CHAPTER 1

INTRODUCTION

1.1 Background

Air is an integral component of every indoor and outdoor environment. Indoor air quality is a major concern in both developed and developing countries. People spend most of their time indoors, both in residential and occupational settings. The quality of air they breathe is very important for their well-being. It is therefore essential to monitor indoor air quality since inadequate quality of indoor air can cause a considerable health burden (WHO, 2009).

Indoor air quality is influenced by factors such as design and ventilation of the buildings and the occupants. Faulty design, including tightened building envelopes, ventilation deficits and improper insulation can lead to increased indoor humidity levels that favour the growth of moulds (WHO, 2009). The quality and globalization of building materials and their components, and construction concepts and techniques have also been found to be associated with increased dampness supporting microbial growth (WHO, 2009). Improper ventilation restricts the dilution of indoor air leading to increased microbial loads. Increased number of personnel beyond permit levels leads to overcrowding, that causes increased concentrations of microorganisms in the form of skin squames and respiratory shedding.
Bioaerosols are airborne particles that are living or originating from living organisms (Macher et al., 1999). They are ubiquitous, complex and unique, comprising of microorganisms such as bacteria and fungi, and their products such as endotoxins. They can be natural or man-made in origin. Exposure to bioaerosols has been associated with adverse health effects, including infectious diseases, acute toxic effects, allergies and cancer (Douwes et al., 2003).

Studies carried out in water recycling industries have shown that the workers are exposed to very high concentrations of microorganisms (Van Tongeren et al., 1997; Douwes et al., 2000a) and such exposures have been implicated in high prevalence of respiratory symptoms and airway inflammation (Sigsgaard et al., 1994; Poulsen et al., 1995; Thorn and Rylander, 1998; Douwes et al., 2000a; Wouters et al., 2002). Another classic example is the occurrence of building-related diseases such as sick building syndrome, which is due to high concentrations of bioaerosols and elevated exposures to them, as a result of increased insulation of buildings combined with poor ventilation (Walinder et al., 2001).

1.2 Need for the study

Healthcare facilities are a unique environment, where patients with hampered immune status, children and elderly, or those requiring longer durations of hospital stay are admitted. In a country like India, which is highly populated, healthcare delivery is complex and highly demanding. Factors such as overcrowding, faulty design and improper ventilation can impact the growth and / or survival of microorganisms. It is therefore essential to study the microorganisms in indoor air of hospitals.
Incidence of HAI is a major cause for concern. While it is not well studied in the developing countries, it is estimated that HAI are higher in developing countries when compared to developed countries (Allegranzi et al., 2011). Few studies carried out in India have shown that HAI by Gram-negative organisms were higher than those by Gram-positive organisms. *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *E.coli*, *Acinetobacter baumannii*, *Enterobacter* species, *Citrobacter* species and other non-fermenters are the commonest Gram-negative organisms causing HAI; among Gram-positive organisms, *Staphylococcus aureus*, *Coagulase-negative Staphylococci*, *Enterococcus* species and *Streptococcus* species were the predominant (Kamath et al., 2010; Mohanasoundaram, 2010).

Studies have shown that most of the common nosocomial pathogens have the ability to survive or persist on surfaces for months. Among Gram-positive bacteria, *Enterococcus* spp. (including VRE), *Staphylococcus aureus* (including MRSA), and *Streptococcus pyogenes* survive for months on dry surfaces (Kramer et al., 2006). Gram-negative bacilli can survive on a dry formica surface from a few hours up to three days (Getchell-White et al., 1989). Many Gram-negative species, such as *Acinetobacter* spp., *Escherichia coli*, *Klebsiella* spp., *Pseudomonas aeruginosa*, *Serratia marcescens* and *Shigella* spp. are capable of survival for months (Kramer et al., 2006).

The survival of these organisms in the hospital environment can be a continuous source of transmission. These organisms gain entry either directly through contact, or indirectly through the hands of health personnel. Although a majority of HAI are inadvertently transmitted through hands of health personnel,
the environment has also been indicated as a source of nosocomial agents occasionally (CDC, 2003).

Environment plays an indirect role in causing HAI, where the hands of the health personnel may acquire the microorganisms, including nosocomially significant pathogens from the environment, through frequent contact with “high touch” areas such as door knobs, and get colonised with these organisms. Acquisition of these organisms also occurs through inanimate objects such as fomites and mobile phones (Sepehri et al., 2009; Srikanth et al., 2010). Studies carried out in different parts of the world have shown that a variety of microorganisms are present in indoor air of hospitals (Jaffal et al., 1997; Sarca et al., 2002; Obbard and Fang 2003; Ekhaise et al., 2008; Qudiesat et al., 2009). Possibilities of airborne microorganisms to cause nosocomial infections and occupational health hazards are also described (Beggs, 2003). Studies have shown airborne transmission of nosocomial infections by Staphylococcus aureus (Farrington et al., 1990; Bernards et al., 1998), Acinetobacter spp. (Allen and Green, 1987; Bernards et al., 1998) and Pseudomonas spp. (Jones et al., 2003).

Few studies have been carried out to determine microbial air quality of hospitals in different parts of India. These studies have documented the presence of high bacterial loads in operating rooms, including Staphylococcus aureus, Coagulase-negative Staphylococcus, Acinetobacter spp. and Klebsiella spp. (Kelkar et al., 2002; Kaur and Hans 2007), and an increase in atmospheric microbial contamination with activity during working sessions in a mobile dental unit (Shivakumar et al., 2007). These preliminary findings indicate the need for long-term studies to determine the microbial profile of indoor air in different locations of healthcare facilities.
Given that microorganisms are present in indoor air, it is essential to determine the factors that favour their growth. Several factors are found to influence the presence and/or survival of airborne microorganisms. Environmental factors that determine these microorganisms to be airborne include the magnitude of air currents, temperature and relative humidity (Stetzenbach, 2002). In order to minimise the presence of airborne microorganisms, it is essential to determine the optimum levels of these environmental parameters.

Apart from airborne microorganisms, their by-products such as endotoxins have been associated with adverse health effects. Endotoxins are Gram-negative bacterial cell wall components which may be released during active cell growth and after cell lysis (Stetzenbach, 2005). Studies on exposure to endotoxins have been carried out in different workplaces such as composting facilities to determine the levels of airborne endotoxins and the associated health effects due to occupational exposure (Liu et al., 2011). So far, no data is available on the existence of endotoxins in indoor air of hospitals. Thus, an attempt was made to determine if endotoxins can be airborne in a low cost intensive care unit of a healthcare facility.

1.3 Aim and objectives

Aim

The current study was designed to study the airborne microorganisms present in different locations of hospital environment, characterise the microorganisms, and study the correlation of the environmental strains with clinical isolates.
Objectives

1. To assess the quality of indoor air in hospital environment such as operation theatres, ICUs and wards, using active and passive methods of air sampling, and characterise aerobic bacteria and fungi isolated;

2. To determine temporal and spatial variation in the airborne microflora in hospital indoor air;

3. To determine the association of the representative strains isolated from air with nosocomial infections through molecular typing methods; and

4. To determine the presence of endotoxin in indoor air samples and in blood samples of patients admitted and healthcare providers in a hospital location.

Research questions

In order to achieve the study objectives, the following research questions were formulated:

1. What are the bioaerosols present in hospital environments?
2. Are there any seasonal variations in bioaerosol concentrations in hospital environment?
3. Do concentrations of bioaerosols vary within and between hospitals?
4. Is there a link between airborne bacteria and nosocomial infections?
5. Can endotoxins get airborne in hospital environment?
6. Can airborne endotoxins have health effects on patients admitted and healthcare providers?