CHAPTER 6

SUMMARY AND CONCLUSION

6.1 Summary

- Bioaerosols in indoor air of five different hospitals were characterized by active (impinger and filter) and passive (exposed plate) methods of air sampling.
- Bacteria were found to be present in higher concentrations when compared to fungi, irrespective of the sampling method and the sampled location.
- Among bacteria, GPC were predominant than GNB, while among fungi, moulds were frequently encountered.
- Coagulase-negative *Staphylococci* and *Micrococci* were the commonly isolated GPC, while *Pseudomonas* sp. was the commonest GNB recovered. *Aspergillus* sp. was the predominant mould documented in the study.
- Among the active and passive air sampling methods used in the study, exposed plate method was found to recover a variety of bacteria and fungi when compared to the other two methods, impinger and filter.
- Indoor microbial loads obtained by exposed plate method were less than that of outdoor air in majority of the sampling locations. In some locations, airborne microbial loads in indoor air exceeded that of outdoor air. This may be attributed to improper ventilation.
- Environmental factors such as temperature and relative humidity were found to have an impact on the airborne microbial loads in both naturally ventilated open system, and artificially ventilated closed system.

- Number of personnel did not have an appreciable impact on the airborne microbial loads.

- Airborne microbial loads were not influenced by the changing seasons. This may be attributed to the prevailing hot and humid conditions irrespective of the season pertaining to the study months.

- Recovery of airborne microorganisms was found to be consistent when samples were collected using exposed plate method. Impinger and filter methods were found to be inconsistent in capturing the airborne microorganisms. This may be due to the inherent deficiencies in the methods.

- Exposed plate method is a useful method for collecting air samples, especially in healthcare facilities, since they are capable of recovering a variety of aerobic bacteria and fungi, thus facilitating the identification of infections due to particle fall-out.

- Airborne microbial loads were found to vary with the sampling location, of the magnitude OR < ICU < ward, and was found to be statistically significant.

- Airborne microbial loads were not influenced by the size (number of beds) of the hospitals. This may be attributed to the infection control practices that are to be followed as per the requirements of the locations irrespective of the size of the hospital.

- *Pseudomonas* sp. was present in indoor air of different hospitals, including the ICUs and ORs, indicating air as a new reservoir for these organisms.
Phylogenetic analysis showed the similarity between the study isolates of *Pseudomonas stutzeri* that are environmental in origin and the clinical isolates of *Pseudomonas stutzeri* in the NCBI database, suggesting that a pathway may exist, allowing for the introduction of these organisms from the hospital environment into patients during healthcare delivery.

Methicillin resistant *Staphylococcus haemolyticus* isolated from environmental (air) sample was found to be similar to the strain (Methicillin resistant *Staphylococcus haemolyticus*) that was recovered from clinical (tissue) sample of a patient admitted subsequently within a week in the same orthopaedic ward. This indicates that air can be a possible source of nosocomial infection.

Endotoxin was present in indoor air of low-cost intensive care unit of a healthcare facility and among health personnel working in the same ICU.

Health personnel had 10.31 times more risk of developing adverse health effects due to exposure to airborne endotoxins than the patients.

### 6.2 Conclusions

This exploratory study has documented the presence of bioaerosols, including bacteria, fungi and endotoxins in indoor air of healthcare facilities, and the possibility of air as a source of transmission of nosocomial infections, thereby generating a baseline data.

Exposed plate method is a useful method and may be preferred over active methods, which are cumbersome and inconsistent, for preliminary assessment of indoor microbial air quality, especially in areas of low bioaerosol concentrations such as healthcare facilities.
Profiling of bioaerosols in different locations of hospitals using active and passive air sampling methods showed that bacteria were in higher concentrations than fungi. Among bacteria, GPC (CNS and Micrococi) were predominant than GNB (Pseudomonas sp.). Among fungi, Aspergillus sp. were commonly seen in all the hospitals. The study findings can be used by hospital authorities to develop guidelines on hospital design with adequate ventilation, appropriate engineering controls and infection prevention measures. This will minimise the entry of fungal spores and reduce aerosolisation of these organisms during healthcare delivery.

Airborne microbial loads were not influenced significantly by the changing seasons and the size of the hospitals.

There was significant variation in the airborne microbial loads with the sampling location. The loads were highest in wards, followed by ICUs and ORs. Since is not possible to rid the hospital environment of these nosocomial pathogens, appropriate location-specific measures such as regulated temperature-humidity levels and air exchanges, as recommended by international guidelines like CDC, need to be implemented to contain their spread.

The similarity between environmental (air) and clinical strains of methicillin resistant Staphylococcus haemolyticus and Pseudomonas stutzeri establishes the possibility of air as a source for transmitting nosocomial infection. However, the link was documented only after a prolonged period of observation suggesting that air is not a major source of nosocomial infection. It is, therefore, not essential to carry out frequent air sampling as a part of routine surveillance. Further, active surveillance may be conducted during an outbreak of nosocomial infections. The study also emphasizes the need for proper hand hygiene...
practices to minimise the acquisition of these airborne particles that settle on inanimate surfaces due to particle fall-out.

The preliminary assessment of indoor air of hospitals for the presence of endotoxins suggests that they may get airborne and health personnel may be at a higher risk of adverse health effects due to exposure to airborne endotoxins when compared to patients. This may be due to occupational exposure to airborne endotoxins that may get aerosolised through procedures in healthcare delivery.

6.3 Scope for further studies

- Air sampling can be carried out to determine the presence of other airborne microorganisms such as *Mycobacterium tuberculosis* and airborne respiratory viruses such as Influenza A, Influenza B and SARS viruses.
- Long-term studies can be undertaken to determine the health effects associated with exposure to airborne endotoxins.
- Studies can be conducted to determine the association of airborne fungi with nosocomial infections.