Assessment of the standardized training residency Exposure Level and Concentration of the Indoor Microbial Aerosols in Hospital Buildings in Winter

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Abstract. In order to deeply analyze the pollution situation, distribution characteristics and exposure level of microbial aerosol in different functional buildings, the concentration, particle size distribution and resident exposure level of bacterial aerosol in different functional places of hospitals were studied in this paper. The results show that: 1) There are harmful environmental exposure and environmental health risks in the standardized training of residents in China, which need to be paid enough attention to improve their occupational environment. 2) The concentration level of indoor bacterial aerosol in various places of hospital in winter is outpatient hall > nurse station > doctor's office > outdoor > general ward. 3) The median diameter of indoor bacterial aerosols in hospital buildings is smaller than that of outdoor ones, and there are differences in particle size distribution of indoor bacterial aerosols in different types of places. When indoor pollution sources are strong or indoor ventilation is poor, the particle size distribution characteristics of bacterial aerosols are mainly affected by indoor pollution sources.

1. Introduction

The concentration level and particle size distribution of indoor microbial aerosol are affected by environmental factors [1], so there are differences in microbial pollution levels in indoor air of different types of buildings [2]. Hospital building environment has the characteristics of large flow of people and frequent activities, especially the outpatient hall and nurse station are relatively concentrated areas of various pathogens, which are easy to cause mass infection.

Therefore, it is of great significance to study the concentration characteristics of indoor microorganisms in different functional places of hospitals and the exposure level of residents trained in the standardized resident training base for improving the indoor microbial pollution level in hospital places, protecting the health of trained residents and formulating the basic data for providing the standard of prevention and protection facilities and equipment.
In this paper, the concentration, particle size distribution and exposure level of bacteria and fungi aerosols in different functional sites were studied. Firstly, the indoor and outdoor bacterial aerosol concentration levels in different functional places were analyzed, and then the particle size distribution characteristics of bacterial and fungal aerosols in different places in hospitals were discussed by logarithmic regression model. At the same time, the difference of indoor bacterial aerosol concentration distribution was analyzed by Kruskal-Wallis test. Finally, the exposure levels of bacterial aerosols in medical staff and consultation rooms of different functional buildings in base hospitals were evaluated, and the differences of human exposure levels to bacterial aerosols in different functional rooms were compared.

In addition, according to the WHO recommended standard and the test results in this paper, when analyzing the concentration level of microorganisms in different functional areas in hospitals, the concentration limit of bacterial aerosol is 500 cfu/m³.

2. Experimental and analytical methods

2.1. Test object
Taking different functional places in a base hospital in Qiqihar, China, which undertakes standardized training for residents, as test objects, microbial aerosols and related environmental parameters in different functional places of these hospitals were tested in winter from 2018 to 2019 and from 2019 to 2020. Four typical functional areas were selected: Outpatient hall, doctor's office, nurse station and general ward. The basic information of each site is shown in Table 1.

| Place            | Site area /m² | Number of people in the room/(person) | Adequate ventilation | Plants | Ground property | Medical and domestic garbage cans |
|------------------|---------------|---------------------------------------|----------------------|--------|----------------|----------------------------------|
| Outpatient hall  | 440           | 40-200                                | No                   | No     | Ceramic tile   | Yes                             |
| Doctor's office  | 20-60         | 5-10                                  | No                   | No     | Ceramic tile   | Yes                             |
| General ward     | 20-30         | 2-6                                   | Yes                  | No     | Ceramic tile   | Yes                             |
| Nurse station    | Semi-open     | 2-6                                   | Yes                  | No     | Ceramic tile   | Yes                             |

2.2. Instruments and drugs
The instruments needed for preparing bacterial culture medium mainly include microbalance, pressure sterilization pot, clean workbench and related drugs. The instrument for collecting bacterial aerosol is cyclone wet wall biological aerosol sampler. The main instrument for culturing culture medium after sampling microbial aerosol is electrothermal constant temperature incubator.

2.3. Experimental method
Indoor bacterial aerosol concentrations in different functional places of hospitals were tested in two winters from 2018 to 2019 and from 2019 to 2020. During the test, a survey was conducted including personnel activities, building characteristics, ventilation, indoor population, air conditioning and sanitation.

2.3.1. Setting of test objects and sampling points. Select a base hospital in Qiqihar, China, which undertakes standardized training for residents. The tests include outpatient hall, doctor's office, nurse station and general ward. Test each site continuously for at least 2 days. According to GB/T 18204.3—
2013 public places hygiene inspection method, part 3: air microorganism [3], sampling points are set and the plane and three-dimensional layout of different places are comprehensively considered. the sampling height is set to be about 1.5 m from the ground and avoid vents.

Before the test, the microbial sampler shall be inspected and calibrated, including duplicate sample verification at the same sampling point and method verification at the same sampling point by natural sedimentation method and impact method.

2.3.2. Microbiological test. The flow rate of bacterial aerosol sampling is 28.3 L/min, and the time is 10 min. When sampling after disinfection with alcohol, take and place the Petri dish in strict accordance with the operation requirements, and avoid the influence of personnel activities and breathing. Figure 1 is a sampling map of microbial aerosol in doctor office of a hospital in a base hospital which is responsible for standardized training of resident.

![Figure 1](image)

**Figure 1.** Field sampling map of microbial aerosol in hospital doctor's office

After the sample is collected, wrap or seal the numbered Petri dish with sealing film immediately, and put it into the constant temperature incubator as soon as possible. The roots were cultured in the medium containing bacteria for 2 days at 36 °C and 28 °C. After the completion of culture, count the bacteria in each culture dish, and correct the counting results by positive-hole [4] correction method.

2.4. Quality assurance and statistical analysis methods
In this study, blank control was carried out in the preparation of the same group of culture media, and the results showed that there was no colony growth in the blank culture media. In addition, before the test, it was verified that impact sampling and sampling for 10 min was the best sampling scheme.

The Kruskal-Wallis test with multiple independent samples was used to analyze the difference of indoor bacterial aerosol concentration distribution in various functional buildings in hospitals.

2.5. Calculation method of microbial aerosol exposure
Exposure refers to the contact of human body with a certain pollutant at a certain time, and the integration of exposure for a certain period of time is the exposure. For convenience of calculation and understanding, the average concentration of pollutants is often used for calculation. The calculation of exposure is shown in Formula (1) [10]:

$$E = \int TC(t) \cdot dt$$

In formula (1), e is the exposure (cfu·h/m³); C(t) is the concentration of pollutants, which is usually replaced by the average concentration in practice (cfu/m³). T is exposure time, h.

For indoor microbial aerosol, it mainly enters the body through the human respiratory system, while a small amount enters the body through other ways such as dietary intake and skin contact can be ignored.
Therefore, according to the definition of exposure, the potential exposure is used to evaluate human exposure, and its calculation method is shown in Formula (2) [5]:

$$D = \int C(t) \cdot IR(t) \cdot dt$$  \hspace{1cm} (2)

In formula (2), $d$ is the potential exposure, cfu /d; $C(t)$ is the concentration of pollutants, which is often replaced by the average concentration in practice, cfu /m$^3$; $IR(t)$ is respiratory rate per unit time, m$^3$/h; $T$ is exposure time, h/d.

The exposed people in the hospital environment are mainly divided into two categories: doctors and medical staff, and the residents trained in the standardized training base of residents are divided into male trainees and female trainees. The respiratory rate of male trainees and female trainees is shown in Table 2[6].

**Table 2. Human respiratory rate under different activity intensity**

| Exposed people                      | Respiratory rate under different activity intensity/ (m$^3$/h) |
|-------------------------------------|---------------------------------------------------------------|
|                                     | Rest  | Sit  | Minor activity | Moderate physical activity | Heavy physical activity |
| Male trained physician              | 0.49  | 0.57 | 0.98           | 1.87                        | 2.82                      |
| Female trained physician            | 0.33  | 0.41 | 0.69           | 1.39                        | 2.13                      |

3. Results and analysis

3.1. Concentration level and particle size distribution of bacterial aerosol in hospital room

3.1.1. Concentration level of indoor bacterial aerosol. Figure 2 shows the average concentration of indoor and outdoor bacterial aerosols in different places of hospitals in winter.

![Figure 2. Comparison of bacterial aerosol concentration in different places of hospital](image-url)
Figure 2 shows that the concentration of bacterial aerosol in outpatient hall and doctor's office is relatively high in winter, with average concentrations of (579±196) cfu/m3 and (550±224) cfu/m3 respectively, both exceeding the concentration limit of 500 cfu/m3 given in this study. The highest concentration of bacterial aerosol was found in the outpatient hall, with the maximum of 841 CFU/m3. The reason is that although the hospital outpatient hall has a large space and relatively good air circulation, the susceptible population and various pathogens are relatively concentrated and the personnel density is large. In the nurse station, general ward and outdoor, the indoor bacterial concentration in the general ward was the lowest, which was (248 ± 166) cfu/m3, which should be attributed to the relatively small indoor personnel density and the staff cleaning on time. In addition, the average concentration of indoor bacterial aerosol in outpatient hall, nurse station and doctor's office was higher than that in outdoor. Because hospital places are often cleaned and disinfected, and the sanitary condition is good, the human activities in indoor pollution sources should have a great influence on the concentration level of bacterial aerosol.

In addition, the results of kruskal-Wallis difference test showed that there were significant differences in bacterial aerosol concentrations in different places of hospitals (Sig < 0.05).

![Figure 2. Comparison of particle size distribution of bacterial aerosol in different places of hospital](image)

3.1.2. Particle size distribution of indoor bacterial aerosol. Bacteria with different particle sizes enter the respiratory tract through human breath at different positions, and their health effects will be different. The first to second stages of microbial sampler can capture bacterial aerosol with particle size above 4.7 μm, which is equivalent to the microbial particles captured by upper respiratory tract, and the third to sixth stages can capture bacterial aerosol with particle size between 0.65 and 4.7 μm, which is equivalent to the particles captured by lower respiratory tract. Figure 3 shows the comparison of the average and standard deviation of bacterial aerosol particle size distribution between indoor and outdoor hospitals in different places in winter. Figure 3 shows that the particle size of bacterial aerosol in doctor's office, nurse's station and general ward is mainly distributed in 1.1 ~ 4.7 μm, and the average concentration of bacterial aerosol in this particle size range accounts for 75.70%, 68.02% and 65.25% of the total average concentration, respectively. By analyzing the respiratory department, it was found that the bacterial aerosol in the doctor's office accounted for 44.73% in the range of 1.1 ~ 2.1 μm. The reason lies in the fact that most people in the doctor's office suffer from diseases. When the patients talk and cough, they will produce a large number of aerosol particles, and the tiny droplets will be quickly dried and contracted into condensation nuclei with a particle size of 0.5 ~ 5 μm, and the condensation...
nuclei will be suspended in the air. However, the particle size distribution of bacterial aerosol in outpatient hall is different from that in doctors' offices and nurses' stations. The particle size distribution of bacterial aerosol is mainly in Grade I, Grade III and Grade IV, and there is little difference between Grade I and Grade V.. However, the proportion of outdoor bacterial aerosol in the first grade is the highest, which is basically consistent with the particle size distribution of bacterial aerosol in the outdoor environment of general colleges and universities. There are obvious differences in particle size distribution of bacterial aerosols inside and outside hospitals.

To sum up, by analyzing the particle size, distribution and median diameter of indoor bacterial aerosols in hospital places, it is found that the median diameter of indoor bacterial aerosols is smaller than that of outdoor ones. When indoor pollution sources are strong or indoor ventilation is poor, the particle size distribution characteristics of bacterial aerosols in hospital places are mainly affected by indoor pollution sources.

3.2. Indoor microbial aerosol exposure

Literature [7] shows that the average exposure time of hospital population in outpatient department is 2h, while the trained residents are determined by their actual working hours, and the average exposure time is 8h. According to formula (1), the exposure amount of bacteria and fungi aerosol of hospital population in each place was calculated, and the results are shown in Table 3.

**Table 3.** Average daily exposure of hospital population in various places

| Hospital            | Bacterial exposure of trained residents/ (cfu·h/m³) | Bacterial exposure of visiting people/ (cfu·h/m³) |
|---------------------|-----------------------------------------------------|-------------------------------------------------|
| Outpatient hall     | 3562                                                | 880                                             |
| Doctor's office     | 4503                                                | 1320                                            |
| Nurse station       | 1891                                                | 627                                             |
| General ward        | 4921                                                | 1358                                            |

It can be seen from Table 3 that the daily average exposure of bacterial aerosol in hospital rooms to medical staff and medical staff is in the range of 627 ~ 1 358 cfu h/m³ and 1 891 ~ 4 921 cfu h/m³ respectively. The exposure of indoor microbial aerosol to medical staff is significantly higher than that to medical staff, mainly due to the difference of exposure time. The exposure of bacteria and fungi aerosol in outpatient hall to hospital population is higher than that in respiratory waiting hall, nurse station and general ward, which is mainly due to the fact that the exposure is mainly affected by the concentration level of microorganisms in different places when the exposure time is the same.

4. Conclusions

1) The standardized training of resident doctors in China is the reserve resource of China's health service and the reserve force of China's medical and health team. They have harmful environmental exposure and environmental health risks, which need to be paid enough attention to. To improve their occupational environment and reduce the health risk of their training environment is conducive to the normal conduct of resident standardized training and provide enough medical talents for the whole country and society.

2) In winter, the concentration of bacteria aerosol in the hospital was in the order of outpatient Hall > pediatric nurse station > doctor's Office > outdoor > general ward.

3) The results showed that the median diameter of indoor bacterial aerosol was smaller than that of outdoor, and the particle size distribution of bacterial aerosol in different types of places was different. When the indoor pollution source intensity was large or the indoor ventilation was poor, the distribution characteristics of bacterial aerosol particle size were mainly affected by indoor pollution sources.
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