# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CONTENT</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECLARATION CERTIFICATE BY THE CANDIDATE</td>
<td>iii</td>
</tr>
<tr>
<td>CERTIFICATION BY THE GUIDE/CO-GUIDE</td>
<td>iv</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>v</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>ix</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>xii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xvii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xix</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS AND SYMBOLS</td>
<td>xxi</td>
</tr>
<tr>
<td>CHAPTER 1 INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Background</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Need for the study</td>
<td>2</td>
</tr>
<tr>
<td>1.3 Aim and objectives</td>
<td>5</td>
</tr>
<tr>
<td>CHAPTER 2 REVIEW OF LITERATURE</td>
<td>7</td>
</tr>
<tr>
<td>2.1 Indoor air quality</td>
<td>7</td>
</tr>
<tr>
<td>2.2 Bioaerosols – nature, sources and associated health effects</td>
<td>8</td>
</tr>
<tr>
<td>2.2.1 Sources of bioaerosols in hospital environment</td>
<td>9</td>
</tr>
<tr>
<td>2.2.2 Factors influencing the bioaerosols</td>
<td>9</td>
</tr>
<tr>
<td>2.2.3 Microbial agents in bioaerosols</td>
<td>13</td>
</tr>
<tr>
<td>2.2.4 Aerobiological pathway</td>
<td>15</td>
</tr>
<tr>
<td>2.2.5 Health effects due to bioaerosols</td>
<td>16</td>
</tr>
<tr>
<td>2.3 Bioaerosol assessments</td>
<td>21</td>
</tr>
<tr>
<td>2.3.1 Principles of bioaerosol collection</td>
<td>22</td>
</tr>
<tr>
<td>2.3.2 Methods for detection of microorganisms</td>
<td>26</td>
</tr>
</tbody>
</table>
2.3.3 Detection of microbial constituents 28

2.3.4 Threshold Limit Values for bioaerosols 32

2.4 Bioaerosols in healthcare facilities 33

2.4.1 Characterisation of bioaerosols in hospitals 33

2.4.2 Variations in indoor bioaerosol concentrations 37

2.4.3 Airborne bacteria in healthcare facilities and association with nosocomial infections 37

CHAPTER 3 MATERIALS AND METHODS 40

3.1 Study design 40

3.2 Environmental sampling 41

3.2.1 Profiling of bioaerosols 41

3.2.2 Temporal variation of airborne microorganisms 44

3.2.3 Comparison of strains from air samples and clinical specimens 45

3.2.4 Sampling for endotoxin assay 45

3.3 Biological sampling 45

3.4 Sampling strategy 46

3.4.1 Preparation for sampling 48

3.4.2 Walk-through 48

3.4.3 Sample collection 50

3.4.4 Sample processing 53

3.4.5 Sample analysis 55

3.5 Aerobic bacteria 56

3.5.1 Phenotypic characterisation 56

3.5.2 Genotypic characterisation 59

3.6 Fungi 65

3.6.1 Phenotypic characterisation 65

3.7 Endotoxin assay 65

3.8 Statistical analysis 66

3.9 Ethical considerations 68
CHAPTER 4    RESULTS AND ANALYSIS

4.1 Microbial profile of air

4.1.1 Characterisation of airborne microorganisms in hospitals

4.1.2 Characterisation of airborne fungi in various locations of hospital

4.2 Factors influencing bioaerosols in indoor air of a healthcare facility

4.2.1 Factors in an artificially ventilated closed system

4.2.2 Factors in a naturally ventilated open system

4.3 Temporal variation of airborne microorganisms

4.3.1 Airborne microbial loads obtained from exposed plate method

4.3.2 Airborne microbial loads obtained from impinger method

4.3.3 Airborne microbial loads obtained from filter method

4.3.4 Comparison between active methods of air sampling

4.3.5 Comparison between indoor and outdoor microbial loads

4.4 Variation in airborne microbial loads within and between hospitals

4.4.1 Location wise comparison of airborne microbial loads

4.4.2 Hospital size wise comparison of airborne microbial loads

4.4.3 Airborne microbial profile

4.5 Correlation of environmental and clinical strains

4.5.1 Correlation of environmental strains of Pseudomonas with pathogenic species

4.5.2 Correlation between clinical and environmental coagulase-negative Staphylococci

4.6 Assessment of endotoxin in indoor air and personnel in an intensive care unit of a hospital

CHAPTER 5    DISCUSSION

5.1 Microbial profile of air

5.1.1 Characterisation of airborne microorganisms in Hospitals

5.1.2 Characterisation of airborne fungi in various locations of hospital

5.2 Factors influencing the bioaerosols in indoor air of a healthcare facility
5.3 Temporal variation of airborne microorganisms
  5.3.1 Choice of air sampling methods
  5.3.2 Temporal variation in airborne microbial loads
  5.3.3 Comparison between active methods of air sampling
  5.3.4 Comparison between indoor and outdoor microbial loads
  5.3.5 Microbial profile of indoor air

5.4 Variations in airborne microbial loads within and between hospitals

5.5 Correlation of environmental and clinical strains
  5.5.1 Correlation of environmental strains of *Pseudomonas* with pathogenic species
  5.5.2 Correlation between clinical and environmental coagulase-negative *Staphylococci*

5.6 Assessment of endotoxin in indoor air and personnel in an intensive care unit of a hospital

CHAPTER 6 SUMMARY AND CONCLUSION

6.1 Summary

6.2 Conclusions

6.3 Scope for further studies

REFERENCES

APPENDICES

Appendix 1: Ethics clearance certificate

Appendix 2 (a): Informed consent form for hospitals

Appendix 2 (b): Informed consent form and proforma for health personnel

Appendix 2 (c): Informed consent form and proforma for patients

Appendix 3: Proforma for walkthrough

Appendix 4 (a): Proforma for air sampling

Appendix 4 (b): Checklist for surface sampling

Appendix 5: Calculation to determine bioaerosol concentrations
<table>
<thead>
<tr>
<th>Appendix</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appendix 6</td>
<td>Characterisation of bioaerosols by active and passive methods of air sampling – a pilot study</td>
<td>202</td>
</tr>
<tr>
<td>Appendix 7</td>
<td>Worksheets pertaining to study objectives</td>
<td>210</td>
</tr>
<tr>
<td>Appendix 8</td>
<td>Details of sequences of <em>Pseudomonas</em> sp. referred from NCBI database</td>
<td>225</td>
</tr>
<tr>
<td>Appendix 9</td>
<td>GenBank accession numbers assigned to study sequences</td>
<td>231</td>
</tr>
<tr>
<td>Appendix 10</td>
<td>Publications and presentations</td>
<td>237</td>
</tr>
<tr>
<td>Appendix 11</td>
<td>Reprints of publications</td>
<td>240</td>
</tr>
<tr>
<td>Appendix 12</td>
<td>Biography</td>
<td>277</td>
</tr>
</tbody>
</table>