sponsored by World Health Organization demonstrated a prevalence of nosocomial infections varying from 3-21% with Surgical site Infection accounting for 5-34% (WHO, 2011). Several studies have reported community based data from national registries for nososocomial infections (Weiss *et al*, 1999 and Horan *et al*., 1992) and the incidence rates of SSI in patients from developed countries (Lecuire *et al*., 2003; Gastmeier *et al*., 2005 and Whitehouse *et al*., 2002). The incidence of hospital acquired infections related to surgical wound is as high as 10% and cost the National Health Service in the UK alone approximately 1 billion pounds (WHO, 2011 and Dumpis *et al*., 2003). In the United States alone, these infections number approximately 500,000 per year, among an estimated 27 million surgical procedures, and account for approximately one quarter of the estimated 2 million nosocomial infections in the United States each year (Weiss *et al*., 1999 and NNIS, 1999).To evaluate operating environments for surgical

patients, a previous study evaluated variations in hospital indoor air quality (IAQ) indices in eight operating theatres at a medical center in northern Taiwan (Wan*et al.*, 2011). In addition to surgical patients, air quality in operating theatres areas is also critical to healthcare workers. Reports have identified an increasing number of adverse health effects associated with time spent in mechanically ventilated buildings, typically in the workplace (Rios *et al.*, 2009, Gómez-Acebo *et al*., 2011, Zhang *et al*., 2012). Symptoms are generally attributable either to exposure to a combination of substances or to increased individual susceptibility to low concentrations of contaminants (Hodgson, 2002).

Postoperative nosocomial infections (NIs) are the single most common class of complication that can reach excessive levels while attracting very little attention. Many health care providers and organizations such as the US Centers for Disease Control and Prevention (CDC), the Joint Commission on Accreditation of Healthcare Organizations and the Surgical Infection Society, consider that periodic audits of postoperative NIs should be mandatory because surveys of this nature decrease infection rates by raising awareness of the issue (Weiss *et al*., 1999). Unfortunately, economic constraints make it difficult to perform such studies. SSIs have a significant effect on quality of life for the patient and are associated with considerable morbidity and extended hospital stay resulting in a considerable financial burden to healthcare seekers.

Identification of risk factors for surgical site infections should encouraged the development of national recommendations for prevention. However most of the studies have been done on hospital acquired infections generally (Malangoni *et al*., 1998 and Bowton, 1999) with few of this studies actually focusing on surgical site infection in Africa. This study was therefore designed to determine the air-borne microbial load and the indoor air quality of operating theatres with respect to acceptable microbial load standards and measure antimicrobial susceptibility pattern of the isolates.

2.2 Indoor Air Quality

Indoor Air Quality (IAQ) is an increasing concern in the world today. In fact “the mere presence of people in a building or residence can significantly alter indoor air quality (Brooks *et al*., 1992).” In a study evaluating student performance conducted in August

2003 by the United States Environmental Protection Agency (EPA) they concluded, "recent data suggests IAQ (Indoor Air Quality) may directly reduce a person's ability to perform specific mental tasks requiring concentration, calculation, or memory (EPA, 2004)." As the time spent indoors on average per person is on the rise (Brooks *et al*., 1992), the need for a more accurate, properly maintained HVAC (Heating, Ventilation, and Air Conditioning) system is becoming increasingly necessary.

In 2002, a report of a working party of the hospital infection control in the UK states that, `Increased health risks to patients will occur if the more specialized ventilation systems installed to supply high quality air to operating departments do not achieve and maintain the required standards. The link between postoperative infection and theatre air quality has been well established. Plants serving conventionally ventilated operating departments, for instance, will be required to ensure the separation of areas within the suite by maintaining a specific direction of airflow between rooms, even when doors are opened. They will also maintain the selected operating department environmental conditions regardless of changes in the outside air conditions or activities within the space. In addition ultraclean operating ventilation systems which are designed to provide an effectively particle-free zone around the patient while the operation is in progress, have been shown to reduce significantly postoperative infection in patients undergoing deep wound surgery. Their use for similar forms of surgery may well be indicated.'

The function of operating theatre ventilation is to prevent airborne microbial contaminants from entering surgical wounds. Under normal circumstances, the main source of airborne microbial contaminants is microscopic skin fragments given off by staff in theatre. A proportion of these skin fragments will be contaminated with microcolonies of bacteria resident, or perhaps transiently present, on that individual's skin. Whilst individuals will have different dispersion levels, overall dispersion is increased with movement and numbers of individuals present (Noble, 1975).

Other sources of airborne micro-organisms are usually less significant. These include improperly filtered outdoor air, contaminated fabrics worn by theatre staff and backtracking of contaminated air from outside the theatre. The patient is not usually a

significant source of airborne contamination; their movement is usually minimal. However, there exists the potential that power tools can create an aerosol from the tissues and any micro-organisms within them.

Airborne micro-organisms can enter surgical wounds by one of two routes: they can either fall directly into wounds or they can land on exposed instruments, and possibly surgeons' hands, and can later be transferred into the wound. The significance of this latter route will vary with the area of exposed instruments and the duration of their exposure, but is thought usually to exceed the contribution of direct wound contamination (Whyte, 1982). A recent survey of operating theatre ventilation facilities for minimally invasive surgery in the UK found that most procedures were carried out in areas without specialist ventilation and/or in facilities that are often referred to as 'treatment rooms' (Smyth, 2005).However, there is a paucity of evidence on whether or not procedures carried out under these conditions are associated with increased infection rates, specifically surgical site infection (SSI).

Guidelines to minimize SSI by identifying interventions during the pre-operative, operative and post-operative phases have been published (National Collaborating Centre for Women's and Children's Health, 2008).Although these guidelines apply to all surgical or operative interventions, they do not address the physical conditions under which minor surgical procedures e those carried out under local anaesthesia and that are superficial, and minimal access interventions (MAIs), i.e. therapeutic or diagnostic procedures that are not considered major in terms of the size of the operative site e should take place.

A classic study of operating theatre ventilation found that counts of airborne microbes increased with the degree of movement and numbers of personnel within the theatre (Bourdillon, 1948).It was shown later that airborne skin squames carrying micro-organisms in a 'raft-like' fashion are shed from the skin surface; during modest activity, humans can shed microbe-carrying skin scales yielding up to 10,000 colony forming units (cfu) every minute (Bethune, 1965; Mackintosh, 1978; Solberg, 1972).

The importance of ventilation in controlling airborne contamination was shown in an early study in England where the comparative rates of infection in hospital ranged from 2% to 7% and the cut-off between a low and high rate was an air count of 5 cfu/ft^3 referred to in the so-called Lidwell Report, the forerunner of Health Technical Memorandum 2025, 'Ventilation in healthcare premises' (Lidwell, 1972 and Whyte, 1982). In 'clean' surgery, surgical sites can be exposed to airborne bacteria, either directly into the wound or indirectly by microbes settling onto surgical/operative instruments which will then, on use, transfer this contamination to the surgical site. This latter route probably accounts for the majority of airborne bacteria in a surgical site or wound (Whyte, 1982).Thus instrument contamination contributes proportionally more to surgical site contamination in this scenario. The critical areas within the operating theatre suite are the operating theatre itself and the preparation room, where sterile instrument packs may be opened and exposed to the air before use. The soiled utility room is under negative pressure (i.e. inward airflow) so that it does not contribute to airborne contamination in theatre.

In the National Institute for Health and Clinical Excellence (NICE) guidelines on SSI, no distinction is made between minor surgical procedures, MAI and conventional surgical operations (National Collaborating Centre for Women's and Children's Health, 2008). However, it is not always clear what is meant by minor surgical procedures or MAI and the individual perception of this may vary according to background and professional practice. Laparoscopic procedures are associated with lower infection rates than those after open procedures but patients who undergo laparoscopic procedures may be pre-selected and have a lower risk of infection as more complicated cases are carried out as conventional surgical operations (Romy, 2008 and Poon, 2009).

Surveillance data of orthopaedic procedures from the Health Protection Agency revealed that Staphylococcus aureus accounted for 39-44% of the bacteria responsible for SSI in these procedures followed by Enterobacteriaceae in 14-19% of cases (Health Protection Agency, 2010).The bacteria recovered from specimens taken from infected wounds following laparoscopic abdominal surgery, minor hand surgery or day surgery, largely reflect the endogenous flora of both patients and staff, and appear to be no different from those following conventional surgical operations (Tocchi, 2000 and Brebbia, 2006).For

example, S. aureus was responsible for 44% of infections of the hand and Pseudomonas aeruginosa and other Gram-negative bacilli are more likely to be responsible for infections arising from laparoscopic gastrointestinal procedures (Tocchi, 2000 and Houshian, 2006).Therefore there does not appear to be any difference in the causativemicrobes of post-operative infection whether carried out asa conventional surgical operation or as a Minimal Access Intervention (MAI)/minor surgicalprocedure.

2.2.1 Indoor Air Meteorological Characteristics

Patient / Theatre Personnel Health:

The aims are: (1) to protect patients from contracting infections from hospital staff; (2) protect staff form contracting infections from patients or other staff members, and to maintain their good health; (3) to protect visitors to the hospital from contracting infections, which could be spread to the community.

Over a decade, Canada Mortgage and Housing Corporation (CMHC) estimated 6% of the Canadian population had severe respiratory problems. This estimate has risen to 25% of the population. These statistics may serve as an indication of the growing number of indoor air quality problems in recent years. In the United States, a 1991 federal estimate indicated that approximately 15% of Americans suffer from chemical sensitivities (Mathews, 1992).

Indoor air quality (IAQ) is an important factor in preventing infections in occupants of hospital facilities. Poor hospital IAQ may lead to hospital-acquired infections, sick hospital syndrome, and various occupational hazards. At present, Taiwan has no IAQ standards for operating rooms (ORs). Inadequate air-conditioning systems and building materials, a low ventilation rate, and overcrowding are associated with indoor air pollution (McCarthy *et al*., 2000 and Scaltriti *et al*., 2007).Chemical compounds, particles, and microbial agents have been investigated in OR air ((McCarthy *et al*., 2000 and.Previous studies found mean concentrations of 1.5 $\times 10^3/m^3$ for ≥5µm particles and $5\times 10^6/m^3$ for 0.5- to 4.9µm particles during surgical procedures in conventionally ventilated ORs with 20 air changes per hour (ACH).During surgical procedures, the concentration of ≥5µm

particles in Taiwanese ORs varies from 8 $\times 10^5/m^3$ to $7 \times 10^6/m^3$ (Li and Hou, 2003). The use of airborne particle concentration as an index of microbial contamination has been proposed (Dharan and Pittet, 2002).

A significant association has been found between the level of 5- to 7- µm particles and microbial contamination in ORs (Dharan and Pittet, 2002).Microbial contamination in an OR significantly affects the risk of surgical site infection (SSI) (Gosden *et al*., 1998 and Whyte *et al*., 1982).

A safe airborne bacterial concentration in ORs is considered to be 180 colony-forming units (cfu)/m^3 during general surgery (Department of Health/Estates and Facilities Division, 2007) and 10cfu/m^3 during prosthetic replacement and arthroplasty procedures (Gosden *et al*., 1998; Lidwell *et al*., 1998 and Mangram *et al*., 1999).Microbial contamination is related mainly to the number of persons (Andersen and Solheim, 2002; Edmision *et al*., 1999) and the human activity in the OR, the apparel worn by OR personnel and the frequency of door opening in theOR.The total bacterial concentration in ORs is significantly higher when personnel are present than when they are absent (Edmision *et al.*, 1999).

2.2.1.1 Humidity, Airway Drying, and Comfort

The relationship between comfort and humidity was reviewed in 1998 (Berglund LG. Comfort and humidity. ASHRAE Journal August 1998;35-41). Comfort complaints for nose, throat, eyes, and skin were noted typically when the dew point is less than 0°C (19% RH at 25°C). The ASHRAE Standard 55, current in 1998, was cited as recommending that in occupied spaces the dew point should not be less than 3°C (24% RH at 25°C) in order to decrease the possibility of discomfort, although ASHRAE Standard-55-2004 does not specify a lower humidity limit but notes that non-thermal comfort factors may place limits on acceptability of very low humidity environments.

This reflects the lack of evidence for adverse health effects at low levels of humidity and the lack of consensus on levels associated with discomfort. The relationship between low humidity and air quality was reviewed in 2001 by Nagda and Hodgson in relationship to

aircraft cabin air quality (Nagda N. L., Hodgson M. Low relative humidity and aircraft cabin air quality. Indoor Air. 2001 Sep;11(3):200-14). The *average* humidity levels in the aircraft cabins ranges from 14 to 19% RH at average temperatures of 23–24°C.

The authors concluded:

"The studies with more powerful experimental designs have demonstrated the effects of low humidity, such as drying of the skin and mucus membranes, and that a modest increase in relative humidity seems to alleviate a great number of symptoms. The exposure duration below during which the effects of low humidity are not noticeable is in the order of 3 to 4 hours. It is conceivable that some symptoms experienced by flight attendants and passengers, especially on flights lasting 3 hours or longer, may stem from low humidity."

"This paper shows that the low humidity experienced in the aircraft cabin environment is likely to result in adverse effects on flight attendants and passengers. These effects include irritation of the eyes, skin, and upper airways, which may be akin to those resulting from ''poor'' air quality.

Intervention studies of building air quality show that a modest – about 10% –increase in relative humidity can alleviate such symptoms. Increased recirculation of cabin air can increase relative humidity, but the benefits and risks of such intervention measures, including any increased risk of infections, remain topics for future research."

A significant point of this paper is the duration of exposure necessary for effects of low humidity to occur, estimated to be in the range 3-4 hours. Reinikainen and Jaakkola (Reinikainen LM, Jaakkola JJ. Significance of humidity and temperature on skin and upper airway symptoms. Indoor Air. 2003 Dec;13(4):344-52) studied the effect of absolute and relative humidity, temperature and humidification on workers' skin and upper airway symptoms, and perceptions in the office environment in Finland. In non-humidified conditions (20.0-31.7% RH) skin and nasal symptoms showed no association with humidity or temperature while pharyngeal dryness diminished when humidity rose. In humidified conditions (26.6-41.2%) nasal dryness and congestion were alleviated by both absolute and relative humidity. The authors concluded that skin dryness and rash,

pharyngeal dryness, and nasal dryness and congestion are alleviated in higher humidity. However, the relationship between these symptoms and pathological changes relating to infection risk is unknown.

One study has looked at the effect of low humidity in hospitals. Nordström *et al*. (1994) - Nordström, Norbäck, and Akselsson. Effect of air humidification on the sick building syndrome and perceived indoor air quality in hospitals: a four month longitudinal study. Occup Environ Med. 1994 October; 51(10): 683–688) studied the effect of steam air humidification on sick building syndrome (SBS) and perceived air quality during the heating season in 104 hospital employees, working in four new and well ventilated geriatric hospital units in southern Sweden. Air humidification raised the relative air humidity to 40-45% in two units during a four months period, whereas the other two units served as controls with relative humidity from 25-35%. The most pronounced effect of the humidification was a significant decrease of the sensation of air dryness, static electricity, and airway symptoms. After four months of air humidification during the heating season, 24% reported a weekly sensation of dryness in humidified units, compared with 73% in controls. Air humidification significantly reduced the measured personal exposure to static electricity. This study shows the effects of raising humidity from 25-35% to 40-45%; whether differences would be seen between 25% and 30-35% is unknown.

2.2.1.2 Possible Consequences of Relative Humidities Below 30% in Hospitals

Relative humidities (RH) below 30% (at usual hospital temperatures) for periods longer than 3-4 hours will likely result in symptoms of dryness (of eyes, nose, throat, and skin) relative to humidities greater than 40%. Whether differences of 5-10% less than RH 30% are perceptible is uncertain. Whether these symptoms are also associated with pathological changes in the respiratory tract is also unknown. While the survival of influenza virus is probably enhanced at RH below 40%, whether there are differences in survival between RH 25% and 30% is unknown; any statistical difference in survival is unlikely to be accompanied by significant differences in risk of infection to patients in hospitals. The effect of low humidity on other pathogens is unlikely to be significant, and low humidity

may be protective for some. Much of the exposure to influenza for patients and healthcare workers occurs to large droplets at distances of less than 3 feet, for which humidity would have little or no effect. The high rate of ventilation in hospitals is likely to mitigate any effect of lower humidity on risk of airborne infection to patients and healthcare workers from small droplets at larger distances. The current lack of a lower limit for humidity in the ASHRAE standard (previously RH 25%) reflects the lack of evidence for adverse health effects at low levels of humidity and the lack of consensus on levels associated with discomfort. This evidence supports lowering the lower limit for humidity in California hospitals, where humidities are rarely below 30% for prolonged periods, to avoid the costs and negative consequences of humidification systems.

However, there is no scientific evidence in regard to infectious disease risk or symptoms of dryness to pick a lower limit. A lower limit based on reasonable statistical fluctuations below the current standard of 30% and preventing sparking could be considered as an alternative.

2.2.1.3 Indoor Air Temperature

The measurable scale of the temperature refers to the Canadian index, called Humidex (Ooi, 1963). This index categorizes human comfort level which is to 'reflect perceived temperature' using combination of temperature and humidity. There is so far no study conducted to give a specific measurable scale of the temperature in the tropical region. The measurable scale also refers to the study of Abdul Rahman (1995). The reason is that perception by the people who live in tropical regions are different from those in temperate and cold regions (Wang and Wong, 2007; Singh *et al*., 2009). Abdul Rahman (1995) in his study found that the most comfortable indoor temperature in Malaysia (tropical region) ranges from 25.5-28°C compared to the general recommendation by World Health Organization (1990), from 18-28°C. As per US Public Health services minimum requirements for OT air are 25 changes per hour, positive pressure compared with corridors, temperature between 18-24º C and humidity of 50 to 55% (Sehulster *et al*., 2003). The reason is hot and humid temperature throughout a year gives an impact to the people's perception (Feriadi and Nyuk, 2004) to the thermal comfort at higher temperature

in contrast to those in temperate region. Scale No.2 (Table 2.1) is considered as the best level of performance of the temperature factor. The measurable scale is as shown in Table 2.1.

2.2.1.4 Indoor Air Humidity

Humidity is derived from the word 'humid' which refers to the water vapor content in the air. The scale of measurement is in percentage ranging from 0-100% relative to the amount of water vapor in the air. Relative humidity shows the level of humidity whether it is dry or humid in particular to indoor environment. The recommended level of indoor humidity (Table 2.2) is in the range of 30-60% (Wolkoff and Kjaergaard, 2007).

Relative humidity is a percentage of that maximum amount of humidity in the air at a given time and is temperature dependant. As the temperature increases or decreases so does the saturation of water vapour/pressure. This, in turn, causes the relative humidity to increase or decrease as a result of the direct correlation between the two (Sensirion, 2007). Relative humidity plays an important role in how individuals perceive the comfort level and quality of the air in the indoor environment. In fact, "the human body is comfortable when relative humidity ranges between 30 and 60 percent," although, this range is not always conducive to optimal health (Minnesota Association, 2004). The percentage of indoor relative humidity can also have a significant adverse effect on the structural soundness of buildings.

2.2.1.4.1 Relative Humidity

Relative humidity that is too high may breed mold, rot, or pests, such as termites or cockroaches (Press, 2004). High relative humidity facilitates the growth of different varieties of mold. In fact, "all molds can potentially cause rashes, headaches, dizziness, nausea, allergic reactions including hay fever and asthma attacks (Loecher, 2007)." The effects can be much worse in people with weakened immune systems, such as the every young and the elderly. The existence of mold is often detected by a musty (Maxwell,

2007) or mouldy (Sun *et al*., 2007) smell. High relative humidity (greater than 50 percent) can "produce enough condensation to stain ceilings and walls and cause flaking paint and peeling wallpaper (Press, 2004)."The latter potentially increases the levels of VOC in the air. At high relative humidity levels microorganisms, such as fungi and bacteria, can survive on nonliving material including dust (Choa et al., 2002). High relative humidities (above 70 percent) also "tend to favor the survival of viruses composed entirely of nucleic acids and proteins." The most common groups of these viruses is the *adeno viruses* and the *coxsackie viruses*. The adeno viruses are a group of viruses that infect the membranes of the respiratory tract, the eyes, the intestines, and the urinary tract (Joel, 2006).

Table 2.1: The Scale of Measurement for Temperature (ºC)

Scale	Description	Celsius
0	Cold	Less than 16
1	Cool	16 – 25.5
2	Comfort	25.5 – 28
3	Warm	28 – 32
4	Hot	32 – 40
5	Extremely Hot	Above 40

Source: Ahmad and Mahyuddin, 2010

Table 2.2: The Scale of Measurement of Relative Humidity (%)

Scale	Description	%
1	Low	Below 30
2	Ideal Comfort	30 – 60
3	High	Above 60

Source: Ahmad and Mahyuddin, 2010.

The effort by ASHRAE and the Health Guidelines Revision Committee was extensive and covered almost all aspects of the OR environment, from fire safety to surgical site infections. Building on the paper "Infectious Disease Risk from Low Humidity" submitted by Dr. Jon Rosenberg (Attachment C), ASHRAE Standing Standard Project Committee

(SSPC) 170 asked Dr. Farhad Memarzadeh of the National Institutes of Health (NIH) to help perform a scientific literature search and evaluation of its findings (Attachment D). SSPC 170 also worked with the Association for Professionals in Infection Control and Epidemiology (APIC), the Association of Perioperative Registered Nurses (AORN), and the Centers for Disease Control & Prevention (CDC) to assess whether there would be any patient safety issues with lowering the RH to 20 percent in the OR. Subsequent to reviewing the information provided by NIH, APIC, and AORN and answering the negative comments from the ASHRAE public review process, the standing committee felt confident there is no difference in patient safety and clinical outcomes between 30 and 20 percent RH. The consensus development process used by ASHRAE is rigorous and well supported by involvement from professionals representing all stakeholders. This amendment is a positive step in maintaining safe patient care and cost-effective delivery of essential procedures.

2.2.1.5 Implications for Infection Preventionists, Perioperative Care Professionals, and Health Care Engineers: Infection preventionists (IP) collaborate with their colleagues who perform surgery and other invasive procedures and with health careengineers to provide as optimal an environment as possible for safe care of the patients served. This change in the lower RH level facilitates flexibility in HVACparameters that will have little, if any, risk of adverse effect on system performanceand patient safety. Importantly, it broadens the range of humidity that health careengineers work hard to maintain without requiring investment in expensivechanges to HVAC systems that heretofore have been needed to keep RH greater thanor equal to 30 percent. In addition, RH is intimately tied to outdoor air conditionsand local climate conditions. Many facilities in the United States are located in morearid climates or areas with variable seasons, which ambient local conditions oftenmake maintaining a 30 percent RH impossible to achieve.

2.2.1.5.1 Ventilation Technical Expert Position: Dr. Farhad Memarzadeh, Director, Division of Technical Resources, at the National Institutes of Health, has conducted critical research on the role of HVAC parameters on outcomes such as surgical

site infection (SSI). He has concluded "there is no clinical evidence or research that shows any correlation between minimum levels of relative humidity and hypothermia or wound infections in short-term patient spaces." Dr. Memarzadeh also investigated the impact of minimum levels of RH on survival of viruses in health care facilities and concluded there is none. Lastly, Dr. Memarzadeh assessed a prior concern about whether discharge of static electricity with the RH at the 20 percent level would be an environmental hazard. He indicated that no such problems have been reported in the literature nor have any been documented in databases of adverse events during surgical care that are maintained by the U.S. Food and Drug Administration (FDA) and the ECRI Institute (Attachment D).

2.2.1.5.2 AORN Position on RH: AORN has endorsed this change in the lower limit of RH and Ramona Conner, Manager of Standards and Recommended Practices, AORN, has indicated the organization will recognize this change as AORN cites the 2010 edition of the FGI *Guidelines for Design and Construction of Health Care Facilities* as the criterion reference for their *Perioperative Standards and Recommended Practices*.

The 2010 FGI *Guidelines* incorporate ASHRAE Standard 170-2008 and therefore the approval of this change by ASHRAE means AORN will adopt this addendum to 170.

Similarly, the CDC will reference the addendum to ASHRAE 170 when they update their SSI, TB and environmental guidelines.

2.2.1.5.3 Impact of Change on Clinical, Regulatory, and Accreditation Requirements: Dr. Lennox K. Archibald, hospital epidemiologist for Shands Hospital at the University of Florida, and adjunct professor of epidemiology in the Division of Epidemiology at the University of Florida, Gainesville, concluded this change in RH will have negligible impact on the pathogenesis and epidemiology of surgical site infections (SSI). He instead continues to reinforce and highlight the multitude of factors and variables that do have a significant impact on the incidence of SSI captured in the CDC *Guideline for Prevention of Surgical Site Infection*, 1999. He stresses that little has changed since this CDC guideline was published and that strategies for prevention need to emphasize processes of care around the surgical site more than environmental HVAC conditions. His assessment of the literature found very few reports of correlation between

RH and SSI—actually, those he did identify involved RH elevated significantly above the upper boundary of 60 percent.

2.2.1.5.4 APIC Position on RH: Judene Bartley, Vice President of Epidemiology Consulting Services and a Clinical Consultant for Premier's Safety Institute, stresses that what evidence exists for a relationship between RH and SSIs involves prolonged periods of RH exceeding 60 percent and that RH is only one variable among others, such as airflow direction and exchange, temperature, and filtration, that affects the incidence of SSI. Being a member of the Health Guidelines Revision Committee, Ms. Bartley emphasizes that the FGI *Guidelines* parameters pertain to *design* NOT to *operations* of health care facilities. During the design process, the IP is an integral member of the ICRA team, who should insist that all HVAC parameters meet design specification during commissioning of newly renovated or constructed spaces, especially these short-term spaces. Requirements from the Centers for Medicare & Medicaid Services (CMS), NFPA 99, and accreditation agencies like the Joint Commission only specify that HVAC variables must be in place. No agency specifies frequency or method of documenting ventilation conditions; rather, these are the responsibility of the team at the health care organization. This *team* needs to reinforce good preventive maintenance and operational practices (e.g., minimizing traffic in and out of the OR during surgery, thoroughly cleaning the OR between cases, etc.). If a variable like RH is out of range, then the facility engineer, IP, and perioperative professionals need to assess risks and enact appropriate responses. Ms. Bartley urges teams to make decisions based on observable conditions likely to pose SSI risks as opposed to relying solely on readings that do not match design specification but have no significant impact on SSI risk.

Advantages claimed for humidity include avoidance of hypothermia in patients, especially during long operative procedures; the fact that floating particulate matter increases in conditions of low relative humidity; and the fact that the incidence of wound infections can be minimized following procedures performed in those operating rooms in which the relative humidity is maintained at the level of 50 to 55 percent.

Temperature, humidity and airflow in the operating rooms must be maintained within acceptable standards to inhibit bacterial growth and prevent infection, and promote patient comfort. Excessive humidity in the operating room is conducive to bacterial growth and compromises the integrity of wrapped sterile instruments and supplies. Each operating room should have separate temperature control. Acceptable standards such as from the Association of Operating Room Nurses (AORN) or the American Institute of Architects (AIA) should be incorporated into hospital policy.

2.3 Air Pollution

Air pollution is one of the major environmental problems confronting the world today. Air pollution is concerned with the things humans add to or put into the air. Air pollution is thus the transfer of harmful amounts of natural and synthetic materials into the atmosphere as a direct or indirect consequence of human activity. In simple words, air pollution is the dust, gas and droplets that are stirred up into the atmosphere as a result of human activities (Chanlett, 1993).

The term "Air Pollution" signifies the presence in the surrounding atmosphere of substances (e.g. gases, mixture of gases and particulate matter) generated by the activities of man or natural disasters in concentrations that interfere with human health, safety or comfort, or injurious to vegetations and animals and other environmental media resulting in chemicals entering the food chain or being present in drinking water and thereby constituting additional source of human exposure (Park, 2006).

Air pollution could also be described as the presence of substances in air in sufficient concentration and for sufficient time, so as to be, or threaten to be injurious to human,

plant or animal life, or to property, or which reasonably interferes with the comfortable enjoyment of life and property. Air pollution on the other hand refers to the discharge of harmful substances into the air to the extent that it can reduce visibility or produce undesirable odour (Abatan, 2007). This is an inescapable consequence of the presence of man and his activities. Today, air pollution has become more subtle and recognizes no geographical or political boundaries. However, air pollution is primarily associated with everyday human activities (Stewart, 1979).

This increase was occasioned by the deposition of particulates or dust raised during the Harmatan season, wind movement of dry particulates and aerosols from the Sahara desert into the northern states, and burning of anthropogenic substances etc. Generally speaking, the concentration of ambient air particulate matter over Nigerian cities is about 500% higher than the 20µg/m^3 threshold of WHO (2005).

A critical examination of the spatial distribution of the ambient air particulate matter over Nigerian cities revealed that the traffic-clogged areas had the highest concentrations with mean annual values of 147.7µg/m^3. Traditional areas which also formed part of the cities, had the lowest mean ambient PM_{10} with 121.2µg/m^3 over the six years of study. This showed a difference of 26.5µg/m^3 which indicates that ambient PM_{10} concentrations in the traffic-clogged areas are about 22% higher than those in the traditional areas. This increase is occasioned by the deposition of particulate from increased vehicular movement, dust raised during the Hammatan season, wind movement of dry particulates and aerosols from the Sahara desert, and burning of anthropogenic substances (Efe, 2008).

2.3.1 Particulate Matter

Comparing urban values with those of the surrounding rural areas showed that ambient PM_{10} concentrations in the rural areas were generally lower than those of the urban areas. The urban environment had mean annual ambient PM_{10} that span 129µg/m^3 to 144µg/m^3, with an overall mean of 135µg/m^3, while the surrounding rural areas recorded mean annual mean ambient PM_{10} value of 57µg/m^3, indicating over 136% difference between the two landscapes. When these values were compared with the aid of paired t-test

statistical analysis, results revealed that a significant difference exists in the ambient PM_{10} concentration between the urban corridors and the surrounding rural areas of Nigeria (Efe, 2008).

2.3.2 Organic Compounds

The classification of organic compounds represents chemical compounds that contain carbon-hydrogen bonds in their basic molecular structure. Their sources can be either natural products or synthetics, especially those derived from oil, gas, and coal. Organic contaminants may exist in the form of gas (vapour), liquid or as solid particles in the atmosphere, food and/or water (Rea, 1992).

2.3.3 Volatile Organic Compounds (VOCs)

In the past, when human bio-effluents were considered to be the most important pollutants of indoor air, carbon dioxide ($C0_2$) was generally accepted as an indicator for indoor air quality (IAQ). $C0_2$ has lost this function partly because today many more sources than human beings emit pollutants into indoor air. In fact the widespread use of new products and materials in our days has resulted in increased concentrations of indoor pollutants, especially of volatile organic compounds (VOCs) that pollute indoor air and maybe affect human health. As a result, the air of all kinds of indoor spaces is frequently analysed for VOCs (Brown *et al*., 1994).

As many VOCs are known to have short-term and long-term adverse effects on human health and comfort, VOCs are frequently determined if occupants report complaints about bad indoor air quality. On the comfort side VOCs are associated with the perception of odours. Adverse health reactions include irritation of mucous membranes, mostly of the eyes, nose and throat, and long term toxic reactions of various kinds (ECA, 1991).

2.3.4 Inorganic Compounds

Inorganic compounds are those which do not contain carbon-hydrogen bonds in their molecular structure. They include carbon dioxide, sulphur dioxide, nitrogen oxides, carbon monoxide, ozone, lead, sand, metal, ammonia and some particulate matter.

2.3.4.1 Carbon Monoxide

The process of combustion can produce a number of pollutants, including carbon monoxide, carbon dioxide, water vapor, and smoke (fine airborne particle material). Of these materials, carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure (Bright *et al.*, 1992). Carbon monoxide is a product of incomplete combustion of organic matter (e.g., gasoline, wood, tobacco). Carbon monoxide should not be present in a typical indoor environment. If it is present, indoor carbon monoxide levels should be less than or equal to outdoor levels (EPA, 2000).

Several air quality standards have been established to prevent human exposure to carbon monoxide. EPA has National Ambient Air Quality Standards (NAAQS) to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (U.S. EPA, 2000). The American Society of Heating, Refrigerating, and Air Conditioning (ASHRAE) recommends that pollutant levels of fresh air introduced to a building not exceed the NAAQS (ASHRAE, 1989).

2.3.4.2 Bioaerosols

Bioaerosols are considered all airborne particles of biological origin, namely, bacteria, fungi, fungal spores, viruses, pollen and their fragments including various antigens. Particle sizes may range from aerodynamic diameters of ca. 0.5 to 100 μm (Cox and Wathes, 1995). Airborne micro-organisms become non-viable and fragmented over time due to desiccation. Indoor air contains a complex mixture of (i) bio-aerosols such as fungi, bacteria and allergens, and (ii) non-biological particles (e.g., dust, tobacco smoke,

cooking-generated particles, motor vehicle exhaust particles, particles from thermal power plants, etc.). Exposure to several of these biological entities as well as microbial fragments (like cell wall fragments, flagella, etc.) and microbial metabolites (like endotoxin, mycotoxins and VOCs) may result in *adverse health effects*. In particular, increase in asthma attacks and bronchial hyper-reactivity has been correlated to increased bio-aerosol levels. Elevated levels of particle air pollution have been associated with decreased lung function, increased respiratory symptoms such as cough, shortness of breath, wheezing and asthma attacks, as well as chronic obstructive pulmonary disease, cardiovascular diseases and lung cancer (WHO, 2002).

2.3.4.3 Infection Control in the facility and the High Risk Areas

Basic minimum sanitation and hygiene, with proper cleaning of hospital twice a day (once in the morning and once in the Evening) with disinfectants should be practiced. Apart from this specific attention should be provided to the High risk areas in the hospital to ensure optimum infection control in the hospital. The High Risk Areas in the Hospital include:

☐Operation Theatre

☐Labor room

☐Intensive care unit/Burn Wards

Activities	**Responsibilities**

Following procedures should be followed for ensuring optimum infection control in the High risk areas: • The floor of the OT and labor room should be cleaning regularly twice every day, and after each procedure performed with use of proper disinfectant as recommended by the hospital infection control committee. • The floor should preferably of marble, or rubber painted to prevent accumulation of germs in the gaps and facilitate dryness. • Unauthorized entries in the OTs and Labor room should be restricted and direct access of attendants and other patients to these areas should be avoided. • Use of personnel protective gears should be encouraged, while working inside the OT, LR and ICU. • All the instruments used should be properly sterilized, either by autoclaving or using manual sterilizers. • Separate entry and exit routs for patients and waste should be defined to prevent cross infection. • Fumigation should be performed at fixed intervals preferably after each procedure.	Incharge of the respective Department (OT-in-charge Matron)

2.4 Operating Theatre and Standard Meteorological Parameters

An operation theatre complex is the "heart" of any major surgical hospital. An operating theatre, operating room, surgery suite or a surgery centre is a room within a hospital within which surgical and other operations are carried out. Operating theatres were so-called in the United Kingdom because they traditionally consisted of semi-circular amphitheatres to allow students to observe the medical procedures .The Old Operating Theatre in London is one of the oldest, dating back to 1822 (Oxford English Dictionary and Wikipedia.com).

The patient is the centre point of a functioning OT complex. He / she is in isolation for varying times, away from his near and dear ones and is physically sick. Efforts are

directed to maintain vital functions, prevent infections / promote healing with safety, comfort and economy.

Cleanliness of the hospital environment is the best starting point to achieve the highest patient safety mandate. There is a need to decrease the bio-burden present in the environment in an operating room. A systematic method of cleaning will decrease the possibility of the transmission of pathogens. Florence Nightingale, "The Lady with the Lamp," and Joseph Lister (1827–1912), a professor at London's King College Hospital were one of the first persons to realize the importance of sterilization. Joseph Lister successfully introduced carbolic acid (phenol) to sterilize surgical instruments and to clean wounds.

During the 1990s, the US Department of Labor, Occupational Safety and Health Administration (OSHA) passed a regulation known as the Blood Borne Pathogen Standard. The standard required institutions to implement policies and procedures for the identification of potential exposure to blood borne pathogens. The Association of peri-Operative Registered Nurses (AORN) developed "Recommended Practices for Environmental Cleaning in the Surgical Practice Setting," which was approved by AORN's board of directors and became effective from January 1, 2003.

Plate 2.1. UCH- Operating Theatre Complex and associated offices (Unrestricted Areas)

"There is no hospital however small, airy or well ventilated, where the epidemic ulcer is not to be found at times, and thus no operation dared to be performed. Every cure stands still, every wound becomes a sore and every sore is apt to run into gangrene. But in great hospitals specially, it prevails at all times and is a real gangrene. It has been named the Hospital Gangrene and such were the ravages at Hotel Dieu of Paris the great storehouse of corruption and disease that the surgeons did not dare call it by its true name."

JOHN BELL (1801) on: Hospital Infections

Plate 2.2. A Clean Corridor of Operating Theatre Suites (Semi-restricted area)

The establishment and working of the operation theatre (O.T.) needs specialised planning and execution and is not a simple civil engineering work. A "civil-mechanical-electrical-electronic- bio medical" combo effort driven and coordinated by the needs, preferences and safety of the medical/ surgical team forms the basis for starting and maintaining an operation theatre. Anaesthesiologists, by virtue of their knowledge of the intricacies of physiology, physics and biomedical aspects of medicine and constant proximity to the operation theatre should preferably be involved from the early stages of planning of operating theatres (Dorsch *et al.*, 1999).

2.4.1 Purpose of Operating Theatre (OT)

OT complexes are designed and built to carry out investigative, diagnostic, therapeutic and palliative procedures of varying degrees of invasiveness. Many such set ups are

customized to the requirements based on size of hospital, patient turnover and may be speciality specific. The aim is to provide the maximum benefit for maximum number of patients arriving to the operation theatre. Both the present as well as future needs should be kept in mind while planning.

Plate 2.3: Operating Theatre and its ancillary rooms (Restricted area/ Sterile Zone)

2.4.2 Different Zones of OT Complex

The location and flow of the patients, the staff and the materials form the three broad groups to be considered during all stages of design (Dorsch *et al*., 1999). Four zones can be described in an O T complex (Bridgen, 1998), based on varying degrees of cleanliness, in which the bacteriological count progressively diminishes from the outer to the inner zones (operating area) and is maintained by a differential decreasing positive pressure ventilation gradient from the inner zone to the outer zone.

(1) **Protective zone:** It includes

- Change rooms for all medical and paramedical staff with conveniences
- Transfer bay for patient, material & equipments
- Rooms for administrative staff
- Stores & records
- Pre & post-operative rooms
- I.C.U. and P.A.C.U.
- Sterile stores

(2) **Clean zone:** Connects protective zone to aseptic zone and has other areas also like

- Stores & cleaner room
- Equipment store room
- Maintenance workshop
- Kitchenette (pantry)
- Firefighting device room
- Emergency exits
- Service room for staff
- Close circuit TV control area

(3) **Aseptic zone -** Includes operation rooms (sterile)

(4) **Disposal zone -** Disposal areas from each OR & corridor lead to disposal zone

2. 4. 3 Sub-areas (excluding OT-complex)

(1) Pre-operative check in area (reception)- This is important with respect to maintaining privacy, for changing from street clothes to gown and to provide lockers and lavatories for staff.

(2) Holding area-This area is planned for IV line insertion, preparation, catheter / gastric tube insertion, connection of monitors, & shall have O_2 and suction lines. Facility for CPR should be available in this area.

(3) Induction room -(anaesthetic room). It should have all facilities as in OT, but there is controversy as to its need. One for each OT is required; ideally each is a duplicate of the other in each floor (Moyle *et al.*, 1992). The anaesthetic room will provide a more tranquil atmosphere to the patient than the OT. It should provide space for anaesthetic trolleys and equipment and should be located with direct access to circulation corridors and ready access to the operating room. It will also allow cleaning, testing and storing of anaesthesia equipment. It should contain work benches, sink(s). It should have sufficient power outlets and medical gas panels for testing of equipment.

(4) **Post anaesthetic care units (PACU) -** preferably adjacent to recovery room. These should contain a medication station, hand washing station, nurse station, storage space for stretchers, supplies and monitors / equipment and gas, suction outlets and ventilator. Additionally 80 sq ft (7.43 sq m) for each patient bed, clearance of 5 ft (1.5 m) between beds and 4 ft (1.22m) between patient bed sides and adjacent walls should be planned.

(5) **Staff room -** Men and women change dress from street cloth to OT attire; lockers and lavatory are essential; rest room TV, etc. are desirable.

(6) **Sanitary facility for staff-** One wash basin and one western closet (WC) should be provided for 8-10 persons. Showers and their number is a matter of local decision. Inclusion of toilet facilities in changing rooms is not acceptable; they should be located in an adjacent space (Bridgen, 1998).

(7) **The anaesthesia gas / cylinder manifold room / storage area-** A definite area to be designated. It should be in a cool, clean room that is constructed of fire resistant materials. Conductive flooring must be present but is not required if non inflammable gases are stored. Adequate ventilation to allow leaking gases to escape, safety labels and separate places for empty and full cylinders to be allocated (Moyle *et al.*, 1992).

(8) **Offices - for staff nurse and anaesthesia staff-** The office should allow access to both unrestricted and semi-restricted areas as frequent communication with public is needed.

(9) **Rest rooms-** Pleasant and quiet rest for staff should be arranged either as one large room for all grades of staff or as separate rooms; both have merits. Comfortable chairs, one writing table, a book case etc., may be arranged

(10) **Laboratory -** Small laboratory with refrigerator for pathologist to be arranged.

(11) **Seminar room-** Since staff cannot leave an OT complex easily, it is better to have a seminar room within the OT complex. Intra-departmental discussions, teaching and training sessions for staff (with audio-visual aids) may be conducted here.

(12) **Store room-** This is designed to store large but less frequently used equipment in the OT. There should be storage space for special equipment after cleaning.

(13) **Theatre sterile supply unit (TSSU) -** Within this area, following are desirable -

i. Temperature between 18^0 -22^0 C, humidity of 40%-50% is the aim.
ii. Air conditioned with 10-12 air exchanges per hour
iii. Storage of sterile drapes, sponges, gloves, gowns and other items ready to use.
iv. Option to store in from one side and remove from other side.
v. Proper inventory to prevent running out of stock.

(14) **Scrub room-** This is planned to be built within the restricted area. Elbow operated or infrared sensor operated taps / water source is ideal. It is essential to have non slippery flooring in this area.

2.4.4 Types of Operating Theatre Complexes

There are three main categories of operating theatres (Bridgen, 1998):

1. The single theatre suite with OT, scrub-up and gowning, anaesthesia room, trolley preparation, utility and exit bay plus staff change and limited ancillary accommodation.
2. The twin theatre suite with facilities similar to 1, but with duplicated ancillary accommodation immediate to each OT, sometimes sharing a small post anaesthesia recovery area.
3. OT complexes of three or more OTs. with ancillary accommodation including post anaesthesia recovery, reception, porter's desk, sterile store and staff change.

2.4.5 Principles to be taken into consideration while planning an O.T. (physical /architecture):

1. Location: Low rise buildings limited to two or three storeys high are preferred because of maximum advantage of natural light and ventilation as appropriate can be derived. The OT should be separate from general 'traffic' and air movement of rest of the hospital, OT, surgical wards, intensive care units (ICU), accident and emergency department (A & E), Radiological department (X-Ray) should be closely related and access is also required to Sterilizing and disinfecting unit (SDU) and laboratory facilities. The location of the operation complex in a multi-storey building is planned on the first floor, connecting to surgical and other wards on the same floor. Adequate electric lift is planned for vertical movement from casualty on the ground floor and ENT, Orthopaedics, Ophthalmology & other wards on the floors above.
2. Zone wise distribution of the area, so as to avoid crisscross movements of men & machines
3. Adequate & appropriate space allotted as per utility of the area

4. Provision for emergency exit
5. Provision for ventilation & temperature control, keeping in mind the need for laminar flow, HEPA filter air conditioner etc.

Doors: Main door to the OT complex has to be of adequate width (1.2 to 1.5 m). The doors of each OT should be spring loaded flap type, but sliding doors are preferred as no air currents are generated. All fittings in OT should be flush type and made of steel.

The surface / flooring must be slip resistant, strong & impervious with minimum joints (e.g. mosaic with copper plates for antistatic effect) or jointless conductive tiles/ terrazzo, linoleum etc., the recommended minimum conductivity is 1m ohm and maximum 10m Ohms. Presently the need for antistatic flooring has diminished as flammable anaesthetic agents are no longer in use.

Walls- Laminated polyester or smooth paint provides seamless wall; tiles can break and epoxy paint can chip out. Collusion corners to be covered with steel or aluminium plates, colour of paint should allow reflection of light and yet soothing to eyes. Light colour (light blue or green) washable paint will be ideal. A semi-matt wall surface reflects less light than a highly gloss finish and is less tiring to the eyes of OT team.

6. **Operation rooms:**
   The number & size can be as per the requirement but recommended size is 6.5 m x 6.5m x 3.5 m. Glass windows can be planned on one side only.
7. **Operation table**: One operation table per OT
   Electric point: Adequate electric points on the wall (at < 1.5 m height from the floor)
   X-Ray illuminators: There should be X-ray film illuminators preferably recessed into the wall.
   Scrub area: to be planned for atleast for 2-3 persons in each OT.
8. There has to be a preparation room in clean zone

9. Corridors not less than 2.85 m width for easy movement of men, stretcher & machines
10. Separate corridors for uses other than going into OT.
11. Rooms for different persons working in OT & for different purpose (it should be as per zone & size)
12. Gas & suction (control, supply & emergency stock) for all OTs & areas where patients are retained. Oxygen, gas and suction pipe to be connected with central facility and standby local facility should also be available.
13. Provision for adequate & continuous water supply:
    Besides normal supply of available water at the rate of 400 litres per bed per day, a separate reserve emergency over head tank should be provided for operation theatre. Elbow taps have to be 10 cm. above wash basins.
14. Proper drainage system.
15. Pre-operative area with reception with separate designated area for paediatric patients is desirable.
16. Adequate illumination with shadow less lamps of 70,000-120,000 Lumens intensity, for assessing patient colour and tissue visibility.
17. The safety in working place is essential, and fire extinguishers have to be planned in appropriate zone.
18. Provision for expansion of the OT complex should be borne in mind during planning stages itself.

2.4.6 Recommendations on the number of OTs required

It is observed that out of all surgical beds, of the hospital, 50%of patients are expected to undergo surgery. Thus for 100 beds, with average length of stay of 10 days for each patient, 10 operations per day can be performed. In general, multiuse OTs, instead of multiple OTs offer advantages of efficient man power utilization, economical maintenance and better training of supporting staff. Thus, in a 300 bedded hospital (with 150 surgical beds), one OT complex with 3 OTs for General Surgery, Gynaecology, Orthopaedics/ENT, one for Endoscopy and one for Septic cases.

2.4. 7 Ventilation

Ventilation should be on the principle that the direction of air flow is from the operation theatre towards the main entrance (Bridgen, 1998). There should be no interchange air movement between one OT and another. Efficient ventilation will control temperature and humidity in OT, dilute the contamination by micro-organisms and anaesthetic agents. There are two types of air conditioning systems: re-circulating and non re-circulating (Gupta *et al.*, 2005). Non re-circulating systems heat / cool the air as desired and convey it into the operating room with ideally 20 air exchange per hour. Air is then exhausted to outside. Anaesthetic agents in the OT air are also automatically removed. These are thus ideal but are expensive. The circulating system takes some or all of the air, adjusts the temperature and circulates air back to the room.

2.4.7. 1 The broad recommendations for an ideal and safe operating theatre include:

- 20-30 air exchanges / hour for re-circulated air
- Only up to 80%recirculation of air to prevent build up of anaesthetic and other gases
- Ultraclean laminar air flow - the filtered air delivery must be 90%efficient in removing particles more than 0.5m m.
- Positive air pressure system in OT: It should ensure a positive pressure of 5 cm H_2O from ceiling of OT downwards and outwards, to push out air from OT.
- Relative humidity of 40-60% to be maintained (Bridgen, 1998)
- Temperature between 18^0 -24^0 C. Temperature should not be adjusted for the comfort of OT personnel but for the requirement of patient, especially in pediatric, geriatric, burns, neonatal cases etc.

2.5 Nosocomial (Hospital-Acquired) Infections

The term nosocomial infection or hospital-acquired infection is applied to any clinical infection that was neither present nor was in its incubation period when the patient entered the hospital. Nosocomial infections may also make their appearance after discharge from the hospital, if the patient was in the incubation period at the time of discharge.

Patients are no doubt better treated in hospitals than anywhere else; however congregating a large number of sick under a single roof could easily facilitate the transmission of infectious disease from one patient to another. One must remember that infections in hospitals have existed since the very inception of hospitals themselves. To say that nosocomial infections are of great importance in hospitalized patients is to state the obvious. Nosocomial infections, even in this modern era of antibiotics, continue to remain an important and formidable consequence of hospitalization. It has been estimated that about 3.5% of patients leave the hospital after having acquired infections, depending on the case, hospital size and multiple other factors.

2.5.1 Historical Milestones

One of the earliest records of hospital infections are perhaps those found in an egyptian papyrus written around 3000 B.C. Needless to say, mere absence of documentation of bacterial infection does not exclude its prevalence prior to this time. Nearer home, in the Indian context a similar account of hospital infection is available in the ancient Ayurvedic literature (ca. 600 B.C.) Again the famous Hindu physician Charaka and surgeon Sushuruta (Ca. 400 B.C.) have also emphasized the need for prevention of infection in clinical practice. Elsewhere in the world too there is ample evidence that hospital infection were prevalent and documented in ancient times viz: the records of Herodatus on the conditions that prevailed in Greek and Roman hospitals in the period 1000 to 600 B.C., and the Hipprocrates treatise (ca 400 BC) testifying the existence of infection. For several subsequent centuries that followed it was generally believed that the

- disease was caused by the contagion and spread by wind and various other types of air currents.

- It soon became recognized that certain medicaments were capable of either preventing or checking the progress of infection.

Place in 1721 used the term **Antiseptics** to describe these substances and, nearly 30 years later, **Pringle in 1750** conducted extensive trials with antiseptics while working with the British army in Flanders. In **1856 Louis Pasteur** conclusively demonstrated that bacteria were responsible for fermentation of wine, which could be prevented by gentle heating whereby the microorganisms were destroyed. The existence of such microorganisms in the atmosphere were proved by him in 1864. In his celebrated lecture to **Acadimie deMedicine on April 30th, 1873.** Louis Pasteur is quoted as having said:

> ***"If I had the honour of being a surgeon, not only would I use absolutely clean instruments, but after cleaning my hands with the greatest care would only use sponges previously raised to a heat of 1300-1500 Fahrenheit. I would still have to fear germs suspended in the air, and surrounding the bed of the patient".***

The now well-known work of **Semmelweiss (1861)** on puerperal sepsis was largely disregarded at the time. He observed that puerperal sepsis was associated with medical staff and students who attended patients and also performed autopsies. Semmelweiss deduced that morbid matter present on their hands derived from cadavers or other patients was responsible for spread of the disease. A drastic reduction in infection rates was achieved by the introduction of hand-washing practices with chlorinated lime.

At about the same time, **Florence Nightingale** in a much quoted remark in her book **Notes on Hospitals.** It may seem a strange principle to enunciate as the very requirement in a Hospital that itshould do the sick no harm. The actual mortality in hospitals, especially in those oflarge crowded cities, is very much higher that any calculation founded on the mortality ofthe same class of diseases among patients treated out of hospitalAlthough Florence Nightingale was sceptical of the germ theory of disease; sheestablished important principles of nursing, hospital design and hygiene. In **1869 Simpson** provided further evidence by the survey of the sequelae of amputation,which

established that sepsis, gangrene and pyaemia were very much common inlarge urban hospitals than in rural practice.

At about this time **Lister** introduced his antiseptic theory, following the extensive use of carbolic acid to pack wounds, especially of compound fractures, sterilize instruments and sutures, decontaminate his hands and as an air spray. He observed that these practices could greatly reduce the incidence of suppuration and gangrene, which quite commonly occurred otherwise.

In **1883 Gustao Neubar** introduced the use of masks and gowns in surgery, and **Halsted in 1890** introduced the use of rubber gloves in surgery. Steam sterilization was discovered by **von Bergman in 1896** and all these measures further increased the safety of surgery and contributed greatly in bringing down rates of infection by use of aseptic and antiseptic techniques. During the period, when many fundamental discoveries in bacteriology were being made, other principles of hospital infection control were also simultaneously established. **Flugge (1897, 1899)** showed the importance of droplet and aerial spread in tuberculosis. By **1894, Hutinel** and others had established basic isolation systems for diphtheria and other infectious diseases in childrens and fever hospitals. With the turn of the century attention began to get focused largely on aseptic techniques in surgery and theses superceded the use of antiseptics. More and more attention was given to the operation theatre and air ventilation.

2.5.2 The Era of Antibiotics

The introduction of penicillin, which heralded the antibiotic era, banished from hospitals the terrible cases of chronic sepsis, mainly caused by Staphylococcus aureus. Nevertheless, the era of antibiotics ushered in for the first time a period in which staphylococcal rather than streptococcal infections dominated the scene. Penicillin-resistant, and later multiply-resistant, S.aureus caused serious wound, burn and other sepsis. With this, interest in air-borne and dust-borne spread as well as transmission on the hands of attendants was revived. Also, the introduction of certain broad-spectrum antibiotics seemed to keep check on S.aureus infections and the importance of multiply-

resistant S.aureus appeared to fade. Interest shifted in the 1950s, 1960s and 1970s to gram-negative bacilli; antibiotic-resistant enterobacteria, such as Escherichia coli, Klebsiella spp. and later on to Serratia spp., which caused large outbreaks. Infection by Pseudomonas aeruginosa came into prominence with the increasing number of patients being rendered susceptible either by illness itself or by treatment. The infecting bacteria appeared to be favoured by the antibiotics in current use in the hospitals. More recently, of late, the extensive use of indwelling medical devices and possibly as a result of the introduction of new antibiotics coupled with their indiscriminate use, the gram-positive cocci have once again emerged as the predominant causes of infection. Methicillin-resistant Staphylococcus. aureus (MRSA), Vancomycin-resistant Enterococcus spp. (VRE) and MRSA with reduced susceptibility to Vancomycin have posed serious problems.

2.5.3 Sources of Hospital Infections

For an infection to occur in the hospital the prerequisites are:

(a) A susceptible host.

(b) A microbe capable of producing an infection.

(c) An environment that is congenial for the multiplication of the microbe.

It is the delicate interplay of these 3 components that ultimately culminates in the occurrence of an infection. Also, various combinations of four main factors influence the nature and frequency of infections. These are:

(i) Low resistance of the patients

(ii) Contact with infectious persons

(iii) Contaminated environmental sites

(iv) Drug resistance of endemic organisms

The source of the infecting organism may be **exogenous** - from another patient or a member of the hospital staff, or from the inanimate environment in the hospital; or it may be **endogenous** from the patient's own flora which at the time of infection may include organisms brought into the hospital at admission and certain others acquired subsequently. In either case, the infecting organisms may spontaneously invade the tissues of the patient

or may be introduced into them by surgical procedures, instrumental manipulation or nursing procedures.

The inanimate environment of the hospital that acts as an important source comprises of:

(a) Contaminated air, water, food and medicaments
(b) Used equipments and instruments
(c) Soiled linen
(d) Hospital waste (Bio medical waste)

A patient comes to the hospital because he is unwell he has an underlying disease for which he may be under investigation including various types of instrumentation or he may be receiving antibiotics. Also if he has an underlying malignancy he may have under gone surgery and may be receiving chemotherapy and/or radiotherapy. All this in turn decreases his host defence mechanisms and his vitality, making him increasingly susceptible to infection. Antibiotic therapy may cause a change in the flora, while instrumentation may lead to direct implantation of organisms. In most instances these could lead to an infection arising from an exogenous or an endogenous source and occasionally the infection could be an autoinfection.

2.5.4 Microbial Causes

A large number of microorganisms are responsible for hospital infection. Infact any microbe may have the capacity/ability to cause an infection in the hospitalized patient. The causative microorganisms may be broadly classified into the following these categories:

1. Those **conventional** pathogens that could cause disease in healthy persons in the absence of any specific immunity to them.
2. Those **conditional** pathogens that could cause disease (other than simple localized infections) only in persons with lowered resistance to infection or when implanted directly into tissue or normally sterile area.

3. Those **opportunistic** pathogens that could cause generalized disease, but only those patients who have a greatly diminished resistance to infection. Of course, one has to bear in mind that these distinctions are by no means clear cut and the grading accorded to each of these individual pathogens could be challenged. A detailed list has been compiled and is available in the WHO manual edited by M.T. Parker.

Infections by Staphylococcus aureus, Group B Streptococci, Enterobacteriaceae and Pseudomonas aeruginosa could either be acquired from other persons (exogenous source) or by self infections (endogenous/autoinfection) whereas most infections by Group A Streptococci are from other persons. Again while most infections caused by Enterococci and other non-haemolytic streptococci, anaerobic cocci, histotoxic clostridia, Bacteroides and Acinetobacter species are self infections, infections with Clostridium tetani, Pseudomonas cepacia, Flavobacterium meningosepticum are nearly always and infections by Pseudomonas aeruginosa and members of the Klebsiella-Enterobacter - Serratia group are often, acquired from independent environmental sources (exogenous). Patients and hospital personnel may acquire infection by HIV and Hepatitis B, C, D viruses through contact with blood positive for these viruses form patients and blood donors.

2.5.5 Types of Hospital-Acquired Infections

The most common types of nosocomial infections that could occur in a hospital set up are:

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1. Surgical wound and other soft tissue infections **(SSI)**.
2. Urinary tract infections
3. Respiratory infections
4. Gastroenteritis
5. Meningitis

In preoperative preparation, shaving of hair from the site, rather than treatment with depilatories or clipping of the hair has been associated with a much higher frequency of infection. In some studies, certain factors of significance such as male sex, emergency operations and the use of surgical drains have come to light. It is generally agreed that

goodsurgical technique is most important. Staphylococcus aureus remains the dominant species in surgical wound infection, followed by the enterobacteria. Bacteroides spp. along with other gut bacteria, very often in mixed growth is found typically in wounds after a colonized viscus has been entered. Although S. aureus may occur in all types of wound, it is the typical cause of the less frequent wound infection in clean surgery. Most commonly, infection of surgical wounds occurs at the time of surgery. Again, in the great majority of cases, the origin of the bacteria appears to be the patient s own body flora (endogenous infection). Much less often it is from a member of the surgical team. However, in any instances the origin is obscure. The usual and common routes are direct spread from the incised organs and intraoperative contamination of instruments and of surgeon's gloves and clothing. Contamination from various types of apparatus has occasionally been described. Although the air-borne route is important in the implantation of prostheses, it occurs only in rare episodes in general surgery. In addition to these endemic infection, which are caused by a variety of organisms, outbreaks of epidemic infections occur from time to time due to the presence of a particular strain of a virulent organism carried by some member of the staff of present in materials that should be sterile. Although these hazards can be reduced by observing aseptic methods, the common development of sepsis after clean operation shows the limitations of aseptic methods and brings home the need for meticulous standards. Occasionally an epidemic increase in the incidence of postoperative wound sepsis may also be caused by some failure in aseptic technique or sterilization. These outbreaks are associated with an increased incidence of infection caused by a wide range of bacteria, and not by one epidemic strain.

The mode of spread of infections is hospital occurs mainly by the following 2 methods:-

1. Aerial
2. Contact

- **Aerial** transmission could be from the nose/mouth of the person or from inanimate sources like the air-conditioning plants, respiratory apparatus etc. a variety of infections including measles, small pox, tuberculosis, sepsis by Staphylococcus aureus and Streptococcus pyogenes, meningococcal infections, respiratory diseases

associated with Streptococcus pneumoniae, Streptococcus pyogenes. From inanimate sources aerial spread could result in respiratory infections by Enterobacteria, Pseudomonas aeruginosa and Legionella.

- **Contact** could be either from other patients, doctors, nurses and other staff or from independent environmental sources. While any of these could lead to respiratory infection, sepsis or diarrhoea, direct contact into tissue or wounds or mucous membranes by infected needles, surgical instruments or by blood and/or blood products could result in serious infections like hepatitis or AIDS.

2.5.6 Control of Nosocomial Infections

The CDC (1985) on the efficacy of nosocomial infection control (SENIC) showed beyond doubt that increase in surveillance activities is able to directly bring down the rates of nosocomial infections. It is only too well known that nosocomial infections are most prevalent in certain high risk areas such as the intensive care renal dialysis and organ transplant units, burns ward, cancer ward, operation theatres, post-operation theatres, postoperative ward nursery and the geriatric ward. Therefore, all methods aimed at containing hospital infections should be primarily focused in these high risk areas. Some of the problems that are likely to hamper an infection control programme in a developing country which has limited resources include:

1. The lack of appropriate operating theatre design and environmental controls
2. The lack of quality control of sterilization and disinfection procedures.
3. The quality of water and food made available in the hospital.
4. The hospital environment itself.
5. The lack of trained staff.
6. The lack of knowledge of hospital infection control principles and practices among the staff.
7. The general misuse of antibiotics both in the community and in the hospital.

2.6 Surgical site infection (SSI)

Surgical site infection can be defined as being present when pathogenic organisms multiplyin a wound giving rise to local signs and symptoms, for example heat, redness, pain and swelling, and (in more serious cases) with systemic signs of fever or a raised white blood cell count. Infection in the surgical wound may prevent healing taking place so that the wound edges separate or it may cause an abscess to form in the deeper tissues. Surgical site infection (SSI) is a major complication following surgery and is associated with increased morbidity and mortality, as well as increased costs (Broex *et al.*, 2009).Over the past decades, the role of air as a vehicle of infection and surface contamination has been the subject of much interest and debate. Infectious complications may range from superficial infections to deep and organ-space infections, many of which may be associated with increased mortality (Whitehouse *et al.*, 2002).

Surgical site infection (SSI) is the second most common health care associated infection next to hospital acquired urinary tract infection (WHO, 2002). The prevalence of SSI varies from country to country depending on level of adherence to infection prevention practice measures in a given health care setting (Jroundi *et al*, 2007). It is increasingly difficult to ignore the burden posed by surgical site infections (SSIs) on patients' safety in terms of pain, suffering, delayed wound healing, increased use of antibiotics, revision surgery, increased length of hospital stay, mortality, and morbidity, which are also reflected in excess healthcare costs (Harrop *et al*., 2012). Surveillance programs focused on healthcare-associated infections (HAIs), including SSIs, are essential tools to prevent their incidence and reduce their adverse effects, thereby allowing for the reduction of patients' risk of infection. As is widely shown in the literature from high-income countries, including the United States, the incidence of HAI can be reduced by as much as 30%, and by 55% in the case of SSI, through the implementation of an effective surveillance approach (Umscheid *et al*., 2011).

2.6.1 CDC Surgical Site Infection Classification and Risk of SSI

Wound infection is most commonly characterized by the classic signs of redness (rubor), pain (dolor), swelling (tumor), elevated incisional tissue temperature (calor) and systemic fever (Fry, 2003). Ultimately, the wound is filled with necrotic tissue, neutrophils, bacteria and proteinaceous fluid that together constitute pus. It is essential for the accuracy of surgical site infection surveillance and comparison of SSI rates for there to be conformity in the definitions used to classify and categorize infections. The CDC *Guideline for prevention of surgicalsite infection*, published in 1999, details the criteria for defining an SSI (Mangram, 1999).

As noted in Figure 1, SSIs are separated into three types, depending on the depth of infection penetration into the wound: superficial incisional, deep incisional and organ/space. An infection must occur within 30 days after surgery to be classified as an SSI; however, if the surgery includes an implanted device or prosthesis, then the infection window extends out to one year. Evidence of incisional pus, cellulitis, deliberate incision and drainage of surgical site and/or diagnosis of SSI by physician are also required for conformance with the definition.

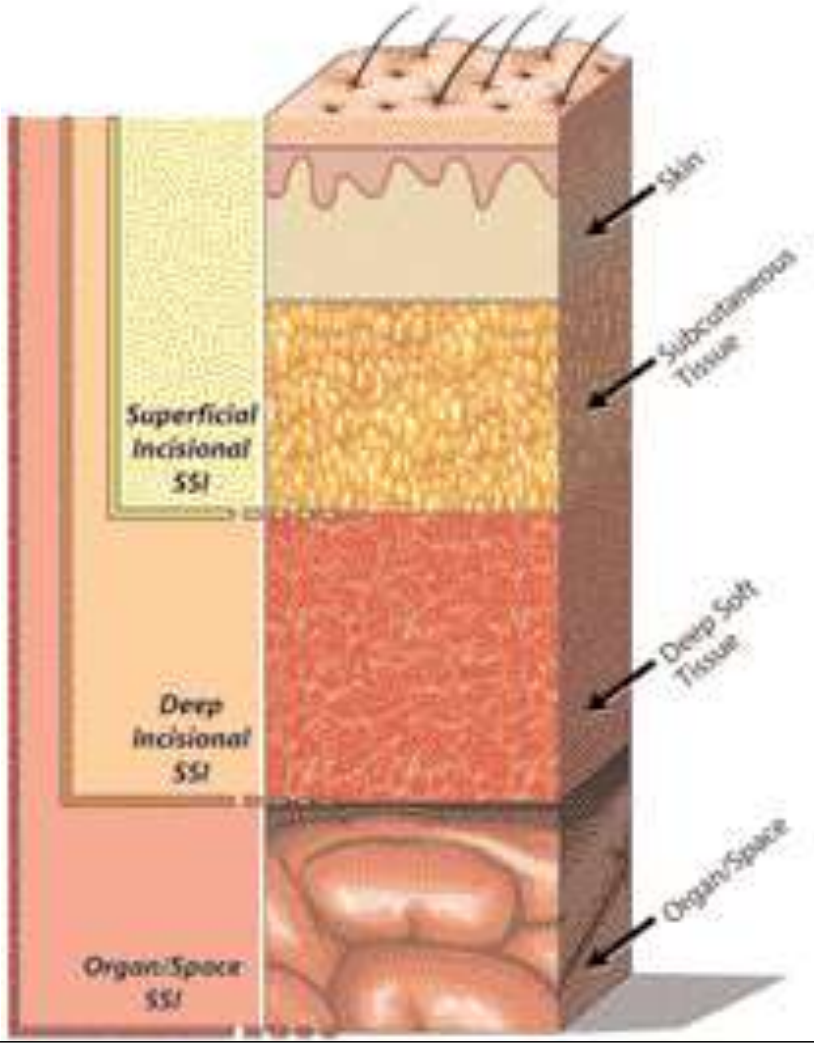

Figure 1: Wound classification

Different surgical sites may contribute to the risk of developing clinical infection. For example, cosmetic operations of the head and neck in otherwise healthy patients pose a much lower risk of SSI than colon resection for cancer in an elderly patient with chronic obstructive lung disease and obesity. Elective procedures have lower SSI rates than do emergency procedures. Stratification of various operations into groups that have similar risks for infection is important so that preventive strategies can be appropriately evaluated among similar patients, and so that quality monitors can be implemented to identify when infection rates are at variance from accepted trends and norms within an institution. An assessment of gross SSI rates without stratification is of only limited value, since overall rates are likely to be a reflection of patient risk rather than quality of performance.

The traditional wound infection classification system was developed in the wake of the ultraviolet light study of 1964 (Horan *et al*., 1992). This classification system was primarily designed to provide a clinical estimate of the inoculum of bacteria likely to be encountered during the procedure and does not address the other determinants of infection defined above. Four separate classes of procedures were identified, each with a unique infection rate.

Clean Wounds

The wound is judged to be clean when the operative procedure does not enter into a normally colonized viscus or lumen of the body. Elective inguinal hernia repair is an example of a clean operative procedure. SSI risk is minimal and originates from contaminants of the OR environment or from the surgical team, or most commonly from skin colonists. The most common pathogen is *Staphylococcus aureus*. SSI rates in this class of procedures should be 2% or less, depending upon other clinical variables.

Clean-Contaminated Wounds

A clean-contaminated surgical site is seen when the operative procedure enters into a colonized viscus or cavity of the body, but under elective and controlled circumstances. The most common contaminants are endogenous bacteria from within the patient. For example, sigmoid colectomy wounds generally contain *E coli* and *Bacteroidesfragilis* as

microbial contaminants. Elective intestinal resection, pulmonary resection, gynecologic procedures, and head-neck cancer operations that involve the oropharynx are examples of clean-contaminated procedures.

Infection rates for these procedures are in the range of 4% to 10% and can be optimized with specific preventive strategies.

Contaminated Wounds

Contaminated procedures occur when gross contamination is present at the surgical site in the absence of obvious infection. Laparotomy for penetrating injury with intestinal spillage and elective intestinal procedures with gross contamination of the surgical site are examples of contaminated procedures. As with clean-contaminated procedures, the contaminants are the bacteria that are introduced by gross soilage of the surgical field. Infection rates will be greater than 10% for this classification of wound, even with preventive antibiotics and other strategies.

Dirty Wounds

Surgical procedures performed when active infection is already present are considered dirty wounds. Abdominal exploration for acute bacterial peritonitis and intra-abdominal abscess are examples of this class of surgical site.

Pathogens to be expected are the pathogens of the active infection that is encountered. Unusual pathogens are often encountered in dirty wounds, especially if the infection has occurred in a hospital or nursing home setting, or in patients receiving prior antibiotic therapy.

2.6.2 Source and routes of infection in the operating room

The risk of postoperative infection is present in all surgical procedures, but it can be particularly serious in certain operations, for example, joint replacement. There are several factors that could affect such infection, namely, patient factors (i.e., susceptibility to infection), surgical field factors (i.e., the thermal plume from the site), room factors (i.e., cleanliness of the OR), and HVAC factors (i.e., air change rate [ACH] and direction of airflow). Figure 2 shows sources, routes, and interactions of many of the factors. In terms

of the bacteria that cause infection, it is agreed in the literature that the primary source of such bacteria are squames, or skin scales or particles, (Woods *et al*., 1986). These particles are of the order of 10 microns in diameter and are shed from exposed regions of skin, both from the surgical staff and also by the patient.

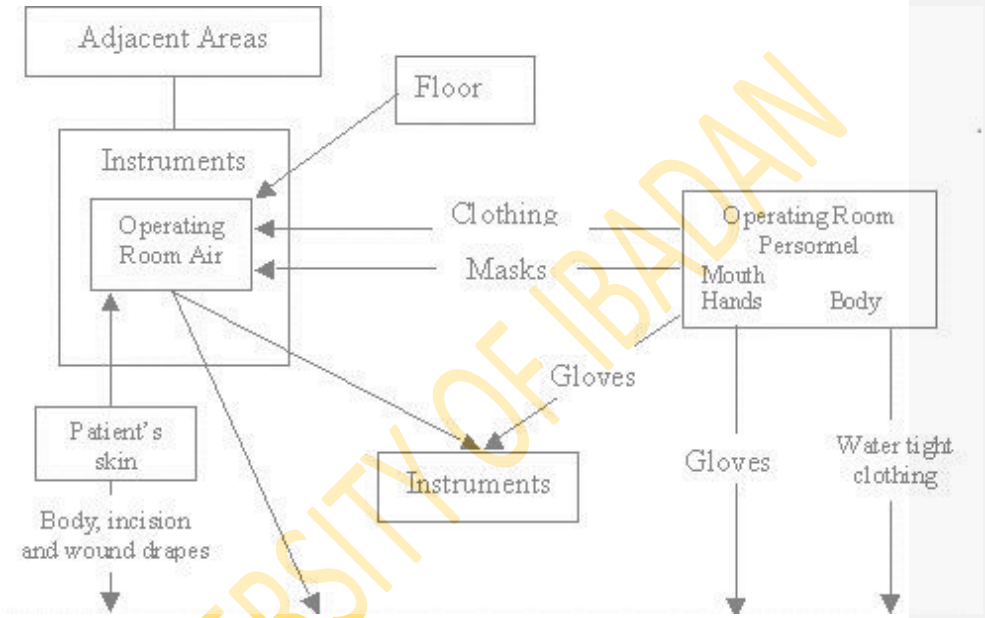

Figure 2.*Source and routes of infection in the operating room (Lewis 1993).*

2.6.3 Economic implications of SSI

SSIs are associated with considerable morbidity and it has been reported that over one-third of postoperative deaths are related, at least in part, to SSI (Astagneau *et al.*, 2001). However, it is important to recognise that SSIs can range from a relatively trivial wound discharge with no other complications to a life-threatening condition. Other clinical outcomes of SSIs include poor scars that are cosmetically unacceptable, such as those that are spreading, hypertrophic or keloid, persistent pain and itching, restriction of movement,

particularly when over joints, and a significant impact on emotional wellbeing (Bayat *et al.*, 2003).

SSI can double the length of time a patient stays in hospital and thereby increase the costs of health care. Additional costs attributable to SSI of between £814 and £6626 have been reported depending on the type of surgery and the severity of the infection (Coello *et al.*, 2005 and Plowman *et al.*, 2001). The main additional costs are related to re-operation, extra nursing care and interventions, and drug treatment costs. The indirect costs, due to loss of productivity, patient dissatisfaction and litigation, and reduced quality of life, have been studied less extensively.

Within the scope of developing countries, several reports of the International Nosocomial Infection Control Consortium (INICC) have also shown that, if surveillance and infection control strategies are applied in limited-resource countries, HAIs can also be reduced significantly (Rosenthal *et al.*, 2013; Tao *et al.*, 2012 and Rosenthal *et al.*, 2012). According to the World Bank's categorization, 68% of the world countries have low-income and lower-middle-income economies, and they can also be referred to as lower-income or developing countries. Today, lower-income countries comprise more than 75% of the world population (Rosenthal *et al.*, 2013). However, far too little attention has been paid to the incidence of SSIs in limited-resource countries, where standard methodological approaches are urgently needed (Aiken *et al.*, 2012)

It is estimated that more than 27 million surgical procedures are performed annually in the United States (Robson; Krizek and Heggers, 1973). Surgical site infection (SSI) continues to be a major source of morbidity following operative procedures. The aging of the population means that not only will the number of operations likely increase, but the National Nosocomial Infections Surveillance (NNIS) Risk Index, which standardizes the risk of SSI for an aging population, will be greater. Despite many decades of the application of refined surgical techniques, environmental changes in the operating room (OR), and the use of preventive antibiotics, infection at the surgical site remains a too common event. The NNIS report for 1986-1996 described an SSI rate of 2.6% for all

operations at the reporting hospitals (Robson; Krizek and Heggers, 1973).It seems likely that overall SSI rates are likely to be greater than reported. Thus, in an era during which economic costs are a source of increasing concern in surgery, SSI prolongs hospitalization and increases many other costs that could be avoided if infection had not occurred.

Kuper, in 2008, published a literature review of research articles related to total knee and hip replacement SSIs. His findings include an annual cost of total joint replacement infections in the U.S. of $250 million. Cost of revision of a total joint due to infection is 2.8 times higher than cost of revision for aseptic loosening, and 4.8 times higher than costs associated with primary total hip arthroplasty. The cost of total knee arthroplasty revision due to infection ranges from $15,000 to $30,000. Total hip arthroplasty revision due to infection results in significantly more hospitalizations, total length of stay, number of operative procedures, outpatient visits and charges, and additional complications than revision due to aseptic loosening of the prosthesis.

In 2003, Olsen *et al*. conducted a retrospective case control study of patients who had either laminectomy or spinal fusion procedures. Forty-one patients with SSI or meningitis were compared to 178 uninfected patients. Of the patients with SSI, all received additional antibiotic therapy, 30 (77%) underwent re-operation due to their infection, and 30 (77%) were re-hospitalized at least once for wound care treatment. The mean readmission length of stay was 8.5 days (mean 6 days, range 0-45 days). The infection, which is an important clinical indicator for quality of patient care and infection control (Imai, 2008), is primarily determined by the overall contamination level of hospital environment like indoor air together with the surgeon's technique during the operation, patient's degree of susceptibility, insertion of foreign material or implants, appropriateness of surgical preparation, adequacy and timing of antimicrobial prophylaxis (Dharan, 2003). Thus to achieve acceptable performance, operating rooms (ORs) and surgical wards (SWs) should accomplish a complex range of infection control measures by considering different contamination risks for SSI because a well implemented infection control program can reduce the incidence of hospital acquired infections (HAIs) by around one-third (though

eradication is impossible) (Kallel *et al*, 2005) as it is done in countries like USA (Zimmerman, 2007).

One of the risk factor for the development of SSI is bacterial contamination of indoor air in ORs and SWs (Landrin *et al*., 2005). So, in any hospital which performs different surgical procedures, the hospital ORs and SWs should be well designed interms of ventilation and air-conditioning (Zimmerman, 2007, Dascalaki *et al*., 2009) because such environments are one of the settings which require the highest hygiene standards than other settings in there (Ulger *et al*., 2009). ORs' and SWs' indoor air (which places patients at a greater risk than the outside environment) could be polluted with bacterial pathogens released into it from various sources (Nunes *et al*., 2005).

Environmental surface reservoirs like floors, patients and carrier health personnel, construction activities and delayed maintenance can act as a source for microbiological air pollution through shedding and environmental disturbance during different activities (Suzuki *et al*., 1984 and CDC, 2009). Factors like number of visitors, extent of indoor traffic, time of day and the amount of materials brought in from outside aggravate the extent of air bacterial flora. In one study, for example, airborne dispersal of *S. aureus* is directly associated with the concentration of the bacterium in the anterior nares. Approximately 10% of healthy carriers will disseminate *S. aureus* into the air. Thus the microbiological quality of air can be considered as a mirror of the hygienic conditions of the operating room (CDC, 2009, Ekhaise *et al.*, 2008 and Kalliokoski, 2003) since reduction of airborne bacteria in the operating room by about 13-fold, for example, would reduce the wound contamination by about 50% (Fleischer *et al*., 2006).

Most of the infections arising from indoor air could potentially be prevented through adequate application of infection control practices (Wood *et al*., 2007). For instance, measuring the degree of bacterial contamination of indoor air and the susceptibility pattern of the isolates to commonly used antibiotics in the area will help to select appropriate antibiotics for empirical therapy. This also helps to revise and, if necessary, design appropriate hospital infection prevention protocols in an effort to minimize the incidence

of costly SSI. Moreover, it provides the tools needed to localize the source and control the spread of SSI (Runner, 2007). SSIs are among the most common hospital acquired infections comprising 14–16 percent of inpatient infections (Skarzynska *et al*., 2000 and Troilet *et al*.,2001). A survey sponsored by World Health Organization demonstrated a prevalence of nosocomial infections varying from 3-21% with Surgical site Infection accounting for 5-34% (WHO, 2011). Several studies have reported community based data from national registries for nososocomial infections (Weiss *et al*, 1999 and Horan *et al*., 1992) and the incidence rates of SSI in patients from developed countries (Lecuire *et al*., 2003; Gastmeier *et al*., 2005 and Whitehouse *et al*., 2002). The incidence of hospital acquired infections related to surgical wound is as high as 10% and cost the National Health Service in the UK alone approximately 1 billion pounds (WHO, 2011 and Dumpis *et al*., 2003). In the United States alone, these infections number approximately 500,000 per year, among an estimated 27 million surgical procedures, and account for approximately one quarter of the estimated 2 million nosocomial infections in the United States each year (Weiss *et al*., 1999 and NNIS, 1999).

The incidence of SSI in African countries is higher than those in developed countries. In an Algerian study, the cumulative incidence of surgical site infection was reported to be 11.9% in 2001(Atif *et al*., 2006). In another Tanzanian study, 19.4% of patients developed surgical site infections after surgery (Eriksen, 2003). In a Ugandan study, the overall cumulative incidence of surgical site infection was 10% among surgical patients in general and 9.4% among women who underwent caesarean section(Hodges and Agba, 1997). In Nigeria, the cumulative incidence was 23.6 per 100 operations (Ameh *et al*., 2009).

Postoperative nosocomial infections (NIs) are the single most common class of complication that can reach excessive levels while attracting very little attention. Many health care providers and organizations such as the US Centers for Disease Control and Prevention (CDC), the Joint Commission on Accreditation of Healthcare Organizations and the Surgical Infection Society, consider that periodic audits of postoperative NIs should be mandatory because surveys of this nature decrease infection rates by raising awareness of the issue (Weiss *et al*., 1999). Unfortunately, economic constraints make it difficult to perform such studies. SSIs have a significant effect on quality of life for the

patient and are associated with considerable morbidity and extended hospital stay resulting in a considerable financial burden to healthcare seekers.

Identification of risk factors for surgical site infections should encouraged the development of national recommendations for prevention. However most of the studies have been done on hospital acquired infections generally (Malangoni *et al*., 1998 and Bowton, 1999) with few of this studies actually focusing on surgical site infection in Africa. This study was therefore designed to determine the air-borne microbial load and the indoor air quality of operating theatres with respect to acceptable microbial load standards and measure antimicrobial susceptibility pattern of the isolates.

2.6.4 Pathogenesis of surgical site infection

The development of an SSI depends on contamination of the wound site at the end of a surgical procedure and specifically relates to the pathogenicity and inoculum of microorganisms present, balanced against the host's immune response.The microorganisms that cause SSIs are usually derived from the patient (endogenous infection), being present on their skin or from an opened viscus. Exogenous infection occurs when microorganisms from instruments or the theatre environment contaminate the site at operation, when microorganisms from the environment contaminate a traumatic wound, or when microorganisms gain access to the wound after surgery, before the skin has sealed. Rarely, microorganisms from a distant source of infection, principally through haematogenous spread, can cause an SSI by attaching to a prosthesis or other implant left in an operative site. Practices to prevent SSI are therefore aimed at minimising the number of microorganisms introduced into the operative site, for example by:

• removing microorganisms that normally colonise the skin

• preventing the multiplication of microorganisms at the operative site, for example by using prophylactic antimicrobial therapy

• enhancing the patient's defences against infection, for example by minimising tissue damage and maintaining normothermia

• preventing access of microorganisms into the incision postoperatively by use of a wound dressings.

Staphylococcus aureusis the microorganism most commonly cultured from SSIs. When a viscus, such as the large bowel, is opened, tissues are likely to be contaminated by a whole range of organisms. For example, after colorectal surgery enterobacteriaceae and anaerobes are encountered and may act in synergy to cause SSI.In prosthetic surgery, the presence of the foreign body (for example, a vascular graft after arterialbypass surgery or a prosthetic joint in orthopaedic surgery) reduces the number of pathogenic organisms required to cause an SSI. In this environment, normally non-pathogenic organisms such as *Staphylococcus epidermidis* (coagulase-negative staphylococcus) may also cause an SSI. Operations on sites that are normally sterile ('clean') thus have relatively low rates of SSI (generally less than 2%), whereas after operations in 'contaminated' or 'dirty' sites, rates may exceed 10% (Health Protection Agency, 2005).

2.6.4.1 The Human Inflammatory Response

With the creation of the surgical incision through the skin and into subcutaneous tissues, 5 critical initiators of the human inflammatory response are activated (Figure 3). Coagulation proteins and platelets are initially activated as part of the human hemostatic mechanism, but they also herald the onset of inflammation. Mast cells and complement proteins are activated, and bradykinin is produced from its ubiquitous protein precursors. The net effect of these 5 factors is vasodilation and increased local blood flow at the site of the surgical incision. While bulk flow is increased, flow velocity is reduced in preparation for margination of phagocytes.

The simultaneous occurrence of increased vascular permeability and local vasodilation facilitates the formation of edema fluid, resulting in increased space between endothelial cells. The increased vascular permeability provides phagocytic access to the injured soft tissue, while edema provides aqueous conduits for the navigation of these phagocytes through the normally condensed extracellular tissues. Activation products from the 5 initiator events described above result in the production of nonspecific chemoattractant signals, while mast cells produce specific chemokine signals that "draw" specific neutrophil, monocyte, and other leukocyte populations into the area of the surgical site. The important point of this discussion about inflammation is that tissue injury from the

incision initiates the mobilization of phagocytes into the wound before bacterial contamination actually occurs from the procedure itself. This mobilization of the innate host defenses before significant intraoperative contamination occurs undoubtedly gives the patient an advantage against infection as an outcome.

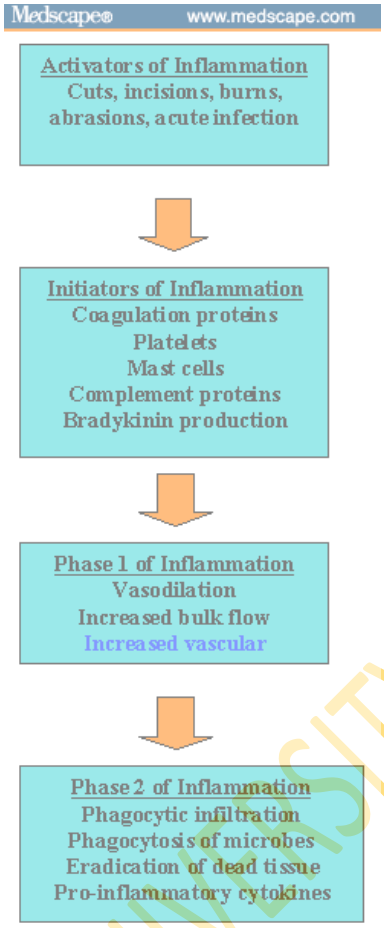

Figure 3. The consequences of inflammation are important for understanding the clinical signs of infection and play a role in determining whether contamination during surgical procedures results in clinical infection.

The abundant release of chemoattractant signals, products of tissue injury, orchestrates the movement of phagocytes into the wound. Chemoattractant signaling proteins bind to local vascular endothelial cells and upregulate selectin proteins on the endothelial surface of these cells, which results in neutrophil "rolling" on the endothelial surface within the post-capillary venule. Further interaction between neutrophil and endothelial cell adhesion proteins anchor the neutrophil to the surface of the endothelial cell, and the chemoattractant gradient then acts as a biological "beacon" to direct neutrophil movement toward the site of injury. Neutrophil presence at the surgical site allows systematic ingestion and digestion of any microbial contaminants from the operation.

By about 24 hours after creation of the surgical wound, monocytes enter the surgical site and initiate 1 of 2 different scenarios. When microbial contamination has been minimal and the early arriving neutrophils have been able to adequately control the bacteria that are present, then monocytes produce local chemical signals to regulate the wound-healing process. Myofibrocytes migrate into the fibrin matrix of the wound, and collagen deposition displaces its fibrin latticework. However, if microbial contamination and proliferation overwhelm the initial neutrophil infiltration, the monocyte assumes the role of a proinflammatory cell with the release of potent cytokines. Tumor necrosis factor (TNF)-alpha is produced and released by the monocytes and serves numerous functions; notably, it becomes a potent paracrine signal to upregulate vigorous neutrophil activity within the wound. TNF-alpha-stimulated neutrophils consume microbes, and lysosomal vacuoles may release reactive oxygen intermediates and acid hydrolases into the extracellular space from its lysosomal vacuoles. The extracellular release of reactive oxygen intermediates and the acid hydrolases results in lipid peroxidation of the local environment, with further tissue injury and further activation of the initiator signals. In this way, the entire inflammatory response is further intensified. Interleukin (IL)-1, IL-6, and other proinflammatory signals are released by the activated monocyte and serve as endocrine signals responsible for fever, stimulation of acutephase reactants, and other responses.

The net effect of vigorous neutrophilic stimulation, tissue autolysis, and sustained stimulation of inflammatory initiation is the creation of a wound space that is a host-pathogen battlefield. Ultimately, the wound space is filled with necrotic tissue, neutrophils, bacteria, and proteinaceous fluid that together constitute pus. The viable tissues around the infected wound typically exhibit the classic signs of inflammation. Wound *rubor* reflects local vasodilation. *Calor* is the warmth of the vasodilated tissues resulting in increased heat conduction. *Tumor* reflects the presence of edema fluid about the wound. *Dolor* occurs from stimulation of nerve nociceptors by the numerous products of the inflammatory cascade and tissue injury. The discharge of pus from the wound interface via the incision completes the natural history of SSI.

2.6.4.2 Determinants of Infection

Despite the fact that every surgical site is contaminated with bacteria by the end of the procedure, few become clinically infected. The interplay of 4 important determinants lead to either uneventful wound healing or SSI: (1) inoculum of bacteria, (2) virulence of bacteria, (3) adjuvant effects of microenvironment, and (4) innate and acquired host defenses.

- **Inoculum of Bacteria**

The variable that has received the greatest amount of attention is the inoculum of bacteria lodged into the wound during the course of the operation (Chetlin and Elliott, 1971). Bacterial contaminants may enter the wound from the air in the OR, or from the instruments or surgeon(s) that come into contact with the wound. Skin bacteria are always present despite the thoroughness of the preparation of the skin. The largest inoculum of bacteria at the surgical site occurs when the operation involves a body structure that ordinarily is heavily colonized by bacteria, such as the bowel. The distal small intestine and the colon have very large concentrations of bacteria with 103 - 104 bacteria/mL of distal small bowel content, 105 - 106 bacteria/mL in the right colon, and 1010 - 1012 bacteria/g of stool in the rectosigmoid colon.

Substantial numbers of bacteria are also present in the stomach of older patients who have hypo- or achlorhydria. Significant concentrations of bacteria are encountered in the biliary tract when patients are over 70 years of age or have obstructive jaundice, common bile duct stones, or acute cholecystitis (Onderdonk *et al*., 1976). Procedures involving the female genital tract will encounter 106 - 107 bacteria/mL. Procedures that enter into the oropharynx, lung, or urinary tract will have significant contaminants depending upon the duration and types of disease that are responsible for the operation. Notably, SSIs are generally the consequence of intraoperative contamination and seldom result from bacterial contamination from distant blood-borne seeding of the wound site during the postoperative period.

- **Virulence of the Bacterial Contaminant**

A second determinant contributing to SSI is the virulence of the bacterial contaminant. The more virulent the bacterial contaminant, the greater the probability of infection. Coagulase-positive staphylococci require a smaller inoculum than the coagulase-negative species. Uncommon but virulent strains of *Clostridium perfringens* or Group A streptococci require only a small inoculum to cause an especially severe necrotizing infection at the surgical site. *Escherichia coli* has endotoxin in its outer cell membrane that gives it a particular virulence. *Bacteroides fragilis* and other *Bacteroides* species are ordinarily organisms of minimal virulence as solitary pathogens, but when combined with other oxygen-consuming organisms, they will result in microbial synergism and cause very significant infection following operations of the colon or female genital tract (Polk and Miles, 1971). While the virulence of the microbe is an important consideration in SSI, it represents the one variable that is intrinsic to the procedural site and the types of bacteria that already colonize the patient and cannot easily be controlled by preventive strategies.

- **The Microenvironment of the Wound**

A third variable that determines infection at the surgical site is the microenvironment of the wound. Adjuvant factors that are products or consequences of the surgical procedure may result in clinical infection by otherwise subinfectious inocula of bacteria.

Hemoglobin at the surgical site is a well-known adjuvant substance. It is generally thought that the release of ferric iron during the degradation of red blood cells stimulates microbial proliferation (Elek and Conen, 1957). Necrotic tissue can act as a haven for contaminants to avoid phagocytic defenses of the host. Foreign bodies, particularly braided silk and other permanent braided suture materials (Nicholas *et al*., 1984), similarly harbor microbes and increase the probability of infection. Dead space within the surgical site also provides a local environment that fosters infection.

- **Integrity of Host Defenses**

The fourth determinant of SSI is the integrity of host defenses. Impaired host defenses can be viewed as innate or acquired. Innate impairment refers to the observation that intrinsic responses in some patients are less effective than in others. Variability is regularly found among all patients in various components of neutrophil function and macrophage mediator production. While innate differences may render some patients vulnerable to SSI and others very resistant, quantitating these differences remains elusive and their potential role in the management of clinical infection is speculative.

By contrast, acquired impairment of host responses is clearly related to increased rates of SSI. Shock and hypoxemia are positively associated with SSI, especially in trauma patients. Transfusion appears to be immunosuppressive (Dellinger *et al*., 1984). Similarly, chronic illnesses, hypoalbuminemia, and malnutrition are significant factors. Hypothermia and hyperglycemia are also recognized as variables that impair the host response, while corticosteroids and other medications may also adversely affect the host and increase SSI rates.

2.6.4.3 The Aggregate Effect

When all 4 determinants are evaluated in the aggregate, it becomes apparent that SSI is a very complex biological process and that determination of the causes of an infection in a specific situation can be problematic.

The complexity of these individual variables also underscores the variety of issues that must be considered in the development of preventive strategies.

2.6.5 Management of surgical site infection

Most SSIs respond to the removal of sutures with drainage of pus if present and, occasionally, there is a need for debridement and open wound care. Many complications of postoperative wounds do not represent infection but exudation of tissue fluid or an early failure to heal, which is common in patients with a high body mass index (BMI).

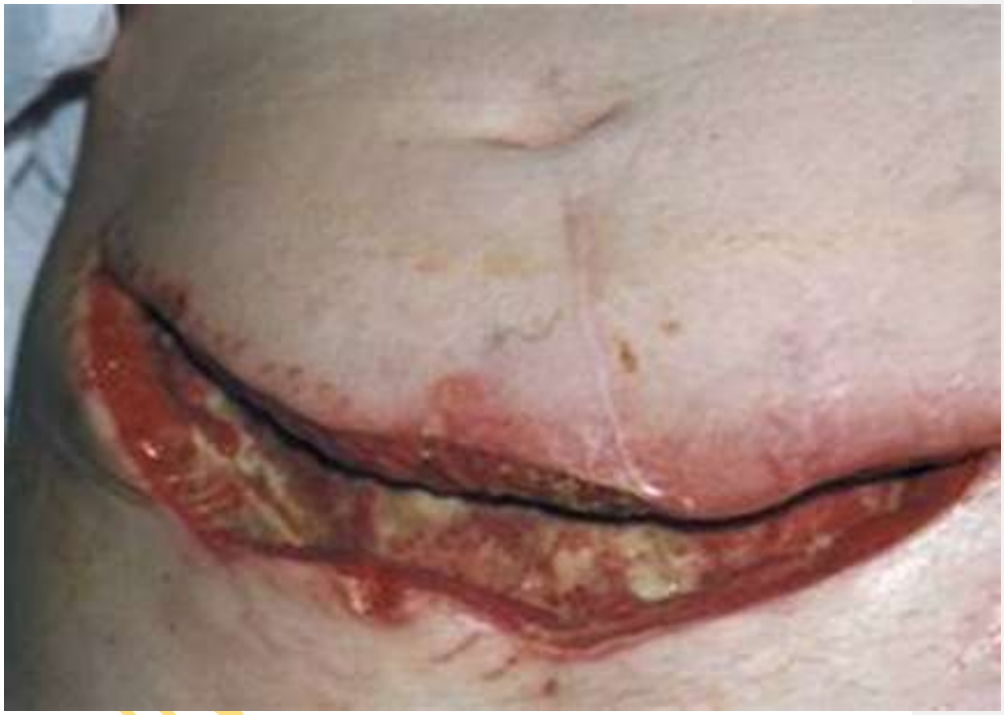

Plate 2.4. Surgical (Wound) site infection

Incomplete sealing of the wound edges can often be managed by using a delayed primary or secondary suture or closure with adhesive tape, but in larger open wounds the granulation tissue must be healthy with a low bioburden of colonising or contaminating organisms if healing is to occur. It is likely that over 15% of postoperative wounds are treated with antibiotics, possibly inappropriately, something which can contribute to the problem of antibiotic resistance.

The appropriate treatment of established SSIs requires careful monitoring and communication between the multidisciplinary postoperative team (surgeons, intensivists, microbiologists, nurses) and the primary care team. If patients are to be returned home early then any SSI needs to be recognised and treated appropriately. Release of pus, debridement and parenteral antibiotics, if indicated, usually requires a return to secondary care. Extensive wound breakdown may need specialist wound management to reduce bacterial burden in the open wound. Wound bed preparation may be required to encourage healing by secondary intention or facilitate secondary suture.

The majority of SSIs become apparent within 30 days of an operative procedure and most often between the 5th and 10th postoperative days. However, where a prosthetic implant is used, SSIs affecting the deeper tissues may occur several months after the operation.Although the outcome measure for SSI used by many studies is based on standard definitions such as those described by the Centers for Disease Control and Prevention (CDC) (Horan *et al*, 1992) or the Surgical Site Infection Surveillance Service(Ridgeway *et al*., 2005), other valid measures based on clinical signs and symptoms have been described such as the Southampton(Bailey*et* al., 1992) and ASEPSIS (Wilson *et al.*, 1986) methods. The CDC definition describes three levels of SSI:

• *superficial incisional*, affecting the skin and subcutaneous tissue. These infections may be indicated by localised (Celsian) signs such as redness, pain, heat or swelling at the site of the insicion or by the drainage of pus.

• *deep incisional*, affecting the fascial and muscle layers. These infections may be indicated by the presence of pus or an abcess, fever with tenderness of the wound, or a separation of the edges of the incision exposing the deeper tissues.

• *organ or space infection*, which involves any part of the anatomy other than the incision that is opened or manipulated during the surgical procedure, for example joint or peritoneum.

In addition, there may also be microbiological evidence of wound infection from cultures obtained aseptically from wound fluid or tissue. However, since skin sites are normally colonized by a variety of organisms, positive wound cultures in the absence of clinical signs are rarely indicative of SSI.

2.6.6 Surveillance for surgical site infection

Surveillance of SSI provides data that can both inform and influence practice to minimise the risk of SSI, as well as communicate more clearly the risks of infection to patients. Surveillance was first recognised as an important tool in reducing rates of infection in the 1980s.The Study on the Efficacy of Nosocomial Infection Control (SENIC) showed that surveillance and infection control programmes that included the collection, analysis and feedback of data on infection rates to surgeons were associated with significant reductions in rates of SSI. Since then, many national surveillance systems have been established and have reported reductions in rates of SSI in association with surveillance, feedback of data to clinicians and benchmarking of rates of SSI.

Consumer demand for information about the performance of healthcare providers has also led to compulsory public reporting of data on HCAIs, including SSIs. In England, reporting of rates of SSI following orthopaedic surgery became compulsory in April 2004 and the other UK countries also have mandatory programmes of SSI surveillance after several types of operative procedure.

National surveillance systems, such as the Surgical Site Infection Surveillance System in England and similar schemes in Wales and Northern Ireland, provide standardised surveillance methods that enable hospitals to benchmark their rates of SSI. Such benchmarking can be a powerful driver for change but requires participating hospitals to use uniform methods of finding and defining cases of SSI that are likely to reliably identify a large proportion of the infections, and a reliable approach to analysing rates of SSI that takes account of variation in risk associated with different procedures and risk factors in the patients undergoing surgery. Most national surveillance systems target surveillance towards defined groups of patients undergoing similar operative procedures, following each case up to identify those that develop an SSI, although the sensitivity of

case-finding will be influenced by the methods employed (Glenister *et al*.,1992).This enables rates of SSI to be calculated using the number of procedures as the denominator. Feedback of rates to individual surgical teams and comparisons with the benchmark rate is essential components of effective surveillance (Haley *et al*., 1985). The risk index developed by the CDC in the USA, which takes account of the underlying illness of the patient, the duration of the operation and the wound classification of the procedure, is commonly used to adjust rates of SSI and improve the validity of comparisons where case-mix may vary over time or between centres (Culver *et al*., 1991).However, comparisons between different surveillance systems is complicated because of variation in both the methods of surveillance and the application and interpretation of case definitions (Wilson *et al*., 2007).

Since some SSIs may take many days to develop, evidence of infection may not become apparent until after the patient has been discharged from hospital. Surveillance focused on detecting SSI during the inpatient stay is thus likely to underestimate the true rate of SSI, a problem that is exacerbated by the increasing trend towards shorter lengths of postoperative hospital stay and day surgery (Mannien *et al*., 2006). Therefore, systems that enable cases of SSI to be identified after discharge from hospital enhance the value of surveillance. However, there are a number of practical difficultiesin reliably identifying SSI in community settings and methods that systematically and accurately identify SSI are required if valid comparisons of rates are to be made (Whitby *et al*., 2002).

CHAPTER THREE

METHODOLOGY

3.1 Study Design

A descriptive cross sectional design comprisingon-site observations, indoor air quality monitoring for particulate matter and microbial flora and questionnaire administration.

3.2 Study Area

The study was carried out in three (3) Operating theatres- comprising a total number of seven (7) operating theatre suites of the University College Hospital situated at Ibadan North Local Government Area of Ibadan, Oyo State, Nigeria.The University College Hospital, Ibadan was established by an act of parliament in November 1952 in response to the need for the training of medical personnel and other healthcare professionals for the country and the West African Sub-Region. The establishment of the Hospital was sequel to a Visitation Panel in 1951 to assess the clinical facilities for the clinical postings of medical students registered for M.B.B.S. degree of the University of London. The visitation panel, led by Dr T.F. Hunt of the University of London rejected the enhanced facilities provided by the Government/Native Authority Hospital at Adeoyo, Ibadan following the establishment of a Faculty of Medicine in the University College, Ibadan (now University of Ibadan) in 1948.

The University College Hospital (UCH) is strategically located in Ibadan, then the largest city in West Africa which is also the seat of the first University in Nigeria. The physical development of the Hospital commenced in 1953 in its present site and was formally commissioned after completion on 20th November 1957. The University College

Hospital, Ibadan was initially commissioned with 500 bed spaces but presently the Hospital has 850 bed spaces and 163 examination couches, The current bed occupancy ranges from 55-60%.

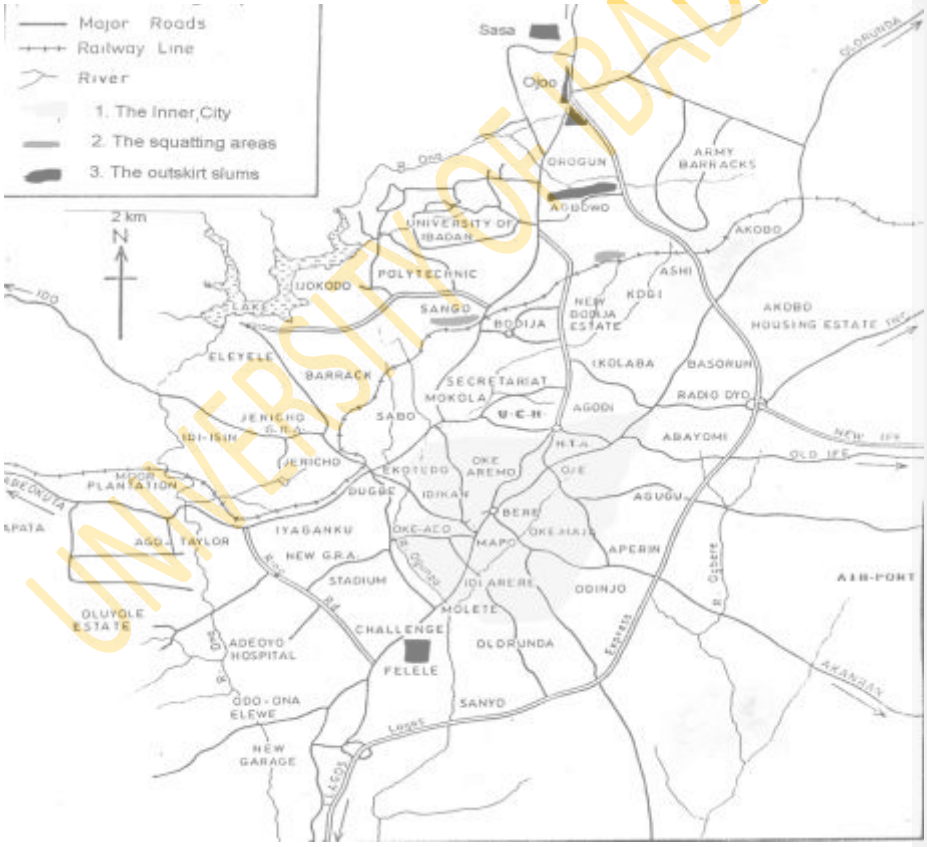

Plate 3a. Map of Ibadan City

Source: Ibadan North Local Government

Plate 3b. University College Hospital, Ibadan; Operating Theatre Complex

Source: University College Hospital, 2013

3.3 Study Population

The study focuses on major active Operating Theatre Units in the surgery department of the University College Hospital, Ibadan consisting of: Main Operating theatre (with 5-Vamed Operating suites) which is located on the second floor of UCH, Gynaecological Operating Theatre (with 1-Operating suite) which is located on the Fourth floor and Emergency Operating Theatre (with 1- Operating suite) which is located on the ground floor. For the purpose of survey, the study population also includes surgical team members (Surgeons, Anaesthetists, and Registered Perioperative Nurses) in the Operating theatre unitsof the hospital facility.

3.4 Eligibility for Inclusion

- Must be, surgeons, anaesthetists, perioperative nurses.
- Must be those that work just within the Operating theatre unit of the hospital facility.
- Must have been employed at least three months before the commencement of the study.
- Must voluntarily agree to participate in the study

3.5 Sample Size Determination

A purposive sampling method wasused to select seven operating theaters where most surgeries are done.

3.6 Method and Instrument for Data Collection

3.6.1 Preliminary Survey

Before embarking on the field work and the collection of data, a preliminary survey of theaters in the hospital was carried out as follows:

- Obtaining the list of Operating theatres in UCH.

- Visiting the selected operating theatres to obtain information about the study participants. Information such as the total number of Operating rooms.
- Environment assessment of the operating theatres.
- Gaining informed consent by explaining to the theatre personnel including porters and contracted-cleaners about the relevance of the work, and the procedures involved step by step.
- Pre-testing the questionnaire to ensure its reliability (this was carried out at Ring Road State Hospital's Operating Theatre).

3.6.2 Data Collection Instruments

The following instruments wereused to obtain information and to answer the stated objectives:

- Observational checklist
- Questionnaire
- Particulate air sampler
- 5:1 Multitester (Temperature, Relative Humidity, light intensity etc)

3.6.2.1 Observational Checklist

An observational checklist was used to assess the physical characteristics of the operating theaters. The investigated characteristics included:

- Location of operating theatres
- Theatre design
- Specific theatre suites
- General hygiene conditions of selected theatre suites (ancillary rooms-induction, scrub-up, lay-up, operating room and disposal).

- Hygiene status of the theatre users
- Ventilation system
- Traffic density
- Population density.
- Infection Control Compliances
- Protective clothing worn by the scrub team
- Linen handling
- Water supply
- Surrounding environment.
- Waste collection, components, storage and disposal (including waste segregation using colour code).

3.6.2.2 Questionnaire

This involved the administration of questionnaire on an interviewer-administered basis. The semi-structured questionnaire was divided into six (6) sections namely:

SECTION A: Socio demographic characteristics

SECTION B: Knowledge of Infection Control Practices

SECTION C: Indoor Air Quality of Operating Rooms

SECTION D: Attitude and Compliance with Specific Guidelines

SECTION E: Commonly used decontaminants and its availability for ORs-environmental hygiene before and after each surgical case

SECTION F: Quality of ventilation

3.7.1 Validity and Reliability of Instrument

The questionnaire was pre-tested at Ring Road State Hospital, Ibadan. During the pretest the questionnaire were administered to 10% of the sample size i.e. 294 respondents. After the pretest, the appropriate modifications based on the pretest outcome, was effected on the instruments. The Cronbach's Alpha method was used to determine the reliability of the

questionnaire. An Alpha coefficient of 0.5 and above is indicative of the reliability of the questionnaire.

3.7.2 Indoor Air Quality Monitoring

Temperature (ºC) and relative humidity (%) of the indoor and outdoor environments of the operating theaters were measured using a multi-tester N21FR (Fig 3.1.1).

A multi-tester N21FR a "5-in-1 Environmental meter" was used to collect data on the temperature and relative humidity. The multi-function environment mater has been designed to combine the functions of sound meter, light meter, humidity meter, thermometer and electrical multimeter into one easy to use instrument with scores of practical application in commercial and non-commercial schools, offices, factories, homes etc. temperature was measured in degrees Celsius (^{0}C)and humidity in (%). Measurements were taken indoor and outdoor for the purpose of comparison. Values obtained were compared with Association of PeriOperative Registered Nurses (AORN) and World Health Organization guideline limit for temperature and relative humidity of 18^{0}C and 50%.

Plate 3.1: A 5-in-1 Multi-tester

3.8.0 Determination of particulate matter ($PM_{2.0\ \&\ 10}$) concentration

Themet-one particle counter (Figure 3.2) is a small, easy to use and completely portable hand-held particle that can provide fast and accurate measurement of particulate contamination in particle per cubic foot. The met-one particle counter was used to measure the number of particles in the houses. The sampler takes a total of 10 samples. After all 10 samples are taken the counter averages the results of the 10 samples to a more accurate result. A conversion factor from the Air Quality Sensor Network for Philadelphia –*Data validation*- was used to estimate the **PM_{10}**. Measurements were taken indoor and outdoor. The ambient and indoor measurements were determined at two periods of the day "Before Surgery" between 6am-7am and "After Surgery" 2pm-5pm. Measurements were taken three times a week for 12weeks spanning the rainy season.

*PM Concentration ($\mu g/m^3$) = Number of Particles × 3531.5 × particle mass**

*The mass of a particle in the PM_{10}channel is 1.21E-4 µg

Plate 3.2 Met-one particle counter

Plate. 3.3: Showing indoor air quality assessment before surgery

Plate 3.4: Measuring the Operating theatre Temperature, relative humidity and Particulate matter

3.9 Media Preparations

3.9.1 Nutrient Agar

A 12.6g of nutrient agar powder was weighed and suspended in 450ml cold demineralised water contained in 800ml beaker.Mixture was stirred gently on a hotplate-stirrer and then heated with vigorous stirring and boiled 15 minutes.The beaker was then removed from the stirrer hotplate using a magnet, and covered with aluminum foil.Mixture wasallowed to cool to 50°C and poured into clean Petri dishes.

Plate 3.5: Media Preparation procedure

3.9.2 Potato dextrose Agar

A 39g of potato dextrose agar powder was weighed and suspended in 1litre of purified water. The mixture was then heated with frequent agitation and boiled for 1 minute to completely dissolve the medium. Mixture was then autoclaved at 121^{o} C for 15minutes. Prepared agar was then allowed to cool and poured into sterile Petri dishes.

A portable autoclave (Fig 3.6) is piece of equipment that is usually used to sterilize objects and supplies by subjecting them to high pressure saturated steam at 121 °C or more, typically for 15 to 20 minutes.

Plate 3.6: A portable Laboratory autoclave

3.9.3 Transportation and preservation of plates

During sample transport and storage all procedures were followed to ensure that inoculated samples are not significantly altered in condition and are in a state fit for analysis at the laboratory. The following conditions were considered to avoid contamination of samples due to container cross-contamination, packaging material or chilling products and degradation due to lack of appropriate preservation, inappropriate storage conditions, excessive storage times and sample cross-contamination.

- ensure samples were appropriately packed to avoid breakage and cross-contamination
- reduce sample degradation through appropriate preservation
- ensure time between sampling and analyzing does not exceed threshold time
- sample containers should be sealed, carefully packed with an appropriate
- packing material, chilled or frozen (as required) and transported in an appropriate cooler (esky) containing ice blocks and at a temperature of between 2°C and 100°C.
- Proper aseptic conditions was ensured at all time, plates were covered with paraffin immediately after sampling.

3.10 Sample Preservation and Incubation

Microbial samples collected were arranged in an ice bath and transferred to the laboratory within 24hours before incubation. The duration and temperature of incubation for bacteria and fungi was 2 days at 37°C and 4 to 7 days at 25°C respectively. Microbiology incubators (Fig 3.7) are designed to promote the growth of microorganisms by maintaining a constant temperature within a narrow range. Water is a major constituent of both broth and agar media. However, when media are incubated at temperatures used for bacterial cultivation, a large portion of water content can be lost through evaporation.

Plate 3.7: A microbiological Incubator

3.11 Microbial Identification

Bacterial identification was based primarily on morphology, Gram staining, growth characteristic and culture characteristics. Some commonly found bacteria were identified at the genus level using the national standard method.

Light microscope was used to determine the colonial features and the morphological structures of the fungi. The determination of the morphological structures of fungi was carried out on material mounted in lactophenol. Fungi isolated were identified to genus level based on micromorphology.

3.11.1 Staining

A gram staining technique that consists of four components**:** a primary stain (Crystal violet, methyl violet or Gentian violet)**,** mordant (Gram's Iodine)**,** decolourizer (ethyl alcohol, acetone or 1:1 ethanol-acetone mixture)**,** counter stain (Dilute carbol fuchsin, safranin or neutral red) was employed for bacterial staining into gram positive and gram negative bacteria. On the other hand, fungi colonies were classified based on spore morphology or colony morphology.

3.11.2 Biochemical Test

Few biochemical tests were applied to each bacteria colony that was impacted on blood agar. Each culture was isolated onto 5% sheep blood agar and incubated for 1 day at 37°C. Catalase, oxidase and coagulase test protocols were then applied to each bacteria culture.

3.12 Data Management

3.12.1 Data Collection Process

The following was put in place to ensure proper and effective management of data. Criteria were stated in the selection of research assistants and the criteria were followed diligently. The research assistants were trained and adequately remunerated. The questionnaires were serially numbered for control and recall purposes. Data collected were checked for completeness and accuracy. Data were imputed into the computer using the SPSS software version 15. The data were sorted, edited and coded manually. Frequency counts was then run to detect missing cases while the data undergo cleaning.

3.12.2 Statistical Analysis

All result from the field were coded, compiled and properly recorded in a prepared form. This was done on a daily basis to forestall the occurrence of missing data. At the end of each working day, the data collected were checked for completeness and stored.

- Descriptive statistics (proportion, means, standard deviation, bar graphs and frequency tables), were used to analyse and summarize the data.
- Inferential statistics Chi-square (X^2) was used to test for association between qualitative variables such as knowledge, attitude among respondents. Odds ratios and their 95% confidence intervals were also computed.
- T-test was used to compare the differences in means between cases and controls. In addition, logistic regression analysis was carried out to test the level of significance in the variables.
- Correlation analyses were performed to determine the relationships between environmental parameters and culturable bacteria and fungal counts isolated

CHAPTER FOUR

RESULTS

4.1 General Conditions of Theatres

Tables 4.1 show the general conditions of UCH operating theatres. Personnel compliance to operational guidelines was found to be inadequate with respect to the use of facemasks and theater scrubs which is not in line with the standard of practice of asepsis in an ideal operating theatre complex. Building characteristics was discovered to be fairly adequate (see plate 4.1).

Table 4.1 and Plate 4.2 shows waste management in the theaters. Solid waste management was observed to be fairly adequate with the presence of waste bins and disposal room. Ventilation was inadequate due to the presence of non-functional dusty vents in such a sensitive environment. Waste water management was observed to be adequate with adequate water supply.

Plate 4.3 shows the condition of the theaters before and after operation. It was discovered that the condition of the theater environment after operation was inadequate. Fig 4.1 shows the trend in the number of cases of SSI over a period of 12 months at the University College Hospital. The number of cases of SSI was high from January to February with a continuous decrease for the rest of the month. The average number of cases of SSI for 2013 was 13 cases.

Table 4.1: Summary of Characteristics of Theaters

Variables	T1	T2	T3	T4	T5	T6	T7
Personnel compliance to guideline	-	-	-	-	-	-	-
Building status	+	+	+	+	+	+	+
Sanitary condition	-	-	-	+	-	-	-
Waste management	+	+	+	+	+	+	+
Ventilation	-	-	-	+	-	-	-
Water supply	+	+	+	+	+	+	+
Waste Water Management	++	++	++	++	++	++	++

Indicator:

Ventilation

- 1 window = -
- 2 windows = +
- >2 windows = ++

Water Supply

- Is water running? = +
- Facilities in place = +
- Accessibility = +

Sanitary Condition

- Presence of flies around facilities = -
- Water spills = +
- Dry and clean = ++

Building Status

- Presence of cracks on the walls/floor = -
- Not Cemented/Plastered = -
- Damp/moist walls with algal growth = -
- Water damage = -

Solid Waste Management

- Absence of waste bin = -
- Flies around waste bin = -
- Waste bin overflow = -
- Presence of disposal room = +
- Waste bin covered = +

Compliance to operating guideline

- Use of face mask during operation = -
- Presence of theater scrubs = -
- Aseptic procedures= -

Key: ++ = Very adequate + = Fairly Adequate
- = Inadequate

(A)

(B)

Plate 4.1: Condition of theaters in the University of Ibadan(A: Showing the unrestricted zone and B: showing (OR) the restricted zone before surgery

(A)

(B)

Plate 4.2: Waste management practices (A:showing Cleaning materials; B: showing the surgical wastes collection bin without a waste segregation).

(A)

(B)

Plate 4.3: Operating theater environment Before (A) and After (B) operation

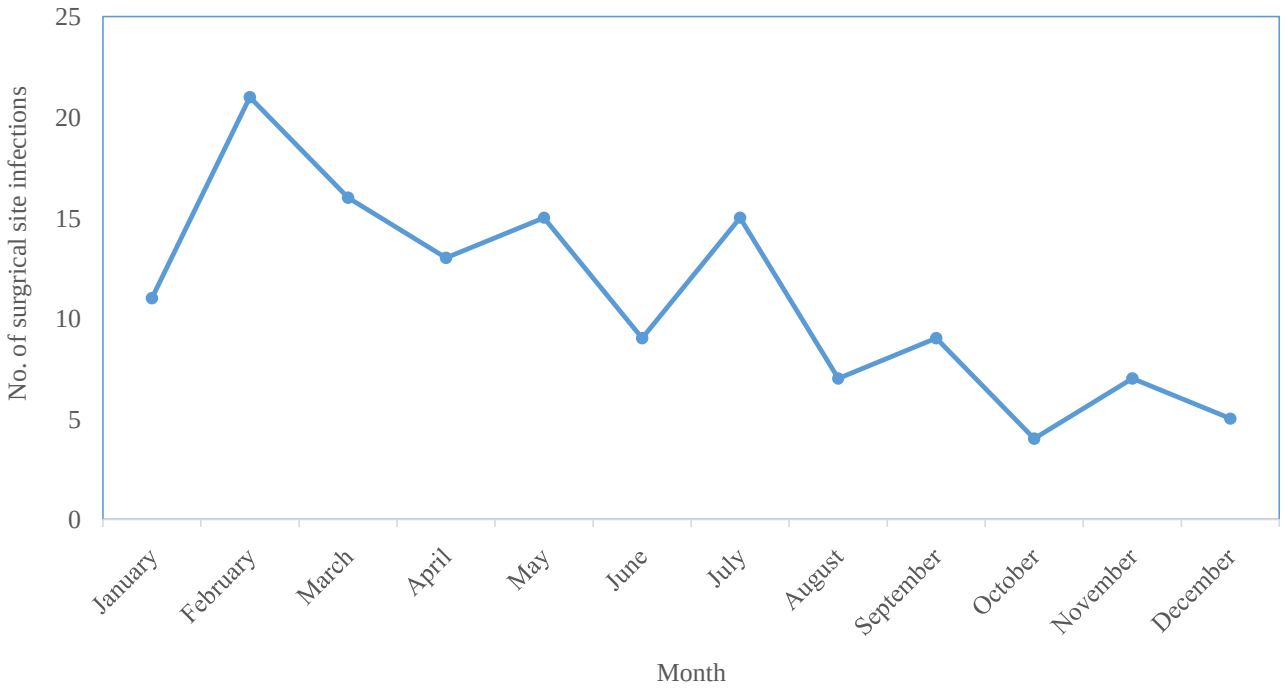

Fig 4.1: No. of cases of SSI at the University College Hospital for the year 2013

Source: Control of Hospital Infection Sub-committee Laboratory Surveillance- 2013 Report, University College Hospital

4.2 Meteorological Characteristics of indoor and outdoor environments of Operating Theatres

Table 4.2–4.6 highlights the mean, minimum (min) and maximum (max) meteorological characteristics of the indoor and outdoor environment of the selected operating theaters before and after operations. Mean indoor temperature and relative humidity (RH) readings after operation were of 31.3 ± 2.1°C and 74.3 ± 6.35 respectively as compared to 28.1 ± 2.0°C and 59.7 ± 4.8% before operations ($p<0.05$). Similarly, mean outdoor temperature and relative humidity (RH) readings after operation was 30.3 ± 1.4°C and 72.5 ± 6.8% respectively as compared to 27.4 ± 1.4°C and 56.7 ± 4.1% before operation ($p<0.05$). The mean indoor and outdoor PM after operation 2560.1 ± 631.5ppm and 2943.1 ± 701.6ppm was higher than readings obtained before operation (1862.9 ± 613.5ppm and 2047.6 ± 613.5ppm) respectively. T7 recorded the highest mean temperature and RH readings (33.08 ± 1.33°C and 78.54 ± 5.08%) respectively when compared to other selected operating theaters.

Fig 4.2 – 4.3 shows that the Emergency operating theatre (T7) recorded the highest temperature (33.08 ± 2.2°C), RH (78.84 ± 6.72%), PM10 (2873 ± 713.34ppm), TBC (144.8 ± 26.86cfu/m3) and TFC (4.61 ± 2.14cfu/m3) readings when compared to the other theatres after operations.Fig 4.4 – 4.6 shows the trend in mean indoor temperature, RH and PM across the weeks of sampling compared to the AORN standard. Mean indoor temperature was higher than the AORN standard across the weeks of sampling. Similarly, mean RH and PM readings were higher than the standard across the weeks.

Table 4.2 Indoor values of Temperature (ºC), RH (%) and PM (ppm) in the Operating Theatres

Sampling site	Parameter	Before			After		
		Mean ± SD	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**
T1	Temperature	26.68±1.04	25.0	28.0	30.99±2.21	28.4	34.5
	RH	57.45±1.29	55.8	61.3	74.37±4.78	68.0	84.0
	PM	2084.78±497.24	1423.0	2643.0	2636.28±524.62	1765.0	3324.0
T2	Temperature	27.31±0.80	25.0	28.6	31.16±1.97	28.0	33.8
	RH	57.68±2.33	55.0	67.2	74.44±5.74	57.0	84.0
	PM	2069.58±487.73	1423.0	2643.0	2671.77±578.62	1765.0	4232.0
T3	Temperature	28.44±1.89	26.0	31.8	31.28±2.0	28.0	33.5
	RH	57.45±2.06	55.0	67.2	74.89±4.85	63.0	84.0
	PM	1870.22±547.26	967.0	2643.0	2718.58±514.71	1765.0	3564.0
T4	Temperature	30.23±1.63	27.0	33.6	31.51±1.97	28.0	33.80
	RH	64.09±5.08	49.0	73.40	75.75±4.92	68.0	84.0
	PM	2221.75±514.64	1125.0	2931.0	2792.25±516.84	1765.0	3522.0
T5	Temperature	26.79±1.82	25.0	35.8	31.56±1.88	28.0	34.50
	RH	61.58±4.58	56.8	68.0	75.60±4.48	68.0	84.0
	PM	1339.42±493.90	782.0	2643.0	2220.06±614.17	1134.0	3432.0
T6	Temperature	27.36±0.99	25.4	28.5	29.81±1.78	27.5	33.5
	RH	57.34±5.66	43.0	67.2	66.41±6.57	55.0	84.0
	PM	1280.06±626.60	356.0	2643.0	2008.92±628.00	1045.0	3546.0
	Temperature	30.17±1.61	26.0	33.2	33.08±1.33	28.9	34.6
	RH	62.24±5.19	56.0	72.0	78.84±5.077	73.0	88.0

T7	PM	2174.78±491.59	1423.0	2985.0	2872.92±560.32	1765.0	3875.0

Table 4.3 Outdoor values of Temperature (ºC) and RH (%) in the Operating Theatres

Sampling site	Parameter	Before			After		
		Mean ±SD	Min	Max	Mean ±SD	Min	Max
T1	Temperature	27.78±1.05	26.0	29.0	30.22±1.44	29.0	33.0
	RH	56.14±2.05	52.0	59.30	72.42±4.84	65.4	81.0
	PM	2137.11±625.15	1123.0	2934.0	2892.58±715.79	2132.0	3848.0
T2	Temperature	27.86±1.01	26.0	29.0	30.43±1.49	29.0	33.0
	RH	56.33±2.20	52.0	60.0	72.55±5.11	64.0	81.0
	PM	2120.56±612.70	1123.0	2934.0	2896.56±720.16	2132.0	3967.0
T3	Temperature	27.69±1.06	26.0	29.0	30.29±1.41	29.0	33.0
	RH	56.14±2.05	52.0	59.3	72.42±4.83	65.4	81.0
	PM	2125.94±625.08	1123.0	2934.0	3044.00±682.77	2132.0	3877.0
T4	Temperature	28.11±1.99	24.0	31.5	30.76±1.54	29.0	33.2
	RH	61.32±2.44	56..0	66.2	70.84±12.88	66.30	81.4
	PM	1947.53±551.89	1032.0	2934.0	2892.58±715.79	2132.0	3848.0
T5	Temperature	27.98±1.18	26.0	30.7	30.44±1.45	29.0	33.0
	RH	55.84±2.52	47.0	59.3	73.76±4.60	66.8	82.2
	PM	1822.25±559.03	879.0	2934.0	3087.81±674.32	2132.0	3848.0
T6	Temperature	26.45±1.21	24.70	29.0	30.10±1.34	29.0	33.0
	RH	51.62±4.94	42.0	59.3	70.68±5.47	61.6	81.0
	PM	1955.19±656.50	879.0	2934.0	2892.58±715.79	2132.0	3848.0
	Temperature	27.97±1.22	26.0	30.8	30.21±1.40	29.0	33.0

T7	RH	59.61±3.71	52.0	68.0	74.53±5.12	66.8	86.0
	PM	2224.36±608.62	1123.0	3243.0	2895.44±713.19	2132.0	3848.0

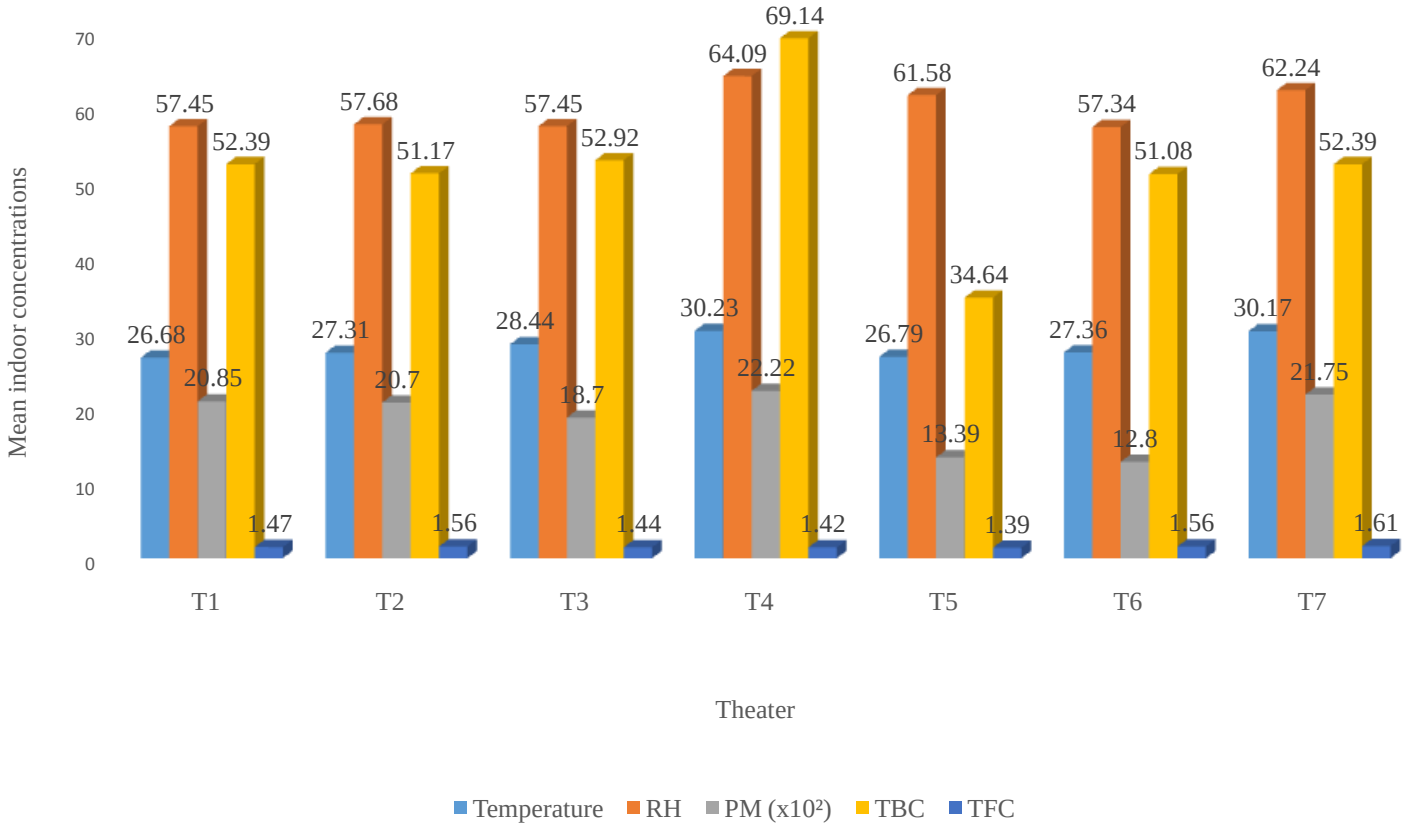

Fig 4.2: Mean indoor concentration of parameters measured across the theaters before operations

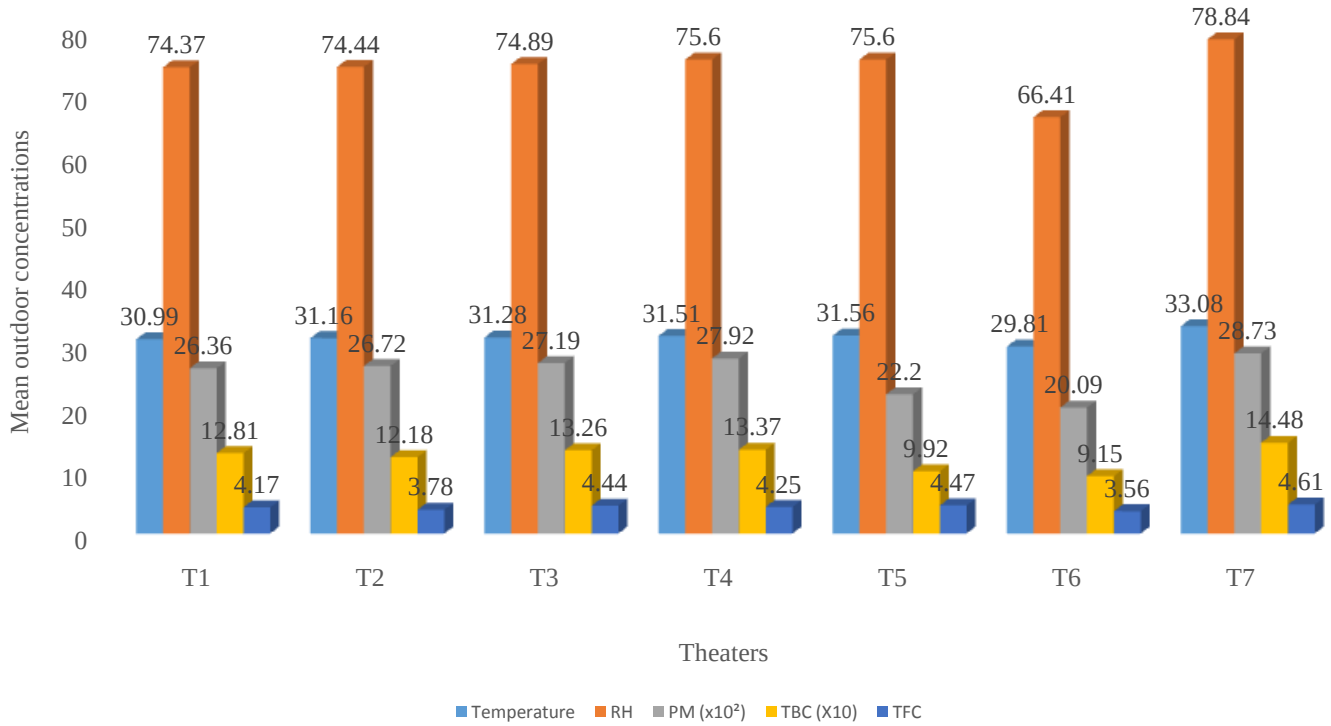

Fig 4.3: Mean indoor concentration of parameters measured across the theaters after operations

Table 4.4: Cumulative Mean indoor Air Temperature (ºC) of All Operating Theaters Before and After Operation

Site	Category	N (%)	Indoor Air Temperature (ºC)				p-value
			Mean	Standard Deviation	Min	Max	
Indoor	Before	252 (100%)	28.1	2.0	26.0	29.0	0.00
	After	252 (100%)	31.3	2.1	29.0	33.0	
Outdoor	Before	252 (100%)	27.4	1.4	26.0	28.2	0.00
	After	252 (100%)	30.3	1.4	29.0	32.6	

Table 4.5: Cumulative Mean indoor Air Relative Humidity (%) of All Operating Theaters Before and After Operation

Site	Category	N (%)	Indoor Air Relative Humidity (%)				p-value
			Mean	Standard Deviation	Minimum	Maximum	
Indoor	Before	252 (100%)	59.7	4.8	52.0	59.3	0.00
	After	252 (100%)	74.3	6.3	65.4	81.0	
Outdoor	Before	252 (100%)	56.7	4.1	51.4	58.5	0.00
	After	252 (100%)	72.5	6.8	65.3	80.9	

Table 4.6: Cumulative Mean indoor and outdoor Air Particulate Matter (ppm) of All Operating Theaters Before and After Operation

Site	Category	N (%)	Indoor Air Temperature (°C)				p-value
			Mean	Standard Deviation	Minimum	Maximum	
Indoor	Before	252 (100%)	1862.9	634.4	1123.0	2934.0	0.00
	After	252 (100%)	2560.1	631.5	2132.0	3967.0	
Outdoor	Before	252 (100%)	2047.6	613.5	1310.0	3123.0	0.00
	After	252 (100%)	2943.1	701.6	2216.0	4013.2	

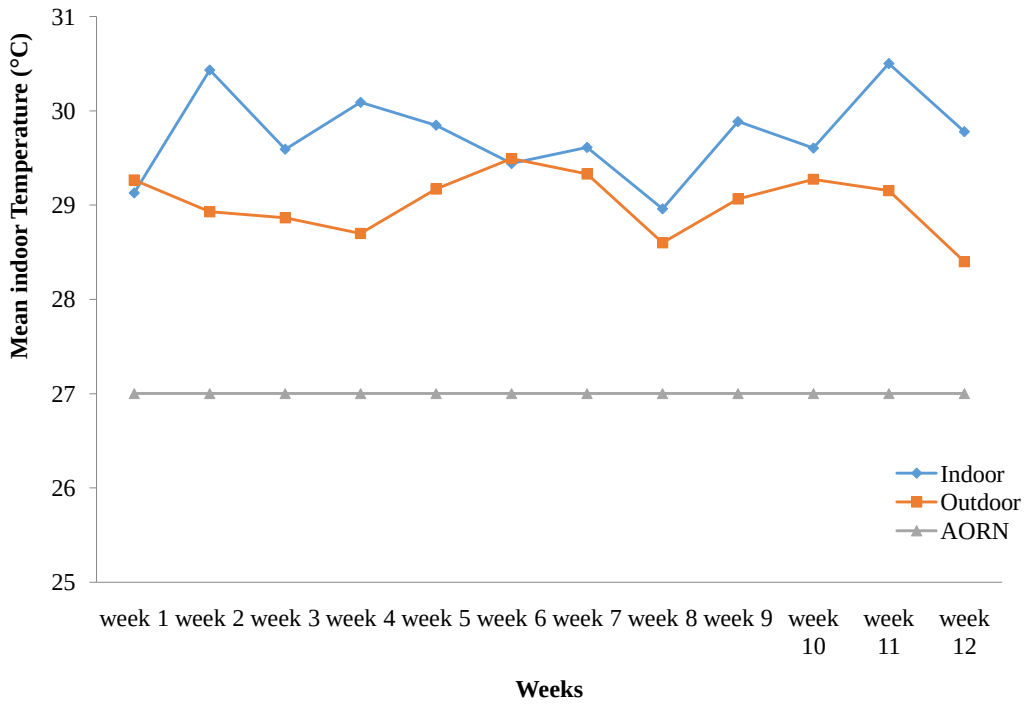

Fig 4.4: Cumulative Mean indoor and outdoor Temperature readings across the weeks for all Operating Theaters

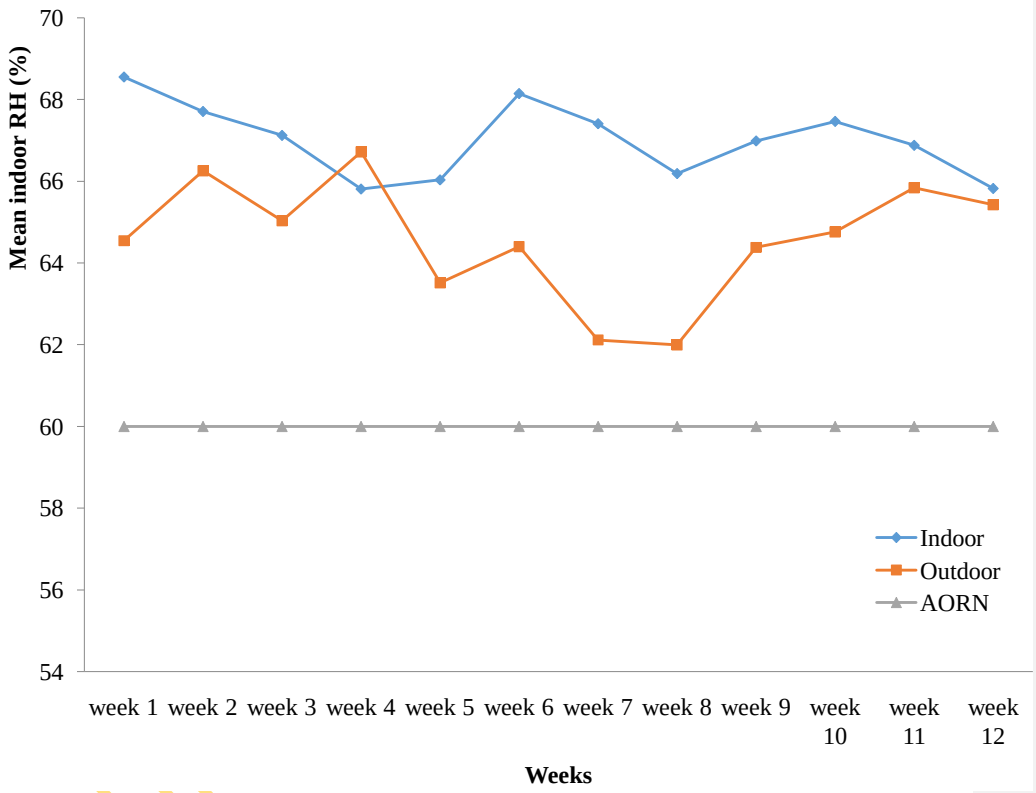

Fig 4.5: Cumulative Mean indoor and outdoor Relative humidity readings across the weeks for all Operating Theaters

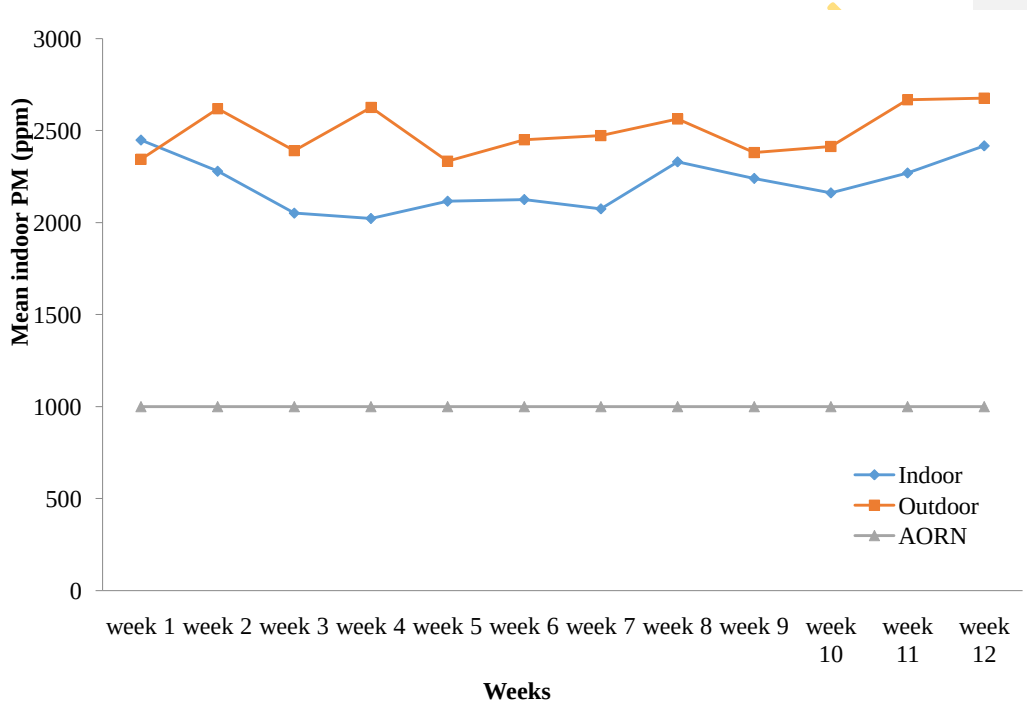

Fig 4.6: Cumulative Mean indoor and outdoor Particulate matter (PM) reading across the weeks for all Operating Theaters

4.10 Indoor and Outdoor Airborne Microbial Burden among cases and controls

Tables 4.7 – 4.12 show the mean ($\chi \pm$ SD), minimum (min) and maximum (max) values of Total Bacteria Count (TBC) and Total Fungal Count (TFC) (cfu/m^3) before and after operations in the indoor and outdoor environment of the selected operating theaters. Fig 4.7 – 4.10 illustrates the cumulative mean TBC and TFC for indoor and outdoor measurements of all theaters before and after operation as compared to American Industrial Hygiene Association (AIHA) guideline. Mean Indoor total bacterial count after operations ($1.217x10^2$cfu/m^3) and before operations ($0.51x10^2$cfu/m^3) were significantly different ($p<0.05$). Similarly, there was a significant difference in the mean indoor fungal count after operations ($0.126x10^2$cfu/m^3) and before operations ($0.046x10^2$cfu/m^3). T7 recorded the highest mean indoor bacterial and fungal count of $1.448x10^2$cfu/m^3 and $0.139x10^2$cfu/m^3 when compared to other operating theaters respectively.

Concurrent outdoor air monitoring in the vicinity of the residential apartment made it possible to estimate the I/O (indoor-to-outdoor ratio) of TBC and TFC for investigated operating theaters before and after operations as compared to standard (see Fig 4.11 and 4.12). The I/O TBC ratio before operations was found to be 1.04 as compared to 1.75 after operations. The I/O total fungal count before operations (3.1) was found to be similar to the value recorded after operation (3.6).

Table 4.7: Mean, Minimum (min) and maximum (max) Indoor TBC (CFU/m³) and the most frequently observed bacteria species isolated from selected operating theaters before and after operation

Sampling Location	Samp. Site	Before				After			
		Mean±SD	Min	Max	Most Frequently Observed Bacteria species	Mean ±SD	Min	Max	Most Frequently Observed Bacteria species
Indoor	T1	52.39(6.35)	78.0	163.0	*Micrococcus spp., Bacillus spp., Staphylococcus spp.*	128.14±24.64	45.0	66.0	*Bacillus spp., Staphylococcus spp, Micrococcus spp., Pseudomonas spp.*
	T2	51.17±7.82	78.0	159.0	*Bacillus spp., Staphylococcus spp., Pseudomonas spp., Micrococcus*	121.75±22.67	36.0	67.0	*Bacillus spp., Staphylococcus spp., Micrococcus spp., Flavobacterium spp.*
	T3	52.92±6.70	87.0	163.0	*Micrococcus spp., Bacillus spp., Staphylococcus spp*	132.56±18.78	45.0	66.0	*Bacillus spp., Staphylococcus spp., Pseudomonas spp., Micrococcus.*
	T4	69.14±16.32	87.0	176.0	*Bacillus spp., Staphylococcus spp., Pseudomonas spp., Micrococcus*	133.72±21.79	25.0	95.0	*Bacillus spp., Staphylococcus spp., Micrococcus spp., Flavobacterium spp*
	T5	34.64±8.67	59.0	138.0	*Bacillus spp., Staphylococcus spp., Pseudomonas spp., Micrococcus*	99.19±18.31	22.0	58.0	*Bacillus spp., Staphylococcus spp., Micrococcus spp., Pseudomonas spp.,*
	T6	51.08±8.10	49.0	163.0	*Micrococcus spp., Bacillus spp., Staphylococcus spp*	91.47±41.46	32.0	66.0	*Bacillus spp., Staphylococcus spp., Micrococcus spp., Pseudomonas spp.,*
	T7	52.39±6.35	78.0	231.0	*Bacillus spp., Staphylococcus*	144.75±26.86	45.0	66.0	*Bacillus spp., Staphylococcus spp., Pseudomonas spp.,*

					spp., Pseudomonas spp., Micrococcus				*Micrococcus*

Table 4.8: Mean, Minimum (min) and maximum (max) Outdoor TBC (CFU/m³) and the most frequently observed bacteria species isolated from selected operating theaters before and after operation

Sampling Location	Samp. Site	Before				After			
		Mean±SD	**Min**	**Max**	**Most Frequently Observed Bacteria species**	**Mean ±SD**	**Min**	**Max**	**Most Frequently Observed Bacteria species**
Outdoor	**T1**	26.17±6.70	87.0	131.0	*Staphylococcus spp., Bacillus spp., Micrococcus spp., Pseudomonas spp.,*	118.08±9.13	19.0	44.0	*Staphylococcus spp., Bacillus spp., Micrococcus spp., Pseudomonas spp.*
	T2	25.69±6.40	19.0	44.0	*Staphylococcus spp., Micrococcus spp., Pseudomonas spp.,*	116.89±11.15	78.0	131.0	*Staphylococcus spp., Micrococcus spp., Pseudomonas spp., Bacillus spp.*
	T3	26.14±6.21	16.0	38.0	*Staphylococcus spp., Bacillus spp., Micrococcus spp., Pseudomonas spp.,*	118.08±9.13	87.0	131.0	*Staphylococcus spp., Bacillus spp., Micrococcus spp., Pseudomonas spp.,*
	T4	42.11±6.21	14.0	88.0	*Staphylococcus spp., Micrococcus spp., Pseudomonas spp., Bacillus spp.*	118.08±9.13	87.0	131.0	*Staphylococcus spp., Micrococcus spp., Pseudomonas spp., Bacillus spp.*
	T5	27.36±7.09	17.0	54.0	*Staphylococcus spp., Bacillus spp., Micrococcus spp., Pseudomonas spp.*	110.08±17.39	59.0	131.0	*Staphylococcus spp., Micrococcus spp., Pseudomonas spp., Bacillus spp.*
	T6	28.14±7.46	19.0	45.0	*Staphylococcus spp., Micrococcus spp., Pseudomonas spp., Bacillus spp.*	118.08±9.13	87.0	131.0	*Staphylococcus spp., Bacillus spp., Micrococcus spp., Pseudomonas spp.,*

	T7	28.97±7.79	19.0	45.0	*Staphylococcus spp., Bacillus spp., Micrococcus spp., Pseudomonas spp.*	118.36±9.46	87.0	134.0	*Staphylococcus spp., Micrococcus spp., Pseudomonas spp., Bacillus spp.*

Table 4.9: Mean, Minimum (min) and maximum (max) Indoor TFC (CFU/m³) and the most frequently observed fungi species isolated from selected operating theaters before and after operation

Sampling Location	Samp. Site	Before				After			
		Mean ±SD	**Min**	**Max**	**Most Frequently Observed Fungal species**	**Mean ±SD**	**Min**	**Max**	**Most Frequently Observed Fungal species**
Indoor	**T1**	3.89±1.28	2.0	8.0	*Penicillium spp., Aspergillus spp., Candida spp., Cladosporium spp., Fusarium spp.*	12.08±2.68	5.0	16.0	*Aspergillus spp., Penicillium spp.,Cladosporium spp., Fusarium spp., Mucor spp.*
	T2	4.08±1.87	1.0	10.0	*Penicillium spp., Aspergillus spp., Fusarium spp., Candida spp., Cladosporium spp., Mucor spp.*	12.56±3.45	5.0	24.0	*Penicillium spp., Aspergillus spp., Cladosporium spp., Candida spp., Mucor spp.*
	T3	4.28±2.25	1.0	11.0	*Candida spp., Aspergillus spp., Penicillium spp., Cladosporium spp., Geotrichum spp., Mucor spp., Rhizopus spp.*	13.14±3.54	5.0	23.0	*Penicillium spp., Aspergillus spp., Candida spp., Cladosporium spp., Mucor spp. Fusarium spp., Rhizopus spp.*
	T4	7.67±2.24	5.0	17.0	*Penicillium spp., Aspergillus spp., Candida spp., Cladosporium spp., Fusarium spp., Neurospora spp.*	13.82±2.79	9.0	22.0	*Aspergillus spp., Candida spp., Penicillium spp., Fusarium spp., Cladosporium spp.*
	T5	3.97±1.86	1.0	11.0	*Aspergillus spp., Penicillium spp., Fusarium spp., Cladosporium spp.*	12.61±3.64	2.0	20.0	*Aspergillus spp., Penicillium spp., Fusarium spp., Cladosporium spp.*
	T6	3.50±2.14	1.0	9.0	*Aspergillus spp., Penicillium*	7.91±3.81	3.0	16.0	*Aspergillus spp., Penicillium*

					spp., Fusarium spp., Cladosporium spp., Candida spp., Neurospora spp				*spp., Fusarium spp., Cladosporium spp., Candida spp.,*
	T7	4.78±2.13	2.0	11.0	*Aspergillus spp., Penicillium spp., Fusarium spp., Cladosporium*	13.86±4.30	8.0	25.0	*Aspergillus spp., Penicillium spp., Fusarium spp., Cladosporium spp.*

Table 4.10: Mean, Minimum (min) and maximum (max) Outdoor TFC (CFU/m³) and the most frequently observed fungi species isolated from selected operating theaters before and after operation

Sampling Location	**Samp. Site**	**Before**				**After**			
		Mean ±SD	**Min**	**Max**	**Most Frequently Observed Fungal species**	**Mean ±SD**	**Min**	**Max**	**Most Frequently Observed Fungal species**
Outdoor	**T1**	1.47±0.77	1.0	4.0	*Penicillium spp., Aspergillus spp., Candida spp., Cladosporium spp., Fusarium spp., Neurospora spp.*	4.17±1.93	1.0	9.0	*Aspergillus spp., Penicillium spp.,Cladosporium spp., Fusarium spp., Mucor spp.*
	T2	1.56±0.81	1.0	4.0	*Aspergillus spp., Penicillium spp., Fusarium spp., Cladosporium spp.*	3.78±1.76	2.0	9.0	*Penicillium spp., Aspergillus spp., Cladosporium spp., Candida spp., Mucor spp.*
	T3	1.44±0.84	1.0	4.0	*Aspergillus spp., Penicillium spp., Fusarium spp., Cladosporium spp., Candida spp., Neurospora spp*	4.44±1.98	2.0	9.0	*Penicillium spp., Aspergillus spp., Candida spp., Cladosporium spp., Mucor spp. Fusarium spp., Rhizopus spp.*
	T4	1.42±0.73	1.0	4.0	*Penicillium spp., Aspergillus spp., Candida spp., Cladosporium spp., Fusarium spp., Neurospora spp.*	4.25±1.86	2.0	9.0	*Aspergillus spp., Candida spp., Penicillium spp., Fusarium spp., Cladosporium spp.*
	T5	1.39±0.73	1.0	4.0	*Aspergillus spp., Penicillium spp., Fusarium spp., Cladosporium spp.*	4.47±2.31	2.0	9.0	*Aspergillus spp., Penicillium spp., Fusarium spp., Cladosporium spp.*

	T6	1.56±0.94	1.0	4.0	*Aspergillus spp., Penicillium spp., Fusarium spp., Cladosporium spp., Candida spp., Neurospora spp*	3.56±1.36	2.0	8.0	*Aspergillus spp., Penicillium spp., Fusarium spp., Cladosporium spp., Candida spp.,*
	T7	1.61±1.02	1.0	4.0	*Penicillium spp., Aspergillus spp., Candida spp., Cladosporium spp., Fusarium spp., Neurospora spp.*	4.61±2.14	2.0	9.0	*Aspergillus spp., Penicillium spp., Fusarium spp., Cladosporium spp.*

Table 4.11: Cumulative Mean indoor and Outdoor Air TBC (cfu/m3) of All Operating Theaters Before and After Operation

Site	Category	N (%)	Air Temperature (ºC)				p-value
			Mean	Standard Deviation	Minimum	Maximum	
Indoor	Before	252 (100%)	52.0	13.0	47.0	62.0	0.00
	After	252 (100%)	121.7	31.3	81.5	123.0	
Outdoor	Before	252 (100%)	29.2	11.5	18.2	38.4	0.00
	After	252 (100%)	116.8	11.2	76.5	118.5	

Table 4.12: Mean indoor and Outdoor Air TFC (cfu/m^3) of Operating Theaters Before and After Operation

Site	Category	N (%)	Air TFC (cfu/m^3)				p-value
			Mean	Standard Deviation	Minimum	Maximum	
Indoor	Before	252 (100%)	4.6	2.3	2.0	5.2	0.00
	After	252 (100%)	12.6	4.1	6.3	14.4	
Outdoor	Before	252 (100%)	1.5	0.8	1.0	2.0	0.00
	After	252 (100%)	4.2	1.9	2.2	6.8	

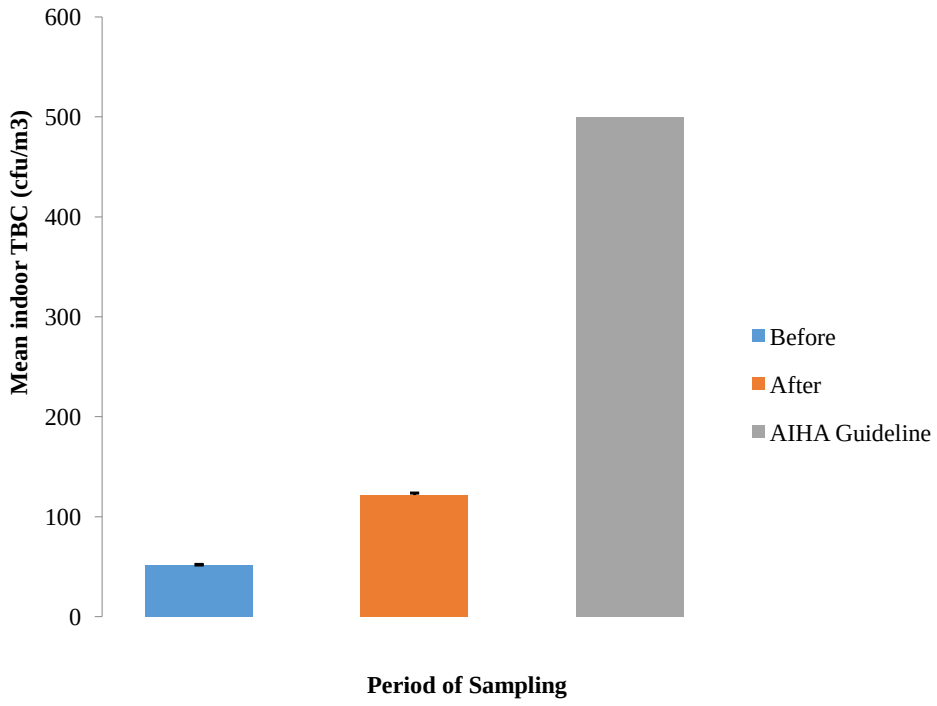

Fig 4.7: Cumulative Mean Indoor TBC before and after operation as compared with AIHA Guideline

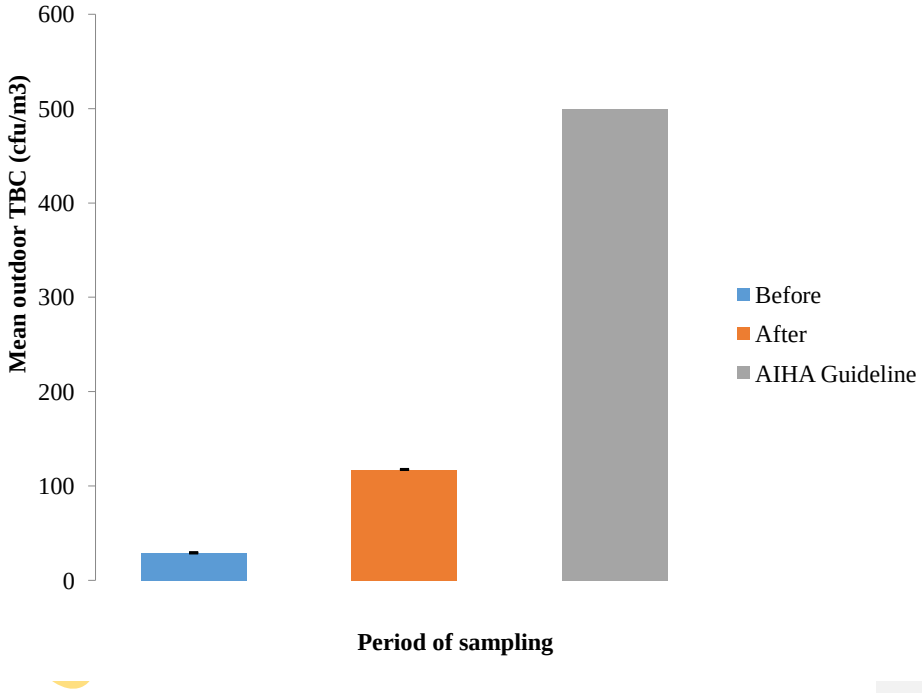

Fig 4.8: Cumulative Mean Outdoor TBC before and after operation as compared with AIHA Guideline

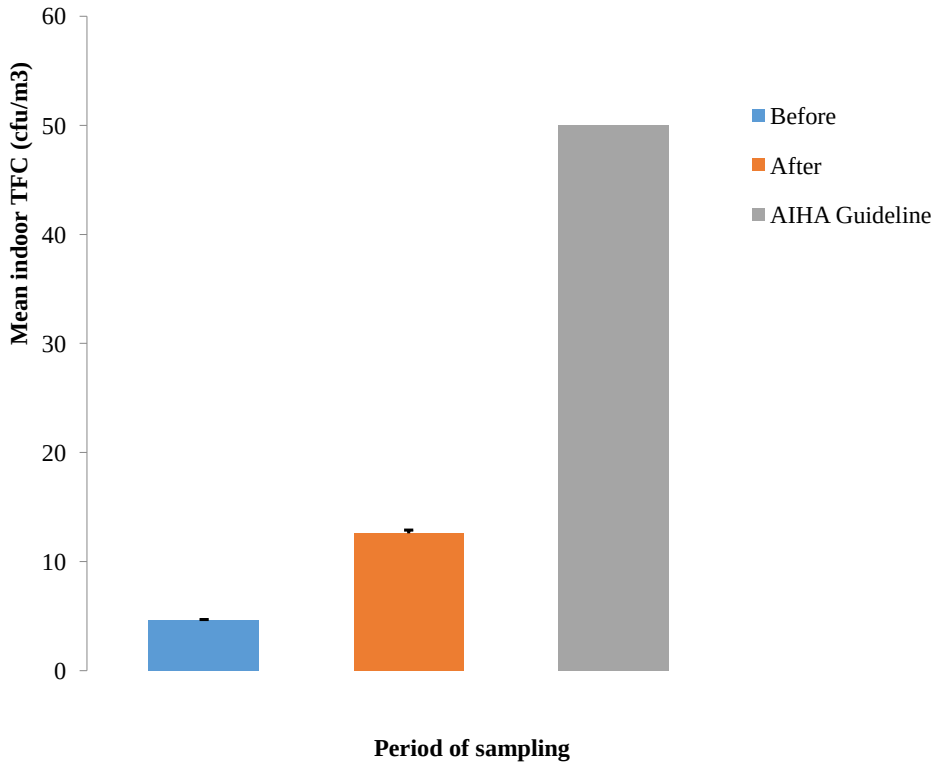

Fig 4.9: Cumulative Mean Indoor TFC before and after operation as compared with AIHA Guideline

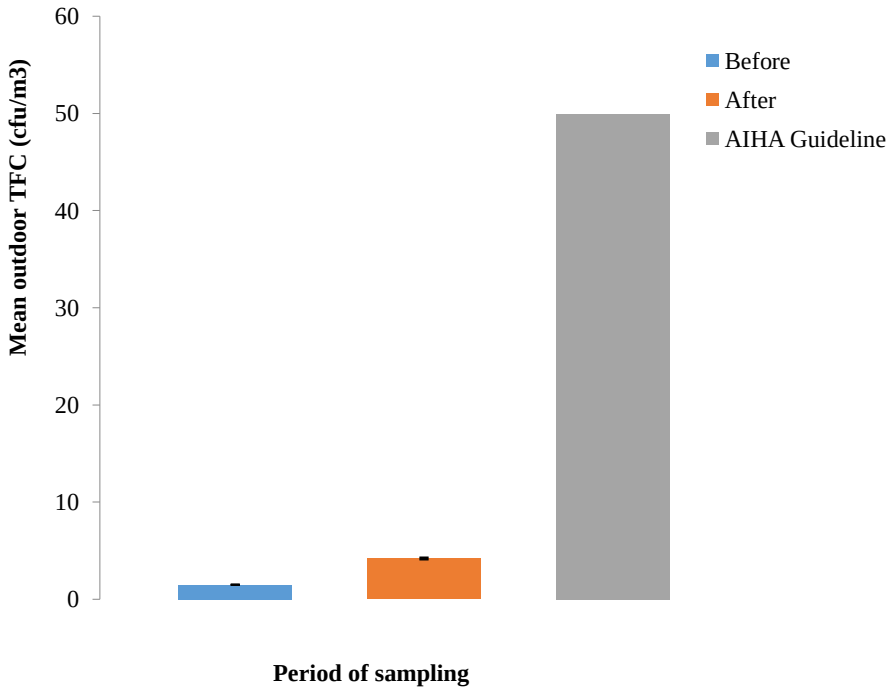

Fig 4.10: Cumulative Mean Outdoor TFC before and after operation as compared with AIHA Guideline

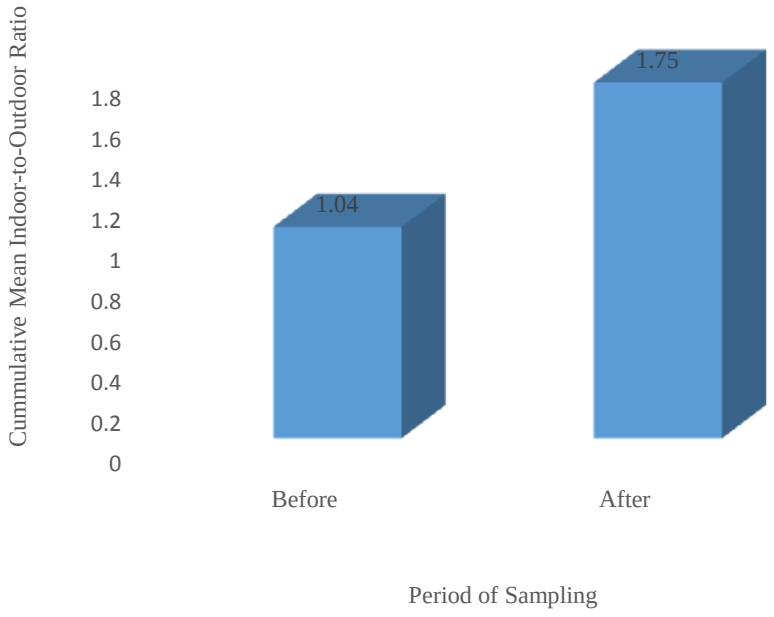

Fig 4.11: Cumulative mean indoor-to-outdoor TBC ratio before and after operation

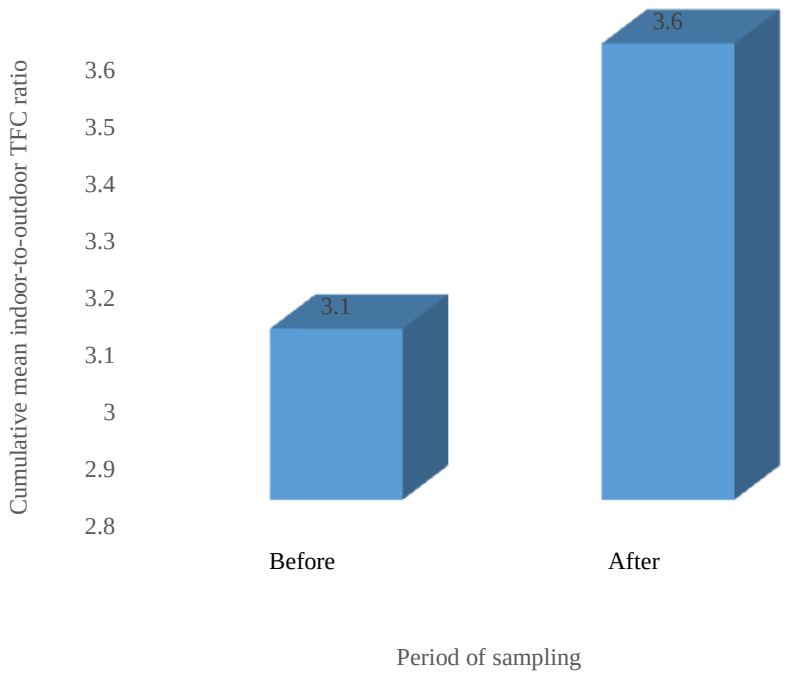

Fig 4.12: Cumulative mean indoor-to-outdoor TFC ratio before and after operation

4.11 Relationship between Meteorological parameters and Airborne Microbial Concentration among cases and controls

Table 4.13 shows the outcome of spearman's correlation (rs) test between total bacteria and fungi levels and environmental parameters such as indoor and outdoor RH and indoor and outdoor air temperature in the operating theaters. Most of the parameters measured were found to be significantly correlated. The indoor relative humidity (RH) was strongly correlated with both indoor TBC (rs = 0.742) and indoor TFC (rs = 0.722). A moderately positive correlation was also observed between indoor PM and indoor TBC (rs = 0.471) and indoor PM and indoor TFC (rs = 0.504). Fig 4.13 - 4.16 shows the strength of the linear relationship between indoor TBC and indoor RH (R^2 = 54.7%) and indoor TFC and indoor RH (R^2 = 48.5%).

Table 4.13: Relationship between Indoor Environmental Parameters and Microbial Concentration using Spearmans' Rank Correlation

Variable	Indoor Temp	Outdoor Temp	Indoor RH	Outdoor RH	Indoor PM	Outdoor PM	Indoor TBC	Outdoor TBC	Indoor TFC	Outdoor TFC
Indoor Temp	1.00									
Outdoor Temp	0.66 0.000**	1.00								
Indoor RH	0.63 0.000**	0.62 0.000**	1.00							
Outdoor RH	0.64 0.000**	0.69 0.000**	0.74 0.000**	1.00						
Indoor PM	0.35 0.000**	0.38 0.000**	0.34 0.000	0.53 0.000**	1.00					
Outdoor PM	0.23 0.000**	0.24 0.000**	0.37 0.000**	0.57 0.001*	0.59 0.000**	1.00				
Indoor TBC	0.60 0.000**	0.57 0.000**	0.74 0.000**	0.79 0.000**	0.47 0.000**	0.48 0.000**	1.00			
Outdoor TBC	0.54 0.000**	0.65 0.000**	0.66 0.000**	0.77 0.000**	0.37 0.000**	0.47 0.000**	0.74 0.000**	1.00		
Indoor TFC	0.59 0.000**	0.56 0.000**	0.72 0.000**	0.76 0.000**	0.50 0.000**	0.53 0.000**	0.78 0.000**	0.70 0.000**	1.00	
Outdoor TFC	0.57 0.000**	0.62 0.000**	0.66 0.000**	0.67 0.000**	0.27 0.000**	0.39 0.000**	0.66 0.000**	0.57 0.000**	0.71 0.000**	1.00

n = 252 * = p< 0.05; **= p<0.001

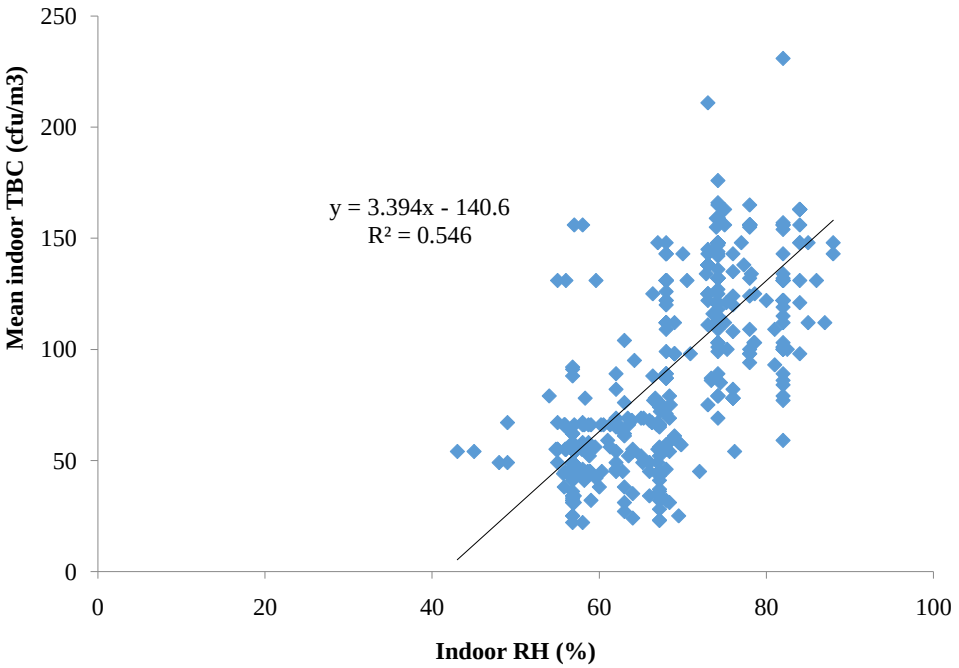

Fig 4.13: Relationship between indoor TBC and Indoor Relative Humidity

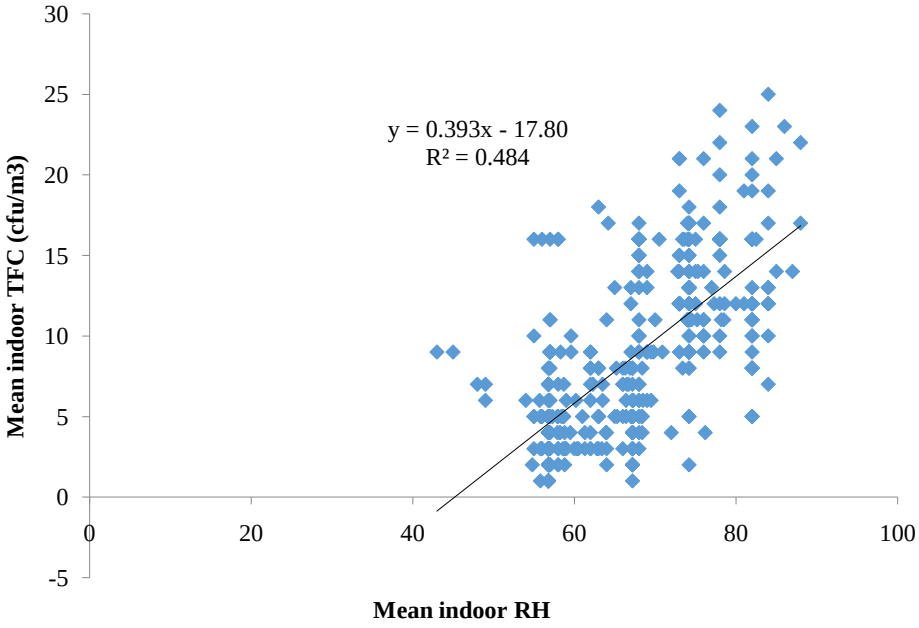

Fig 4.14: Relationship between indoor RH and indoor TFC

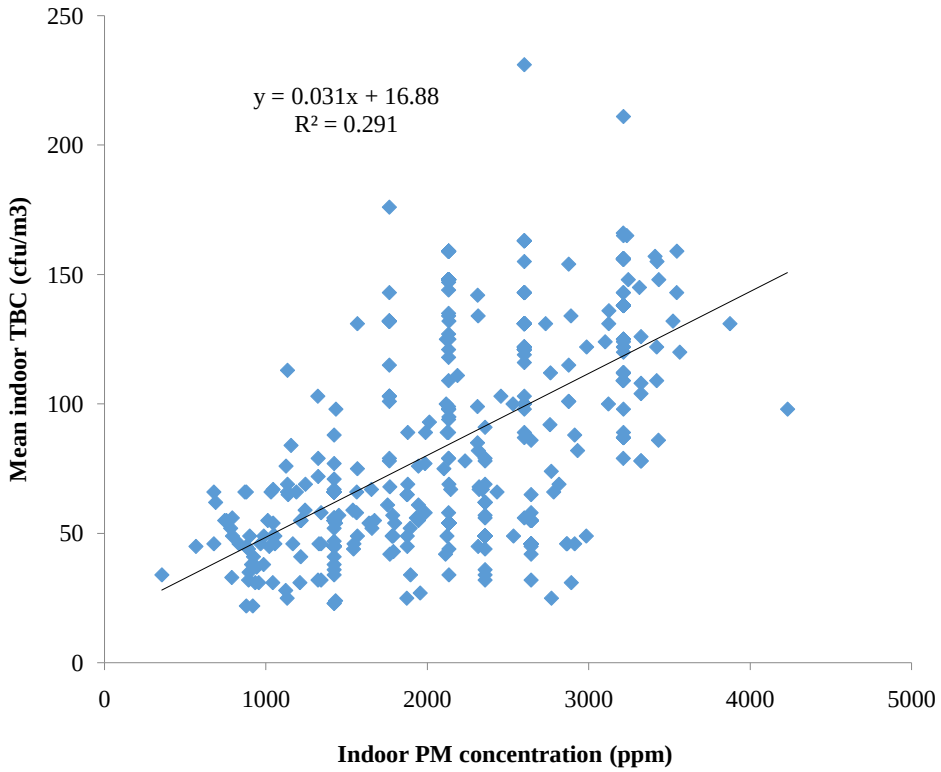

Fig 4.15: Relationship between indoor TBC and Indoor PM concentration

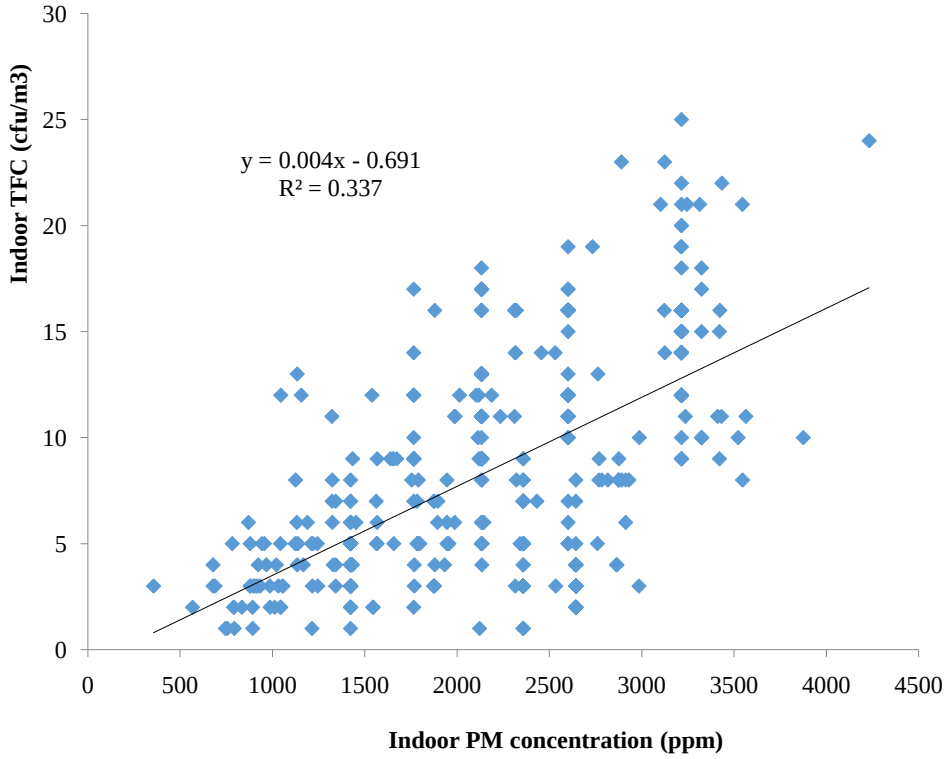

Fig 4.16: Relationship between indoor TFC and Indoor PM concentration

Plate 4.6: Showing growth of *Aspergillus spp.* on Potato Dextrose Agar from T-4

Plate 4.7: Showing growth of *Penicillium spp.* (Pink), *Aspergillus spp*. (Brown), *Cladosporium spp.* (White) *and others* on Potato Dextrose Agar from T7

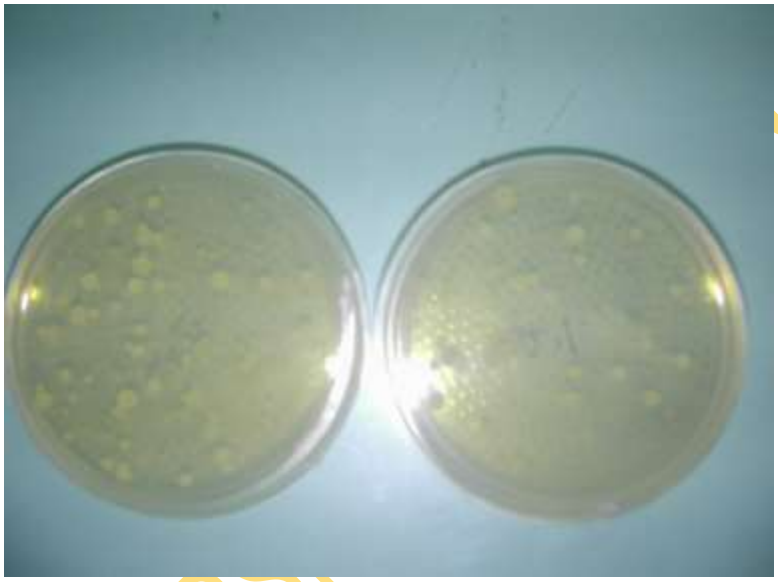

Plate 4.8 Showing bacterial colony on Nutrient Agar

4.13 Socio-demographic characteristics of Respondents interviewed at the operating theaters

Theater personnel's who were directly involved in series of operations were surveyed to elicit vital information on socio-demographic characteristics. The age of respondents ranged from 15 to 47 years with a mean age of 28.77 ± 5.55 years. Majority, 99 (69.2%) of respondents were female. Majority, 90 (62.9%) of respondents were married, 48 (33.6%) were single while 5 (3.5%) were Divorced. The Yoruba ethnic group was highest among respondents 109 (76.2%) followed by Igbo 18 (12.6%) and Hausa 5 (3.5%). Majority 77 (53.8%) of respondents had been on the job for only < 10 years (see table 4.14 for details).

Table 4.14: Socio-demographic characteristics of Respondents

Demographic Characteristics	Cases N (%)
Age: (Years)	
21 – 25	22 (15.4%)
26 – 30	31 (21.7%)
31 - 35	24 (16.8%)
36 – 40	31 (21.7%)
41 – 50	25 (17.5%)
51 and above	8 (5.6%)
Sex	
Male	44 (30.8%)
Female	99 (69.2%)
Marital Status	
Single	48 (33.6%)
Married	90 (62.9%)
Divorced	5 (3.5%)
Ethnicity	
Yoruba	109 (76.2%)
Hausa	5 (3.5%)
Igbo	18 (12.6%)
Others	11 (7.7%)
Year of Experience	
< 10 yrs	77 (53.8%)
10 – 25 yrs	40 (38.0%)
>25 yrs	26 (18.2%)

Mean age of respondents (years),

Non-responses were excluded

4.15 Respondents Knowledge on Indoor air quality of Operating rooms

Table 4.15 highlights respondents' level of knowledge on indoor air quality of operating rooms. A large proportion, 113 (85.0%) of respondents believed that poor indoor air quality of operating theatre suites results in diseases while majority, 103 (77.4%) of respondents indicated that airborne dispersal of *Staphylococcus aureus* is directly associated with the concentration of the bactrium in the anterior nares. Majority, 131 (97.0%) of respondents were knowledgeable on the fact that "environmental surface reservoir like floors, patients and carrier health personnel, construction activities and delayed maintenance and environmental disturbing during different activitieswhile a little more than half 87 (64.9%) of respondents had the understanding that temperature/humidity is a source of discomfort in the operating suite.

More than half, 100 (76.3%) of respondents believed that efficient ventilation will control temperature and humidity in OR, dilute the contamination by microorganisms and anaesthetic agents while slightly above half of respondents 82 (62.1%) understood that ultraclean laminar airflow-filtered air delivery must be 90% efficient in removing particles more than 0.5mm. Majority 112 (84.2%) of respondents were also of the opinion that temperature should not be adjusted for the comfort of OT personnel but for the requirement of patients, especially in peadiatric, geriatric, burns and neonatal cases.

Table 4.15: Respondents knowledge on risk factors for ARIs

Variable	Options	Cases N (%)
Poor indoor air quality of operating theatre suites cause diseases	*True	113 (85.0)
	False	20 (15.1)
Airborne dispersal of S.aureus is directly associated with the concentration of the bactrium in the anterior nares	*True	103 (77.4)
	False	30 (22.6)
Environmental surface reservoir like floors, patients and carrier health personnel, construction activies and delayed maintenance and environmental disturbing during different activities	True	131 (97.0)
	False	2 (3.0)
Temperature/humidity is a source of discomfort in your operating suite	*True	87 (64.9)
	False	47 (35.0)
Efficient ventilation will control temperature and humidity in OR, dilute the contamination by microorganisms and anaesthetic agents	*True	100 (76.3)
	False	31 (23.6)
Ultrclean laminar airflow-the filtered air delivery must be 90% efficient in remiving particles more than 0.5mm	*True	82 (62.1)
	False	50 (37.9)
Temperature should not be adjusted for the comfort of OT personel but for the requirement of patients, especially in peadiatric, geriatric, burns, neonatal cases	*True	112 (84.2)
	False	21 (15.8)

4.7 Attitude and compliance to specific operating guidelines

Table 4.16 highlights the attitudes of respondents towards compliance to specific operating guidelines. Slightly more than half of respondents 97 (79.4%) agreed that "hand washing is the most effective method of preventing the spread of infection", while almost half 100 (80.3%) of respondents' agreed that the use and disposal of sharps such as needles should never be recapped, rather discard using the sharp box. A great proportion of respondents' 121 (90.1%) agreed that facemasks should always be worn by non-scrubbed staff while 145 (65.9%) agreed that it is crucial to change clothes on exit and re-entry into the Operating Theater Department. More than half 179 (81.4%) also agreed that the risk of suboptimal compliance may be increased in developing countries like Nigeria due to such factors as inadequate funding for infection control educational programs while almost half 109 (49.5%) support the opinion that infection is an important clinical indicator for quality of patient care and infection control.

Table 4.16 Attitude and Compliance with specific operating guideline by theater personnel

Variable	Options	Respondents N (%)
Hand washing is the most effective method of preventing the spread of infection	Agree	97 (79.4)
	Indifferent	35 (18.2)
	Disagree	12 (2.4)
Use and disposal of sharps: Needles should never be recapped, rather discard using the sharp box	Agree	100(80.3)
	Indifferent	23(9.6)
	Disagree	21 (8.1)
Facemasks should always be worn by non-scrubbed staff	Agree	121 (90.1)
	Indifferent	14 (.8)
	Disagree	10 (3.6)
Changing clothes when leaving theatres: It is crucial to change clothes on exit and re-entry into the Operating Theater Department	Agree	145(65.9)
	Indifferent	9(4.1)
	Disagree	66(30.0)
The risk of suboptimal compliance may be increased in developing countries like Nigeria due to such factors as inadequate funding for infection control educational programs.	Agree	36(16.4)
	Indifferent	5(2.3)
	Disagree	179(81.4)
Infection is an important clinical indicator for quality of patient care and infection control	Agree	109(49.5)
	Indifferent	28(12.7)
	Disagree	83(37.7)
Healthcare associated infections (HAIs) have a major impact on our healthcare service and the population it serves	Agree	159(72.3)
	Indifferent	22(10.0)
	Disagree	39(17.7)
Surgical operations provide opportunity for the transmission of infection between patients and healthcare workers and between patients	Agree	115(52.3)
	Indifferent	16(7.3)
	Disagree	89(40.5)

CHAPTER FIVE

5.0 DISCUSSION

The findings from this study revealed that the building characteristic was fairly adequate. This was as a result of the presence of personnel changing room; theater zoning and line demarcation. Minimal microbial growth on walls and ceilings was also discovered in some of the theatres. This could contribute to the burden of airborne bacterial and fungal in such environment probably leading to cases of surgical infections. Building factors or pollution in buildings most frequently and consistently associated with surgical site infections are the presence of moisture, water damage, overcrowding and microbiological pollutants (Bornehag *et al*., 2001).

Solid waste management was observed to be fairly adequate owing to the fact that wastes collected after surgery are not properly handled according to stipulated guideline. A similar study carried out by Broex *et al.,* 2009 found a similar inadequate waste management in a hospital environment. Ventilation was inadequate due to the presence of non-functional dusty vents. The vents were meant to remove dusty air from the indoor environment but due to lack of appropriate maintenance system, the vents remained dusty and non-functional. Waste water management was observed to be adequate with respect to the absence of stagnant water in scrub sinks in addition to absence of odour and flies around the scrub sinks. Water supply was found to be fairly adequate due to the irregular supply of water and absence of back-up water.

The mean indoor and outdoor air temperature of operating theaters after operations (31.3 ± 2.1, 30.3 ± 1.4) was slightly higher than the values obtained before operations (28.1 ± 1.4; 27.4 ± 1.4) ($p<0.05$). A similarl study by *Sibel et al*., (2009) in Turkey found the mean indoor (21.0 ± 3.7ºC) and outdoor (11.1 ± 8.4ºC) air temperature to be much lower. This difference is obviously due to the nature of the environment where the study was carried out.

The high RH's observed in majority of the operating theaters after operations could be as a result of high moisture content released by individuals during operation which accumulates after the operation. The mean indoor and outdoor air RH after operations (74.3 ± 6.3; 72.5 ± 6.8) was found to be higher than before operations (59.7 ± 4.8; 56.7 ± 4.1) ($p< 0.05$). The high indoor

relative humidity obtained after operations in the operating theaters could breed mold, rot or pests, such as termite or cockroach. With such high relative humidity levels, microorganisms such as fungi and bacteria, can survive on non-living materials including dusts (Choa et al., 2002). A positive relationship was found between Indoor RH and indoor TBC with a strong the linear relationship (R^2 = 54.7%) which could be due to the strong coefficient of correlation (rs = 0.74). According to Choa et al., 2002, microorganisms attaches to airborne particles such as dusts which in the presence of sufficient moisture proliferate and multiply. This study also confirmed a direct relationship between indoor TBC and TFC and indoor PM. High relative humidity above 70% also tends to favour the survival of viruses that infect the membrane of the respiratory tract (Fang et al., 2007).

The findings from this study revealed that, during the study period the indoor bacterial load of operating theaters was almost two times higher than the outdoor concentration. Some possible conditions that could have contributed to this situation include the fact that individuals spend more time in the indoor environments, the windows were poorly designed, with inadequate ventilation such that the indoor air relative humidity was high enough to support bacterial growth. Tong and Lighthart (2000) also found that the bacterial counts were higher in indoor air than outdoor air during winter. The results were indicative of the fact that the outdoor environment contributes to microbial build-up in indoor environment. This was also similar to a study carried out by Fang et al. (2007) and Nevalainen and Seuri (2005) on indoor and outdoor airborne bacteria in child daycare.

The indoor airborne bacterial load after operations ($1.217x10^2 cfu/m^3$) was lower than the acceptable limit proposed by the American Industrial Hygiene Association (AIHA, 2001) for residential locations ($\leq 5.0x10^2 cfu/m^3$) but higher when compared to the burden obtained before operations ($0.51x10^2 cfu/m^3$). Similarly, the indoor fungal load after operations ($0.126 x10^2 cfu/m^3$) was higher than the burden obtained before operations ($0.046x10^2 cfu/m^3$). The high bacterial and fungal load recorded after operations could be due to overcrowding, poor housing status and inadequate ventilation. Similarly, Toivola et al., (2002) recorded the highest bacterial burden in an overcrowded environment. This suggests that the number of persons in a building is

directly proportional to the level of bacteria build-up in the indoor environment. According to Broex et al., 2009, microbial contamination of indoor air of operating theatres is one of the risk factors for the development of Surgical Site Infections (SSI). Operating theatre environment, including personnel, can become contaminated with microorganisms capable of causing SSI, morbidity, prolong hospitalization of patients or even death.

According to this study, the highest bacteria burden after operations was recorded in T7. There are several possible reasons for this. T7 is the most commonly used operating theater. Individuals are constantly active in this setting and airborne bacteria were dispersed into the air from crowded group of people according to Toivola *et al*., (2002). Therefore, the airborne microorganisms could be said to be of human origin. In similar terms, Bartlett *et al*. (2004) found that occupants contribute to the concentration of indoor airborne bacteria and the individual concentration of bacteria such as *Micrococci* and *Staphylococci* are related to occupancy or occupant activity.

This study also found that the predominant bacteria species observed indoor and outdoor among cases and controls were Gram-positive bacteria: *Staphylococcus spp*., *Micrococcus spp*., *Bacillus spp*., *Pseudomonas spp*., and *Streptococcus spp*. A similar study carried out by Nafstad *et al*., (2004) found that most of the bacteria isolated from the indoor and outdoor environments of day care centre were Gram-positive bacteria: *Staphylococcus spp.*, *Bacillus spp*., *Streptococcus spp.* and *Micrococcus spp.* Majority of these bacteria occur in most environments; particularly in dusty, unsanitary places inhabited by human or other animals (Brickus *et al*., 1998). Many of the species of bacteria isolated from the buildings were normal flora of such environments and are non-pathogenic. Predominant fungal species isolated from both the indoor and outdoor samples among cases and controls were: *Aspergillus spp*., *Penicillium spp*., *Candida spp*. *Cladosporium spp*. and *Fusarium spp*. in descending order.

The findings from this study revealed that, the mean age of respondents was 28.77 ± 5.55 years and the age range was between 15.0 – 47.0 years. The relatively young age of respondents was

expected considering the study environment. The respondents were majorly Muslims and belonged to the Yoruba ethnic group.

5.1 Respondents Knowledge on indoor air quality in an operating theatre

Understanding people's knowledge, beliefs and attitude as regard indoor air quality in an operating theatre is crucial as it can help to direct educational initiatives and public health communication (Ward *et al*., 1997). The knowledge recorded obviously has no relationship with the level of education. This finding contradicts the report by Sarab, 2007 in a study of surgical site infections and its association with knowledge, attitude and practice among Tanzania. A similar study carried out by Ameh *et al*., 2009 in Nigeria also found out that as many as 60% of respondents were knowledgeable about surgical site infections.

The high level of knowledge observed among respondents when asked if poor indoor air quality of operating theatre suites cause diseases could be due to previous experience of theatre personnel. Result from this study showed that a large proportion of respondents believed that airborne dispersal of S.aureus is directly associated with the concentration of the bactrium in the anterior nares. This could also be connected with past experience and witness of cases of SSI as previously stated.

The good knowledge was observed among respondents when asked if efficient ventilation will control temperature and humidity in OR, dilute contamination by microorganisms and anaesthetic agents. In contrast, a study by Thomas *et al*., 2007 on indoor air quality and hospital acquire infections found a good knowledge of respondents about issues relating to air quality. A large proportion of respondents shear the opinion that temperature/humidity is a source of discomfort in your operating suite. This knowledge could be linked to respondents' knowledge on indoor meteorological conditions. The high knowledge recorded among respondents when asked if temperature should not be adjusted for the comfort of OT personnel but for the requirement of patients, especially in paediatric, geriatric, burns, neonatal cases was obviously as a result of experience and level of education.

5.2 Respondents Attitude and compliance to specific guideline

The attitude and behaviour of respondents concerning factors that affect their health are formed at an early stage in life. Knowledge and understanding of health may reinforce formed attitudes. The agreement among a large proportion of respondents with respect to hand washing as the most effective method of preventing the spread of infection could be attributable to societal influence about the hygienic condition of the body. Similarly, the positive attitude of respondents towards the fact that the use and disposal of sharps such as needles should never be recapped, rather discard using the sharp box was the result of knowledge about clinical procedures. A similar response was reported by Kazi *et al*., 2008 in a study on hospital acquired infections among patients that came for surgery in Bangladesh.

Respondents' attitude towards the use of facemask was highly positive. Although, majority of respondents are aware of the diverse health effect of not using facemask while performing operation (Graham, 1990) but due to the rash behavior of theater personnel to rush into surgery, it remained neglected. Similarly, a high proportion of respondents were of the opinion that the risk of suboptimal compliance may be increased in developing countries like Nigeria due to factors such as inadequate funding for infection control educational programs.

The believe among a large proportion of respondents that infection is an important clinical indicator for quality of patient care and infection control could be as a result of respondents' understanding of the nature of the signs of hospital acquired infections such as SSI. A high proportion of respondents were also of the opinion that healthcare associated infections (HAIs) have a major impact on our healthcare service and the population it serves while majority of respondents also agreed that surgical operations provide opportunity for the transmission of infection between patients and healthcare workers and between patients.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study assessed the indoor meteorological parameters, building characteristics and airborne microbial load in relation to surgical site infections in operating theatres of the University College Hospital. The knowledge and attitude of theatre personnel on indoor air quality in a theatre and compliance to specific guideline was also documented. Characteristics and condition of the theatres was also determined using an observational checklist. Indoor and Outdoor meteorological conditions and airborne microbial concentration were determined using specialized equipment for determining air temperature, relative humidity, total bacterial and total fungal count.

There is strong empirical evidence that suggests that the indoor air quality after surgery could have contributed to the acquisition of surgical site infections when compared to results obtained before surgery. Similarly, inadequate ventilation, waste management practices and building characteristics were also found to be associated with hospital site infections such as surgical site infections.

Mean indoor temperature and relative humidity (RH) readings after operation was higher than values recorded before surgery and exceeded the AORN standard but owing to the characteristic high temperature condition in this part of the world, it is unlikely to have any significant effect on hospital acquire infections such as surgical site infections Similarly, mean outdoor temperature and relative humidity (RH) readings after operation was also greater than the values obtained before surgery. In addition, the mean indoor and outdoor PM after operation was found to be higher than the indoor and outdoor PM before surgery which also exceeded the AORN standard.

The mean Indoor total bacterial count after operations was higher than before surgery but within the AIHA guideline of 500cfu/m3. Similarly, mean indoor fungal count after operations was above the values obtained before operation. It can be said that the operational procedure contributed to the burden of indoor bacteria and fungi in the indoor environment of the operating theatres. T7 recorded the highest mean indoor bacterial and fungal count when compared to other operating theaters respectively.

Therefore, this study has been able to implicate inadequate surgical operating procedure as an independent risk factor for surgical site infections among surgical patients. The indoor environment has also been implicated as major source of microbial contamination. The level of occupancy was found to be directly proportional to the concentration of bacteria in the indoor environment. Although, the level of linear relationship between Indoor TBC and indoor RH was moderately high probably due to the low coefficient of correlation.

6.2 Recommendations

Infection prevention within the hospital is very necessary because infection acquired in the hospital or brought into the hospital from the community are potential hazards for all persons having contact with the hospital, effective measures must be developed to identify, control and prevent.

EMPLOYEE HEALTH

This must aim at:

1. protecting patients from contracting infections from hospital staff.
2. protecting staff form contracting infections from patients or other staff members, and to maintain their good health.
3. protecting visitors to the hospital from contracting infections, this could be spread to the community.

EDUCATION

All heath care workers must have knowledge of infection control in order to serve as an infection

control link nurse/ practitioner in their unit. Thus providing supports to the infection control committee of such hospital.

AUDIT

The quality of different aspects of the infection control service should be accessed regularly, to review and continuously strengthen the safety standards for patients and employees.

OPERATING ROOM ENVIRONMENT

The operating team should adhere to a tested scrub protocol using reliable antiseptics. The surgical site should be prepared by using potent and reliable antiseptics appropriate to the site. Every effort should be made to avoid breaking aseptic techniques during the entire procedure. Most infections are acquired in the operating room, so good surgical practices are crucial to their prevention. Excellent surgical technique is widely believed to reduce the risk of SSI. This includes maintaining effective haemostasis while preserving adequate blood supply, preventing hypothermia, gently handling tissues, avoiding inadvertent entries into a hollow viscus, removing devitalised tissues, using suture material appropriately, eradicating dead space, and appropriately managing the postoperative incision.

FURTHER SUGGESTIONS

- There should be an improvement in sanitary condition of all the operating suites.
- Strict measure should be taken to enforce compliance with specific infection control guideline in our operating theatre suites.
- Standard meteorological parameters should be maintained in each suites to ensure a safe surgery and prevent litigation.
- There is a need to further study the Efficiency of Air exchange and indoor air quality
- Routine surveillance of operating rooms should be carried out to ensure the environmental parameters comply with standards and Air-exchange systems be ON at all time without comprising the standards.

- Periodic personnel (Nose swab) surveillance should be carried out to ensure that their patients are safe from cross-contamination.
- Prophylaxis and post-operative antibiotics should be tracked regularly to minimize strains' resistance.

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Appendix I

Questionnaire on Microbial Load and Indoor Air Quality of Operating Theatres in University College Hospital Ibadan.

Dear respondent,

I am Ogundare, Johnson Oluwaseuna postgraduate student of the Department ofEnvironmental Health Sciences in the Faculty of Public Health, University of Ibadan. I am presently carrying out a research on **Microbial Load and Indoor Air Quality of Operating Theatre in University College Hospital Ibadan.** I wish to kindly request your voluntary participation by providing honest answers to the following questions, as this would increase the quality of the findings. I am assuring you that all information provided by you would be used for research purposes only and strict confidentiality would be ensured.

Serial Number.....Name of the Theatre/Op suite.....

SECTION A: SOCIO-DEMOGRAPHIC INFORMATION

Instruction: Please tick the options that best represent your interest

1. Age of respondent 1. 21-25 [ ] 26-30 [ ] 3. 31-35 [ ] 4. 36-40 [ ]4. 41-50 [ ] 5. 51 above [ ]

2. Sex 1. Male [ ] 2. Female [ ]

3. Marital Status 1. Single [ ] 2. Married [ ] 3. Divorce [ ] 4. Separated [ ] 5. Others

4. Ethnicity 1. Yoruba [ ] 2. Hausa [ ] 3. Igbo [ ] 4. Others _____

6. Postion/ current designation?

a.Surgeon: 1. Consultant [ ] 2. Senior Registrar [ ] 3. Registrar [ ]

b. Anaesthetist: 1.Consultant [ ] 2. Senior Registrar [ ] 3. Registrar [ ]

c. Perioperative Nurses:1. NO [ ] 2. SNO [ ] 3. PNO [ ] 4. CNO[ ] 5. ADN[ ]

7. Years of practice (in years) _____

SECTION B1: KNOWLEDGE OF INFECTION CONTROL PRACTICES IN THE THEATRE

Instruction: Please tick the options that best represent your choice

SA- Strongly Agree, **A**- Agree, **U**- Undecided, **SD**- Strongly Disagree, **D**- Disagree

		SA	A	U	SD	D
8.	Infection is an important clinical indicator for quality of patient care and infection control					
9.	Healthcare associated infections (HAIs) have a major impact on our healthcare service and the population it serves.					
10.	Surgical operations provide opportunities for the transmission of infection between patients and healthcare workers (HCWs) and between patients					
11.	Microorganisms can be found on a large number of surfaces in the operating theatre environment					
12.	Environmental contamination in conjunction with colonisation pressure (i.e., the proportion of patients/HCWs colonised with an organism) is thought to play a role in transmission of microorganisms.					
13.	Surgical site infection (SSI) is the second most common health care associated infection next to hospital acquired urinary tract infection					
14.	Infectious complications may range from superficial infections to deep and organ-space infections, many of which may be associated with increased mortality					

15.	Infection control (IC) practices are paramount to minimizing healthcare associated infections.					
16.	Low compliance with Universal Precautions (UP) and Standard Precautions (SP) increases rate of Surgical Site Infections in developing countries					
17.	Infectious complications may range from superficial infections to deep and organ-space infections, many of which may be associated with increased mortality					

SECTION B2: KNOWLEDGE ON INDOOR AIR QUALITY OF OPERATING ROOMS

(To the questions below, please tick the options that best represent your opinion)

S/N	QUESTIONS	YES	NO	DON'T KNOW
18.	Poor indoor air quality of operating theatre suites cause diseases			
19.	Airborne dispersal of *S. aureus* is directly associated with the concentration of the bacterium in the anterior nares. Approximately 10% of healthy carriers will disseminate *S. aureus* into the air.			
20.	Environmental surface reservoirs like floors, patients and carrier health personnel, construction activities and delayed maintenance can act as a source for microbiological air pollution through shedding and environmental disturbance (Traffic) during different activities			
21.	Temperature /humidity is a source of discomfort in your operating suite			
22.	Efficient ventilation will control temperature and humidity in OR, dilute the contamination by micro-organisms and anaesthetic agents.			
23.	Relative humidity of 40-60% to be maintained in ORs			
24.	Temperature between 20^0-24^0C. Temperature should			

	not be adjusted for the comfort of OT personnel but for the requirement of patient, especially in pediatric, geriatric, burns, neonatal cases etc.			
25.	Ultraclean laminar air flow – the filtered air delivery must be 90% efficient in removing particles more than 0.5mm.			
26.	Your OR is not very clean			

SECTION C: ATTITUDE AND COMPLIANCE WITH SPECIFIC GUIDELINES
Instruction: Please tick the options that best represent your opinion

SA- Strongly Agree, A- Agree, U- Undecided, SD- Strongly Disagree, D- Disagree

		SA	A	U	SD	D
27.	***Hand washing:*** Hand-washing is the most effective method of preventing the spread of infection					
28.	***Use and Disposal of sharps:*** Needles should never be recapped, rather discard using the sharp box					
29.	***Face masks:*** Facemasks should always be worn by non-scrubbed staff					
30.	***Changing Clothes When Leaving Theatre***: It is crucial to clothes on exit and re-entry into the Operating Theatre Department.					
31.	The risk of suboptimal compliance may be increased in developing countries like Nigeria due to such factors as inadequate funding for infection control educational programs, high patient load per HCW, crowded operating rooms, and inadequate resources (e.g., personal protective equipment (PPE), sharps containers, operating theatre scrubs and hand wash detergent dispensers).					

Appendix II

Observational checklist on Indoor Air Quality and Infection Control Practices in Selected Operating Theatres in the University College Hospital Ibadan, Oyo State

THEATRE'S NAME:_____

SUITE CODE: _____

FLOOR AREA:_____

NAME OF THE OPERATING ROOM: _____ MONTH:_____

SECTION A : FACILITY CONDITIONS

	ABSENT	PRESENT	CONDITIONS		
			High (+ +)	Moderate (+)	Poor (-)
Water spills around the environment					
Presence of flies					
Faeces around the toilet					
Presence of odour from toilet					
Water facility in the toilet					
Toilet well flushed					

SECTION B : OPERATING ROOM INDOOR BUILDING CHARACTERISTICS

Building Material _____

Roofing Material _____

State ofRoof 1. Leaking [ ] 2. Not Leaking [ ]

	ABSENT	PRESENT (Functioning)	CONDITIONS		
			High (+ +) Optimally	Moderate (+) Sub-optimally	Poor (-) Not Functioning
Central Air conditioner					
Upright Air Conditioner					
Damp Walls					
Adequate Ventilation					
Dusty Vents					
Cobwebs around?					

SECTION C: SURGICAL TEAM/OTHER THEATRE PERSONNEL COMPLIANCE WITH UNIVERSAL PRECAUTIONS AND INFECTION CONTROL PRACTICES

	YES	NO	REMARK
Regular hand washing (as required)			
Use of facemask			
Changing of theatre wears (outfit) only within operating theatre department			
Utilization of sharp boxes for sharps			
Utilization of kick buckets in OR for olid wastes			
Recapping of needles			
Eating in OR			
Noise control			

SECTION D: SOLID WASTE MANAGEMENT IN THE DISPOSAL ROOM

	ABSENT	PRESENT	CONDITIONS		
			Adequate (+ +)	Fairly Adequate (+)	Inadequate (-)
Waste Disposal Bins					
Waste disposal bins covered?					
Waste bins overflow before disposal?					
Waste bins washed after each disposal (Color coding)?					
Waste segregation					
Proper disposal of waste bin					

Flies around waste bin					
Sharp objects in surrounding					

SECTION F: WATER SUPPLY IN EACH OPERATING SUITES

	ABSENT	PRESENT	CONDITIONS		
			High(+ +)	Moderate (+)	Poor (-)
Water supply facilities within each operating suites' scrub-up room					
Rusty sinks/taps					
The water running always					
Antiseptic (scrubbing) lotion availability					

SECTION C: WASTE WATER MANAGEMENT

	ABSENT	PRESENT	CONDITIONS		
			High (+ +)	Moderate (+)	Poor (-)
Stagnant Water in scrub sinks					
Scrub sinks clean and dry when not in use					
Waste deposits in sinks					
Odour from scrub-up sinks					
Presence of flies					

SECTION G: DUMPSITE

	ABSENT	PRESENT	CONDITIONS		
			High (+ +)	Moderate (+)	Poor (-)
Within the operating department vicinity					
Dumpsite Odour					
Flies at Dumpsite					

Appendix IV

READINGS FOR ENVIRONMENTAL MONITORING AT THE BASELINE

WEEK 1

TEMPERATURE (^{O}C) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	26	27	26.5	28.1	30	29	28.5	30	26	29	30	30	32	35
WED	26	29.6	28.3	28.7	29.3	29.8	30	30.1	27	30.4	28	30	29	32
FRI	28	28	28	27.4	29	32	28	32.4	26	26.8	28.4	28.2	27	30

WEEK 2

TEMPERATURE (^{O}C) OF THE OPERATING ROOMWEEK 1

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	29	29	30	29	29	29	30	30	30	30	28	29	29	30
WED	28	30	28	30	28	30	28	30	28	30	28	29	30	31
FRI	27	29	28	29	29	30	28	29	26	29	28	30	30	28

WEEK 3

TEMPERATURE (^{O}C) 0F THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	28	29	28	31	28	30	29	30	29	30	28	29	29	32
WED	28	30	28	30	28	30	29	30	29	30	29	30	29	32
FRI	28	31	28	31	28	30	29	30	29	30	29	30	29	31

WEEK 4

TEMPERATURE (^{O}C) 0F THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	28	29	28	29	29	30	30	32	27	38	28	29	29	31
WED	28	28	29	29	29	32	28	29	28	30	28	29	29	30
FRI	29	30	28	29	29	29	28	29	28	29	29	29	28	29

WEEK 5

TEMPERATURE (^{O}C) 0F THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	28	29	28	31	28	30	29	30	27	28	28	29	30	32
WED	29	30	29	30	29	31	29	30	28	29	28	30	29	32
FRI	28	30	28	30	28	30	30	32	28	29	29	30	28	31

WEEK 6

TEMPERATURE (^{O}C) 0F THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	28	30	28	31	28	30	29	30	27	28	28	29	29	30
WED	28	30	29	30	29	30	28	30	28	29	28	31	28	32
FRI	30	31	28	31	28	32	29	30	28	28	29	30	29	31

WEEK 7

TEMPERATURE (^{O}C) 0F THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	29	29	28	31	28	29	28	30	27	28	28	29	29	32
WED	28	30	29	30	29	31	29	32	28	26	28	29	28	29
FRI	28	30	28	31	28	30	30	30	29	28	29	30	29	31

WEEK 8

TEMPERATURE (^{O}C) 0F THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	28	29	28	31	28	30	29	30	29	30	28	29	29	32
WED	29	30	28	30	28	30	29	30	29	30	29	30	29	32
FRI	28	31	28	31	28	30	29	30	29	30	29	30	29	31

WEEK 9

TEMPERATURE (^{O}C) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	28	29	28	32	28	30	29	30	28	28	28	29	30	32
WED	29	30	28	30	29	30	29	32	27	28	29	31	28	32
FRI	28	30	29	31	28	31	28	30	28	29	28	30	29	31

WEEK 10

TEMPERATURE (^{O}C) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	28	30	28	30	28	30	29	30	28	28	28	31	29	30
WED	28	30	28	30	29	31	28	30	28	29	28	30	30	32
FRI	30	31	29	31	28	30	29	30	28	28	29	30	29	31

WEEK 11

TEMPERATURE (^{O}C) 0F THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	28	28	28	31	28	30	29	30	28	28	28	29	29	30
WED	28	30	28	30	28	30	30	32	27	28	29	30	29	30
FRI	28	32	29	29	29	32	29	30	27	28	28	31	29	31

WEEK 12

TEMPERATURE (^{O}C) 0F THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	28	29	28	31	28	30	29	31	28	28	28	29	29	32
WED	30	32	29	30	29	32	28	29	28	29	28	29	29	30
FRI	29	31	28	31	28	30	29	30	27	28	29	30	28	30

WEEK 1

RELATIVE HUMIDITY (%) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	56.8	58.2	56.8	56.4	61.4	61.4	59.0	65.5	58.8	67.6	54.1	56.4	60	68
WED	67.5	74.2	72.7	83.5	78.8	56.4	58.8	66.6	54.5	57.4	58.4	56.1	66	55
FRI	56.8	56.4	58	59.2	56.9	69.4	60.6	59.8	52	55	56	56.4	68.1	53.8

WEEK 2

RELATIVE HUMIDITY (%) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	53.1	51.4	66.2	64.6	72.1	68.5	79.9	68.2	67.8	69.8	67.2	69.4	68.1	69.5
WED	48.8	54.8	53.9	57.7	62.0	54.5	64.0	53.0	65.3	57.5	68	69.8	58.9	60.2
FRI	50.8	55.0	55.8	57.0	58.8	55.5	62.8	64.2	58	55.6	58.6	52.8	60.0	56.6

WEEK 3

RELATIVE HUMIDITY (%) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	62.5	57.3	67.0	56.7	71.7	58.5	58.0	56.4	64.5	58.5	64.3	66.4	70	74
WED	65.5	64.7	66.6	57.4	70.0	56.3	59.4	56.3	66	62.6	62	68	68.8	60.4
FRI	65.2	67.5	67.5	58.5	69.4	55.2	59.1	55.3	66.1	58.5	59.9	60	58.0	64.3

WEEK 4

RELATIVE HUMIDITY (%) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	73.8	71.4	63.2	64.5	79.4	76.4	71.1	68.5	64.5	63.2	75.6	68.2	75.6	75.2
WED	66.4	79.9	75.6	75.4	78.2	70.0	68.4	64.7	56.2	55.0	68	66	70	68.2
FRI	75.6	74.9	75.7	75.6	77.7	70.5	60	55.8	62.5	58.2	70	72.2	68.6	70.2

WEEK 5

RELATIVE HUMIDITY (%) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	63.7	67.3	57.0	66.7	61.7	68.5	58.0	66.4	50.2	54.5	65.3	66.4	64.2	68.4
WED	67.2	63.7	65.6	72.4	71.0	66.3	52.4	56.3	50	52.6	62.5	68.7	62.8	60.5
FRI	65.6	62.9	64.7	62.5	69.4	56.2	69.1	65.3	50.1	53.5	56.9	60.2	68.0	64.3

WEEK 6

RELATIVE HUMIDITY (%) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	66.7	62.3	77.0	66.7	71.8	62.5	58.0	60.4	54.5	51.5	64.7	65.4	70.8	74.2
WED	59.5	68.7	62.6	56.4	70.0	66.3	55.4	57.3	50	52.6	62.8	68.6	62.8	60.4
FRI	64.2	67.8	62.5	56.5	68.4	65.2	57.1	52.3	48.1	52.5	57.9	60.7	58.7	65.3

WEEK 7

RELATIVE HUMIDITY (%) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	63.5	57.4	64.0	56.2	61.7	58.5	58.6	54.4	50.5	48.5	60.3	63.9	68.4	74.9
WED	62.5	54.7	69.6	57.4	70.5	61.3	59.4	65.3	56	52.6	62.9	68.8	58.8	66.4
FRI	59.2	57.5	68.1	58.5	65.4	65.2	59.1	52.3	49.1	55.5	59.9	60.8	58.7	63.3

WEEK 8

RELATIVE HUMIDITY (%) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	62.6	57.3	67.0	56.7	71.7	58.5	58.0	56.4	52.5	51.2	64.3	66.4	70	74.6
WED	65.5	64.7	66.6	57.4	70.0	56.3	59.4	56.3	56	52.6	62	68	68.8	60.4
FRI	65.6	67.5	67.5	58.5	69.4	55.2	59.1	55.3	66.1	48.5	52.9	60	58.0	64.3

WEEK 9

RELATIVE HUMIDITY (%) OF THE OPERATING THEATRE

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	59.5	67.3	66.4	56.4	61.7	58.4	58.0	56.4	54.5	50.5	64.3	66.4	63.8	68
WED	58.5	54.7	68.6	67.4	70.0	56.7	59.4	58.3	47.9	52.6	62.7	68	68.8	62.4
FRI	70.2	63.5	62.5	68.5	69.4	54.2	54.1	55.3	53.7	49.5	59.9	60.8	58.3	67.3

WEEK 10

RELATIVE HUMIDITY (%) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	68.5	58.3	67.6	56.9	71.7	58.5	58.0	57.4	48.3	52.7	64.3	66.4	72.6	74.9
WED	65.2	54.7	60.6	67.4	70.6	56.8	59.4	56.3	52	55.2	62.8	68.5	68.8	62.4
FRI	65.7	69.5	67.8	58.5	69.4	55.2	59.1	54.3	50.1	56.5	59.9	60	57.0	68.3

WEEK 11

RELATIVE HUMIDITY (%) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	62.5	57.3	67.0	56.7	71.7	58.5	58.0	56.4	55.5	48.5	64.3	66.4	67	74
WED	65.5	64.7	66.6	57.4	70.8	56.3	59.4	56.3	56	52.6	62	68	68.8	60.4
FRI	56.2	67.5	67.5	58.5	69.4	55.2	59.1	55.3	52.1	56.5	59.9	60	58.0	64.3

WEEK 12

RELATIVE HUMIDITY (%) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	72.5	55.3	67.0	56.7	71.7	58.5	58.0	56.7	50.5	56.5	64.3	66.4	56.9	62.2
WED	68.5	64.7	63.6	50.4	72.0	66.3	57.4	56.3	55	52.3	62.8	68	68.8	60.4
FRI	65.4	64.5	68.5	58.6	65.4	55.2	59.1	55.3	48.1	51.7	59.9	60.8	58.0	64.3

WEEK 1

PARTICULATE MATTER 10(ppm) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	2934	3848	2493	1251	3843	94365	634	540	2978	1214	3664	2601	1278	2444
WED	3456	1458	6471	6849	9729	6120	1098	5895	459	639	522	1350	2169	1359
FRI	2358	2601	1818	2628	3858	35290	2117	4365	3186	2691	1432	2678	2623	2800

WEEK 2

PARTICULATE MATTER 10(ppm) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	162	54	153	387	360	414	117	99	54	126	248	176	471	517
WED	306	333	834	306	174	228	2971	360	270	174	304	109	336	218
FRI	396	585	873	369	315	99	243	297	541	124	218	229	403	108

WEEK 3

PARTICULATE MATTER 10(ppm) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	3459	843	2944	1251	3834	9345	436	3978	2114	4663	6201	1276	2443	1889
WED	4562	1438	6442	7656	9687	8845	1096	6593	678	1287	6749	5467	23456	4539
FRI	3456	2436	7968	2345	5786	3546	4563	2435	3547	4536	6759	2435	6784	8796

WEEK 4

PARTICULATE MATTER 10(ppm) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	3934	3748	2453	2251	3853	95365	734	547	2578	1814	3564	2641	1478	2464
WED	3656	2458	6481	6649	9759	6420	2098	5855	489	739	532	1380	2669	1349
FRI	2858	5601	1828	3628	3878	33290	2517	4375	3486	3691	1732	2658	2653	2860

WEEK 5

PARTICULATE MATTER 10(ppm) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	1623	5434	153	387	3460	414	127	98	52	126	248	176	4712	4517
WED	3062	3313	8346	3056	1734	228	2971	360	270	174	334	109	3362	3218
FRI	3968	5825	8737	3769	3153	99	244	297	544	324	218	229	4035	2108

WEEK 6

PARTICULATE MATTER 10(ppm) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	164	55	153	387	460	414	127	99	54	124	248	276	472	517
WED	305	343	834	306	174	228	271	360	273	174	324	109	336	218
FRI	386	575	873	99	65	99	243	297	541	124	258	229	403	108

WEEK 7

PARTICULATE MATTER 10(ppm) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	645	564	153	386	364	414	117	996	854	146	278	1767	471	527
WED	316	583	8634	4306	1745	2457	2971	360	270	274	334	1097	336	618
FRI	3967	4585	8473	5369	3815	954	243	697	741	424	218	229	433	108

WEEK 8

PARTICULATE MATTER 10(ppm) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	762	548	353	377	60	54	1176	5499	54	126	248	276	471	537
WED	386	3337	847	336	174	328	271	363	270	174	324	119	3361	1218
FRI	96	85	845	469	315	299	47	97	54	524	218	229	403	108

WEEK 9

PARTICULATE MATTER 10(ppm) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	62	54	1531	6387	360	414	113	99	541	126	244	276	4778	3517
WED	3061	3353	834	306	774	228	2971	365	270	174	324	159	356	218
FRI	3968	585	873	369	315	99	243	297	541	324	238	229	403	158

WEEK 10

PARTICULATE MATTER 10(ppm) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	1643	5489	553	387	360	464	157	99	54	126	248	176	471	517
WED	346	323	834	336	174	228	2971	360	240	124	3341	2109	3362	2182
FRI	3562	5585	874	379	315	945	7432	3297	5445	3124	218	229	403	108

WEEK 11

PARTICULATE MATTER 10(ppm) OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	121	254	143	387	360	414	117	329	254	126	248	176	472	557
WED	336	353	824	306	174	228	2971	5360	270	174	3404	2109	336	218
FRI	456	585	573	369	315	99	243	297	541	124	2218	1229	2403	4108

WEEK 12

PARTICULATE MATTER 10 OF THE OPERATING ROOM

	T1		T2		T3		T4		T5		T6		T7	
DAY	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
MON	293	348	493	1251	383	4365	634	540	278	214	364	261	1278	2444
WED	345	148	647	684	729	120	1098	5895	459	639	522	1350	269	159
FRI	235	260	1818	2628	3858	5290	217	465	3186	2691	432	278	263	280