Microbial level assessment of indoor air quality in hospital wards

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SUMMARY
Inpatients spent usually several days or months to stay in the wards, poor indoor air quality of wards may lead to the significant bio-aerosol exposure risk of them. The objective of this study was to assess airborne bacteria and fungi levels of wards, and detect their characteristic in the existing modern hospital, it was designed according to present Codes in China. In this study, the Pediatrics, Cardiology and Respiratory were selected to conduct field experiments, and the contamination index was proposed to characterize airborne microbial levels. The microbial contamination indexes of indoor air quality show that wards were contaminated both in summer and winter, the bacterial and fungal concentrations in wards were mainly affected by indoor air-conditioning system, air temperature and humidity, personnel density, occupants’ activities. The obtained results should be used to contribute to recommendations for useful guidelines for design Code and hygienic specification of hospital.

INTRODUCTION
Nowadays, the HVAC systems are required not only to create a comfortable indoor environment, but also to maintain a safe and healthy indoor environment. In recent years, the number of the health problems are increasing, which caused by deterioration of indoor air quality, Sick Building Syndrome (SBS) and Building Related Illness (BRI). Plenty of evidence shows that these problems related to indoor air pollutants and biological aerosols. Some respiratory diseases such as rhinitis, asthma, and pneumonia are generally recognized to be caused by airborne bacteria and fungi (airborne microbes), which are carried by aerosols. Especially after the global outbreaks of SARS, H1N1, Ebola, MERS and so on, the epidemics caused by microbial infections became serious threats to people’s lives and took thousands of lives away, so people begin to pay more and more unprecedented attention to and study on the hygienic safety issues about indoor airborne microbe. In the coming Five years, the source of indoor airborne microbe and level assessment will be as a significant study field in China. A set of assessment system and evaluation methods suitable for China’s national conditions will be established.

Reviewed from the previous studies, most of them used the sedimentation, it is a passive sampling method, easy to be influenced by field condition, only a few of studies used the impactor to sample, all the studies did not detect the characteristic. For example, Korea researchers found that in spring and autumn the airborne bacterial concentrations were 404 CFU/m³ in hospital and 586 CFU/m³ in postpartum nurse center (Kim and Chi 2007). Jo W K and Seo (2005) found in winter, the airborne bacterial concentrations were 389 CFU/m³ in bars, 371 CFU/m³ in internet cafes and 1002 CFU/m³ in classrooms, and the concentrations in NEFP (no rain-front period) were 3891 CFU/m³ in bars, 2188 CFU/m³ in homes. Pastuszka et al. gave that the bacterial concentrations were 1021 CFU/m³ in healthy homes, 1100 CFU/m³ in moldy homes, and 272 CFU/m³ in offices from Upper Silesia, Poland (Pastuszka et al. 2000). Dong-UK et al. (2013) found that the lobby air was contaminated with microorganisms, the level recorded of bacteria was 7.2 × 102 CFU/m³; fungi: 5.5 × 102 CFU/m³. In China, the researchers found that the indoor bacterial concentration ranges from 47 to 12341 CFU/m³ for different ordinary civil buildings (Fang et al. 2013, Sun et al. 2011, Kang and Lv 2012).

For the airborne fungi, the concentrations were 382 CFU/m³ in hospital and 371 CFU/m³ in postpartum nurse center (Kim and Chi 2007). In winter, the airborne fungal concentrations were 237 CFU/m³ in bars, 209 CFU/m³ in internet cafes and 371 CFU/m³ in classrooms, and the concentrations in NEFP (no rain-front period) were 4169 CFU/m³ in bars, 2570 CFU/m³ in homes (Jo and Seo 2005). In China, the researchers found that the indoor fungal concentration ranges from 60-4000CFU/m³ (Fang 2015, Xie et al. 2008, Zhao et al. 2013), and found the urban and suburban indoor fungal concentration were 9099 CFU/m³ and 8333 CFU/m³ in winter, 3608 CFU/m³ and 7302 CFU/m³ in summer (Pei-Chih et al. 2000).

A few studies identified the dominant airborne microbe, most airborne bacteria were identified Gram-positive bacteria by microscopy (Kim and Chi 2007). The dominant fungal genera identified were Aspergillus spp, Penicillus spp, Alternaria spp and Cladosporium spp, both in winter and summer (Feng et al. 2007, Lee and Jo W K. 2006, Parat et al. 1997). Verde S C et al. (2015) found that the prevalent indoor fungal genera were Penicillus (41%) and Aspergillus (24%).

The documents mentioned above were on ordinary civil or public buildings, while hospitals are quite different from them due to the special function and occupants, which make hospitals to be special public service places. And the pathogenic microbes are relatively concentrated in hospitals. Those microbes would cause a series of health problems related to exposure to them. As the occupants like patients, infants and old people in hospitals are relatively weak and poor immune to infections, the health risks are greater. So the HVAC systems in hospitals are not only required to keep occupants comfortable but also to maintain safe and healthy medical environments for patients and medical staffs. Besides, the environments should be beneficial to the treatments and rehabilitations, reduce nosocomial infections and control stress.

Though it is so necessary to study the indoor air in hospitals, there are few researches on hospital indoor air microbes all over the world. The Nigerian and UAE researchers thought indoor air microbe contaminations in hospitals were related to human traffic and occupants’ activity stages (Awosika et al. 2012). The French researchers (Sautour et al. 2009) found in
indoor air, fungal concentrations were significantly lower in winter (2.7 to 3.1 CFU/m³) than in summer (4.2 to 5.0 CFU/m³) in both haematology wards, and the airborne microbial concentrations changed with the seasons in hospitals. In the haematological wards, the presence of Aspergillus spp was stable during the year (close to 20%). Bjerkandera spp was particularly abundant in winter (close to 30%); levels of Penicillium spp were highest in autumn while levels of Cladosporium spp were highest in spring and summer.

In this study, a series of field experiments in air-conditioned wards were performed and the airborne microbial contaminations were characterized. The obtained results are intended to contribute to recommendations for useful guidelines facilitating control and management of environment control systems in hospital wards, and it should be used to propose for the airborne microbiological assessment system and evaluation methods suitable for China's national conditions. In addition, these data could be the scientific bases for bacteriostasis and degerming in wards under the existing design and operation condition.

MATERIALS AND METHODS
A prospective study on airborne microbes was carried out in a modernized comprehensive hospital of a large type, occupying a size of over 360 thousand square meters of building area, owing 2900 beds, and the annual inpatient reach 120 thousand persons. It has ranked among the first group in comprehensive capability in China. No local sources of industrial air pollution were found in the vicinity of the hospital.

Experimental equipment
JWL-6 Microbe Impacting Sampler (Beijing Detector Inc., China) at the flow amount of 28.3l/min was used for microbiological air sampling, and the aerodynamic diameter range for each stage are as follows: Stage 1 (> 7.0μm), Stage 2 (4.7μm-7.0μm), Stage 3 (3.3μm-4.7μm), Stage 4 (2.1μm-3.3μm), Stage 5 (1.1μm-2.1μm), Stage 6 (0.65μm-1.1μm).

The XFS-280 Portable Pressure Steam Sterilizer was used for sterilization, the operating pressure range is 0.142Mpa-0.165Mpa, and operating temperature range is 126°C-129°C. The digital temperature and humidity recorder (Testol175-H2 hygrolologNT) is used to measure the air parameters like relative humidity, temperature, and supply air velocity, the measurement range of RH is 0.0-100%, and temperature range is -20°C-70°C.

Sample points
Three wards of different departments were selected as sampling rooms, which were on 3 different floors in an internal medicine building that consists of 13 floors. The wards were from Department of Pediatrics on the 2nd floor, Department of Cardiology on the 5th floor and Department of Respiratory on the 8th floor, which were the same of orientation. The number of sampling points depended on the room size. 2 sampling points were set in each ward which was on the diagonal of the ward. The height of the points was 1.3m. According to the microbial detection principles and methods, the layout is shown as Fig. 1.

The outdoor pedestrian entrance area on the 1st floor was selected as outdoor sampling point in winter. The outdoor air inlet and a vacant meeting room on 6th floor were selected as comparative testing points. There were seldom people near the air inlet and the air-conditioner in the meeting room was off during the sampling periods.

**Sampling time**
According to the patients, doctors and nurses' activities schedule in the wards, 9:00-11:30 a.m. and 14:30-17:00 p.m. were selected as field survey and sampling. Four sampling campaigns were performed in 19th, 21th, 25th and 29th Jan 2015 (winter), and three times were performed 19th Jun. 5th and 15th Jul 2016 (summer). The indoor air-conditioners in wards were on during sampling periods.

**Microbial air sampling**
The Microbe Impacting Sampler was used to sample actively, and sampling length is 2min each time. In the meantime, the number of occupants in the wards, occupants' activities, air supply velocity, temperature and relative humidity were recorded at the sampling time. The LB Agar medium is used for bacterial culture (tryptone 10g, yeast extract 5g, NaCl 10g, agar 15-20g, distilled water 1000ml), and the Sabourand's agar is used for fungal culture (peptone 10g, glucose 40g, agar 20g, distilled water 1000ml, pH 5.5-6.0). Bacteria plates were incubated at 37°C for 2 days, and Fungi plates were incubated at 28°C for 3-5 days.

**Analysis method of experiment data**
The airborne microbe concentrations were expressed in CFUs per cubic meter (CFU/m³) and the limit of quantification was 1 CFU/m³. It was calculated as the follow:

\[ Q = \frac{1000N}{(28.3TM)} \text{ CFU/m}^3 \]  \hspace{1cm} (1)

Where Q is the total airborne microbe concentration of a sample point and N is the total number of the microbe colonies on glass culture dishes of a sampling point, T is the sampling length, the value is 2 min, and M is the sampling times of one sample point.

The airborne bacteria were classified into Gram-positive or Gram-negative by the color after died by Gram’s Method, the 1000X lens was used to identify bacteria. On the other hand, the airborne fungal genera were identified according to the classification methods of Ainsworth and Baron by observing the form, shape and color of colony and spore through the microscope, the 400X lens was used for fungi identity.
Data were managed with SPSS (version 17.0). The data of 2 sample points were confirmed validity if they met following conditions. The bacterial and fungal concentrations from each sampling point fitted normal distribution (Sig. > 0.05), and there were no significant differences between the concentrations from the 2 sampling points in the same ward, analyzed by T-test (Sig. > 0.05).

**Microbial assessment method of indoor air quality**

In China, current national Codes for different indoor environments require for different threshold of airborne microbe, most of them are suitable for the ordinary civil or public buildings, and among them, some are for sedimentation, some are for impacting method. But there is only one standard (GB15982-2012) addresses the threshold in wards by sedimentation method, that is, the airborne bacterial concentration must be less than 600 CFU/m³.

It is found that the bacterial threshold for the general indoor environments (offices, homes, shops and cabins) by sedimentation method is about 1.57 times higher than that by impacting method, on the contrary, for the rooms (operating rooms and ICUs) in hospital with air cleaning facilities, the threshold by impacting method is 1.43 times higher than that by sedimentation method.

As we know, air conditioner systems in wards are almost the same as normal indoor environments, quite different from the operating rooms and ICUs in hospital, in terms of the concentration relationship of different sampling methods for normal rooms, the bacterial threshold for the general wards by impacting method should be 400 CFU/m³, besides, the WHO recommends the airborne bacterial concentrations in general wards should be 200-500 CFU/m³, so the estimated threshold concentration is reasonable based on the current documents.

There is not any current national standard Codes had addressed the airborne fungus thresholds in general wards, but there is a suggestion that the fungal threshold can be estimated according to the ratio of indoor airborne bacterial and fungal concentrations (Zhang et al. 2007, Gong 2011), as shown in Table 1, the R represents the ratio.

**RESULTS AND DISCUSSION**

**Bacterial concentrations of different sites**

The bacterial concentrations were classified statistically according to the departments. Concentrations of different wards from stage 1-6 are shown in Table 2-3.

**Table 2 Airborne bacterial concentrations of different wards in winter**

<table>
<thead>
<tr>
<th>Site</th>
<th>Stage</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Pediatrics</td>
<td>266</td>
<td>294</td>
</tr>
<tr>
<td>Cardiology</td>
<td>223</td>
<td>284</td>
</tr>
<tr>
<td>Respiratory</td>
<td>159</td>
<td>213</td>
</tr>
<tr>
<td>Outdoor</td>
<td>495</td>
<td>389</td>
</tr>
</tbody>
</table>

**Table 3 Airborne bacterial concentrations of different wards in summer**

<table>
<thead>
<tr>
<th>Site</th>
<th>Stage</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Pediatrics</td>
<td>202</td>
<td>297</td>
</tr>
<tr>
<td>Cardiology</td>
<td>135</td>
<td>264</td>
</tr>
<tr>
<td>Respiratory</td>
<td>213</td>
<td>487</td>
</tr>
<tr>
<td>Outdoor</td>
<td>38</td>
<td>53</td>
</tr>
<tr>
<td>Meeting room</td>
<td>7</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 2 shows that the airborne bacterial concentration of the Cardiology in winter was the highest, followed by pedestrian area and the Pediatrics, the concentration of the Respiratory was the lowest. The indoor airborne bacterial concentrations were 786-1589 CFU/m³, the concentration of outdoor pedestrian area was 1449 CFU/m³. Table 3 shows that the airborne bacterial concentrations of intake and meeting room were much lower than other sampling points in summer. The airborne bacterial concentrations were 1749-2865 CFU/m³ in wards, 314 CFU/m³ in vacant meeting room with air conditioner off and 565 CFU/m³ at the outdoor intake point. The percentage of airborne bacterial concentrations in winter. The concentrations of stage 1-3 took a large percentage of the total airborne bacterial concentrations in winter, ranging in 64.90-77.30%. In summer, the concentrations of stage 2-5 ranged 79.80-92.00% of the total airborne concentrations.

**Fungal concentrations of different sampling points**

The fungal concentrations were classified statistically according to the departments. Concentrations of all sampling rooms from stage 1-6 are shown in Table 4-5.

**Table 3 Airborne fungal concentrations of different wards in winter**

<table>
<thead>
<tr>
<th>Site</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Stage 4</th>
<th>Stage 5</th>
<th>Stage 6</th>
<th>Total</th>
</tr>
</thead>
</table>

In order to assess airborne bacterial and fungal contamination in this paper, the index W is proposed to characterize microbial level of indoor air quality, it reflects mostly the degree of airborne microbial contamination in wards. It can be calculated as follows:

\[ W = \frac{C}{S} \]  

Where \( W \) is the microbial contamination index, \( C \) is the measured concentration, \( S \) is the threshold. If \( W \leq 1 \), Airborne microbial contamination can be negligible, if \( W > 1 \), there is contamination, the \( W \) is bigger the contamination will be heavier.
As a result microscopy of winter bacterial samples, a total of 3487 colonies were identified, among them there were 960 colonies of Pediatrics, 1098 colonies of Cardiology, 638 colonies of Respiratory, and 791 colonies of pedestrian area. In winter microscopy, the Gram-positive bacteria made up 90% of the total colonies, among them more than 85% were Gram-positive cocci.

For summer bacterial samples, 4689 colonies were identified by microscopy, which included 1888 colonies of Pediatrics, 1127 colonies of Cardiology, 1415 colonies of Respiratory, 48 colonies of inlet point and 211 colonies of meeting room. The summer bacterial colony characteristics, more than 98% of total indoor bacterial colonies were identified Gram-positive, and furthermore 85% of total indoor bacterial colonies were Gram-positive coccus. 50% of total outdoor bacterial colonies were Gram-positive coccus and all outdoor Gram-positive bacterial colonies took about 81.3% of total outdoor colonies.

**Characteristics of fungal microscopy**

The fungi were observed under the microscope after culture, and then identified by spore characteristic. Among winter samples, 756 fungal colonies of indoor points and 156 of pedestrian area were identified. Which contained 21 species, they were Aspergillus spp. (Asp-), Penicillium spp. (Pen-), Cladosporium spp (Cia-), Candida spp (Can-), Trichoderma spp (Tri-a), Botrytis cinerea spp (Bot-), Bipolaris spp (Bip-), Chaetomium spp (Cha-), Trichophyton spp (Tri-n), Cephalosporium spp (Cep-), Alternaria spp (Alt-), Epicoccum spp (Epi-), Gloeosporium roseum spp (Gli-), Syncephalis tengii spp (Syn-), Trichothecium roseum spp (Tri-m).

For summer condition, 395 fungal colonies of indoor points and 26 of outdoor were identified. A total of 6 species were identified, they were Aspergillus spp, Penicillium spp, Alternaria spp, Cladosporium spp, Trichoderma spp, and Rhizopus spp.

In winter, the most dominant fungal genera of indoor points were Aspergillus spp, then Penicillium spp and Trichoderma spp. Comparison fungal genera indoor fungal genera with outdoor's, it can be seen that Penicillium spp is the most dominant outdoor fungal genus then followed by Alternaria spp and Cladosporium spp. However, in summer, the dominant indoor and outdoor fungal genera were almost the same, the most dominant fungi were Penicillium spp, then Aspergillus spp.

**Potential airborne contamination sources**

The bacterial concentrations of wards were higher than most reported studies. Taking into consideration the number of occupants in surveyed wards, the appropriate explanation could be that the personnel density affects the airborne bacterial concentrations. These wards were mostly full of 3 patients and 3 caregivers together with occasional visitors or medical staffs. The bacterial concentration of Respiratory was significantly lower than other wards in winter, it could be found that at the time of sampling, the number of occupants in Respiratory was smaller than other wards, according to the field records. And in summer, the number of occupants in Pediatrics was the biggest of all wards, and the airborne bacterial concentration of Pediatrics was the highest, it could be summarized as that the personnel density and occupants’ activities are the main influencing factors of airborne bacterial concentration. Supporting our findings, researchers in Korea found the indoor levels of airborne bacteria were high in childcare centers and low in elderly welfare facilities due to the active behavioral pattern of children in small spaces (Kim and Chi 2007); in United Arab Emirates, it was found that Pediatric
ward and female medical wards had the highest total count of bacteria, because of in Pediatric and female medical wards which exceeded visitors in other hospital areas (Jaffal et al. 1997); and a study on microbiological assessment of a hospital in Nigeria revealed that MMW (male medical ward) recorded the highest indoor airborne bacterial concentration and closely followed by MSG (male surgical general ward), the two wards were at their maximum personnel capacity (Awosika et al. 2012). Further, the outdoor airborne bacterial concentration was far less than wards in summer, and the concentration of meeting room was the lowest. It is known that nobody was in the meeting room and air-conditioners were off, but wards air-conditioners were on and windows were nearly closed. Thus it can be seen that there were few of correlations between indoor and outdoor airborne bacterial concentration but the personnel density and occupants’ activities for air-conditioning wards. Moreover, the dust in the air duct and the condensate water of air-conditioner are identified as sources of indoor airborne bacteria (Dong et al. 2008), and the effect of HVAC system is mainly to isolate the intake of outdoor particles (Parat et al. 1997), so the indoor airborne bacteria are from interior sources such as patients and HVAC system of the ward.

According to the suggested bacterial and fungal thresholds, it is found that there are generally microbial contaminations in the wards. The fungal contamination in summer is more than in winter, and the airborne bacterial contamination is far more heavily in winter. The hospital managers should take measures and targeted to disinfect. Although the existing hospital wards were designed according to present Codes in China, there had been the indoor airborne bacteria and fungi exposure risk of occupants, such as inpatients, caregivers, visitors and medical staff. It should take effective measures to reduce bio-aerosol contamination in hospital wards.

The Table 10 shows the average ratio is about 4 after removing the abnormal data. According to the Table 1 and these experimental data, the airborne fungal threshold concentrations in general wards are suggested to be 100 CFU/m³ by impacting method and 150 CFU/m³ by sedimentation method. The mean contamination indexes W of indoor air quality can be calculated in accordance with the formula (2), W values are as follows.

| Table 11 The contamination indexes of indoor air quality |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
|                            | Bacteria  | Fungi                              |
|-----------------------------|----------|------------------------------------|-----------------------------|-----------------------------|
|                            | Summer   | Winter                             | Summer                      | Winter                      |
| Pediatrics                  | 3        | 7                                  | 4                           | 2                           |
| Cardiology                  | 3        | 4                                  | 7                           | 3                           |
| Respiratory                 | 2        | 6                                  | 3                           | 3                           |
| Outdoor                     | 4        | 1                                  | 3                           | 2                           |
| Meeting room                | —        | 1                                  | —                           | 2                           |

The bacterial concentration of all wards in summer were higher than in winter, and the indoor temperature and relative humidity of air-conditioning summer wards were higher than in winter. It could be deduced that the indoor temperature and relative humidity maybe affect the airborne bacterial concentration, some other studies got the same conclusions (Jo W K and Seo 2005, Pastuszka et al. 2000, Lee and Jo W K 2006, Zhu et al. 2003).

Comparing bacterial with fungal concentrations at the same sample point in winter and summer, it can be seen that both concentrations of airborne bacteria and fungi in winter were the highest in Cardiology. But in summer, the highest airborne bacterial concentration in Pediatrics and the highest airborne fungal concentration was in Cardiology. It is not sure if the indoor temperature or relative humidity affects the airborne fungal concentration. According to the field records, it shows that the indoor personnel density and occupants’ activities may not be the main influencing factors of airborne fungal concentrations. Some studies indicated that indoor airborne fungal concentrations were significantly high due to the dampness or mold (Pastuszka et al. 2000, Lee and Jo W K 2006, Salonen et al. 2007), and the dust in the air duct and the condensate water of air-conditioners were identified as sources of indoor airborne fungi (Yao 2008). So, the air humidity and HVAC system could be the main sources of airborne fungi in wards.

**Microbial contamination index of indoor air quality**

Based on the experimental data, the ratio of indoor airborne bacteria and fungi in different sampling wards are shown in the Table 10.

<p>| Table 5 The ratio of indoor airborne bacteria and fungi |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|</p>
<table>
<thead>
<tr>
<th></th>
<th>Pediatrics</th>
<th>Cardiology</th>
<th>Respiratory</th>
<th>Outdoor</th>
<th>Meeting room</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>3.52</td>
<td>2.36</td>
<td>2.27</td>
<td>4.24</td>
<td>—</td>
</tr>
<tr>
<td>Summer</td>
<td>—</td>
<td>5.40</td>
<td>7.08</td>
<td>2.96</td>
<td>1.72</td>
</tr>
</tbody>
</table>

CONCLUSIONS

The microbial levels of indoor air quality in hospital wards were revealed by the field experiments in winter and summer. Some highlight conclusions could be drawn as following:

a) The airborne bacterial concentrations in winter are much lower than in summer, but the airborne fungal concentrations show the opposite condition. The bacterial concentrations affected by indoor the temperature, relative humidity, HVAC system, personnel density and occupants’ activities; the airborne fungi concentrations affected by indoor air humidity and HVAC system. During the sampling period, wards air-conditioners were on and windows were nearly closed. The outdoor air supply by air-conditioning systems, the outside airborne microbes will be mostly isolated by filters, the outside sources shouldn’t be main influencing factors.

b) According to the bio-aerosol size distribution, the airborne bacterial concentrations of the size bigger than 3.3μm ranged 64.90-77.30% in winter while in summer that of 1.1-4.7μm ranged 79.80-92.00%. Airborne fungal concentrations of the size bigger than 1.1-4.7μm ranged 75.70-83.00% in winter while in summer the size bigger than 1.1μm ranged over 95%.

c) The aerosols sizes ranged 5-10μm could enter the trachea or bronchus, and the smaller than 5μm the aerosols could be deep into the respiratory tract and alveoli. The weak patients’ long time exposure to this kind of indoor environment would be very harmful. With better understanding airborne microbe...
contamination characteristics and the influencing factors, some effective infection prevention or air control measures in wards should be established to reduce bio-aerosol exposure risk of occupants especially the vulnerable group.

d) The Gram-positive bacteria are most frequent phenotype by microscopy in wards bio-aerosols, and the dominant fungal genera are Aspergillus spp. Penicillium spp. Alternaria spp and Cladosporium spp. both in winter and summer.

e) The suggested assessment method was proposed based on current Codes and documents, that is, airborne fungal threshold concentration in wards are respectively 100 CFU/m³ by impacting method and 150 CFU/m³ by sedimentation method, the airborne bacterial threshold concentration are 400 CFU/m³ by impacting method and 600 CFU/m³ by sedimentation. According to the index of microbial contaminant, there were somewhat problems of indoor air quality in the hospital wards in spite of meeting present design Codes in China.

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