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The effect of air-conditioning parameters and deposition dust on microbial growth in supply air ducts

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ABSTRACT

To investigate the effect of air-conditioning parameters (including temperature, relative humidity and air velocity) and deposition dust on microbial growth in supply air duct, a complete test facility according to ASHRAE Standard 62.1-2007 was constructed. A series of experiments for testing microbial concentration (including bacteria and fungus) were conducted under different working conditions (such as different temperatures and relative humidity). The air velocity was constantly kept at 2.0 m/s. Orthogonal design was employed for the analysis of test data. The results indicated that air velocity attenuation down the direction of the supply air affected dust distribution at the bottom of duct, to some extent, and the number of microorganisms was positively correlated with the quantity of dust. In the range of temperature 22–32 °C and relative humidity (RH) 40–90%, microbial growth significantly accelerated with higher temperature and RH increasing. The organic compounds composing the dust also had great impact on microbial growth. The basic researches are contributed to control the growth of microorganism and improve the indoor microenvironment in the air-conditioning room.

1. Introduction

In recent years, great consideration has been paid to create healthy indoor air quality. Many researches indicate that IAQ has great relation to the ventilation and air-conditioning system of building [1–3]. HVAC system was used to supply fresh air and remove the pollutants caused by the activity of occupants, the equipment of furniture and the materials of decoration. However, the modern large building is so airtight on account of energy saving. When the HVAC system cannot be designed and maintained appropriately, it can act as the source of indoor pollution [4,5]. The supply air duct as the major HVAC component provided large inner surface area. After long-time operation, a mass of dust involving microorganisms deposited on the internal underside of duct. The reproduction of microorganism releases various metabolic products such as odors, toxin and allergic substance which can transmit to the whole building with wind and intensify the microbial contamination of indoor air, furthermore, severely influence the IAQ and human health [6–9]. Chang found out that high moisture contributed to the growth of *Penicillium chrysogenum* [10]; Wilson noted *Ramu lispora* Miura mainly grew on fan impeller, duct system and the coil [11]; Pasanen investigated the accumulated dust on the air duct of 24 houses fixing mechanical ventilation and found *Cladosporium* sp., *Penicillium*, *Aspergillus* and yeasts made up more than 90% of fungi [12]; Sugawara found that the concentration of fungi in the air duct was consistent with that in air-conditioning room [13]; Liu from Tongji University found that the accumulated dust in the air duct directly affected the PM10 and the concentration of microorganisms via the survey of the HVAC [14]; Chen from Tsinghua University indicated that 82% HVAC were moderately and seriously polluted [15]. Lu maintained that microorganism could grow on the surface of supply air system, diffused to down stream and then affected the concentration of the microorganisms [16].

The above studies showed that the effects of the airborne microorganisms on the IAQ and human health relate to the ventilation and air-conditioning system. Air duct has supplied a hotbed for microorganisms. The accumulated dust and microorganisms in the supply air duct have turned into a pollution source [22–24]. However, the mechanism of contamination process is not clear enough since the situation is hardly perceived, only when the maintenance and reconstruction of the system take place. Hence, we investigated the effect of air-conditioning parameters (including temperature, relative humidity (RH) and air velocity) and deposition dust on microbial growth in supply air ducts by setting up test facility according to ASHRAE Standard 62.1–2007. The basic researches are contributed to control the growth of microorganism and improve the indoor microenvironment in the air-conditioning room.

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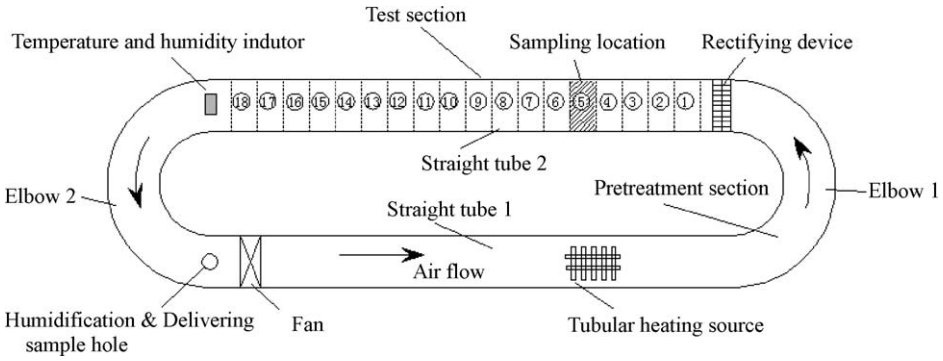

Fig. 1. Layout of the test facility.

2. Experiment design and test

2.1. Test facility

The test facility was composed of air duct system and regulatory system. The tests were conducted in the college of Environmental & Municipal at the Xi'an University of Architecture and Technology.

2.1.1. Air duct system

The duct design conforms to ASHRAE Standard 52.2-1999. The duct is a closed-loop wind tunnel through which air can be continuously circulated (Fig. 1). The test duct is constructed of galvanized iron sheet with the cross 0.1 × 0.1 m. The whole air duct was constituted with two straight pipes and elbow 0.1 m radius. The straight duct 1 and the elbow 1 composed the pretreatment device, including the axial fan, tubular heating source and rectifying device. The original dust was delivered to the hole behind the fan. The straight tube 2 was the test section, including the inductor of the temperature and humidity. The top surface could be unclosed in order to sample from the bottom of the air duct.

2.1.2. Regulatory system

The regulatory system constituted of one temperature and humidity controller (WSD-ZDB/A (TH)), two contact voltage regulators and one ultrasonic air humidifier. The technical parameters of the temperature and humidity are shown in Table 1. Temperature and humidity controller was connected with the inductor at one end. At the other end, it was connected with the heat source and humidifier. The auto-controlling could be realized by directly checking the temperature and humidity with the inductor controlling the opening and closing of the heat source and humidifier. The nozzle of the humidifier was joined to the hole on the air duct by the plastic pipe. The vapor supplied by the humidifier was uniformly distributed with the air movement, could assure the uniform distribution of humidity in the air duct. Two contact voltage regulators were used to control the voltage of fan and heat source, respectively. The air velocity 0–0.2 m/s was available by controlling the frequency of the fan. The temperature between 22 and 40 °C and the relative humidity between 30% and 95% could be carried out by controlling the voltage of heating and humidifier, respectively. In addition, the test of the velocity uniformity, concentration uniformity and leakage were conducted in the laboratory.

Table 1
Technique data of temperature and humidity controller (WSD-ZDB/A (TH)).

Technique data	Range of measuring	Precision	Resolution
Temperature	−55 to 125 °C	±0.5 °C	0.1 °C
RH	10–99% RH	±5% RH	1% RH

2.2. Experiment process

2.2.1. Original dust sampling and characterization

The centralized air ventilation system in Shannxi History Museum was chosen as the object. We sampled the dust by using vacuum cleaner in six different parts on the supply air duct [17]. The dust were conserved in jar in drying method, then sterilized and sealed out especially moisture. The original dust possessed the following properties: moisture content 5.13%, pH 6.38; the analysis of particle size was conducted by the laser particle size analyzer (LS230), the result is that particle size <1.475 μm, particle size ≪9.867 μm, particle size <28.63 μm made up 10%, 50%, 90%, respectively (Fig. 2).

The bacteria deposited on dust comprised 53% gram positive and 47% gram negative by checking on the basis of experiment incubation. The detective fungi contained *Penicillium*, *Aspergillus*, *Cladosporium*, *Alternaria*, *Mucor*, and *Acaulospor*, of which the predominant bacteria were *Penicillium*, *Aspergillus*, and *Cladosporium*.

2.2.2. Determination of experimental parameters

To simulate the actual situation, the boundary conditions could be selected as follows:

Air velocity: 2.0 m/s (simulating the lowest air velocity in supply air duct).
Temperature and RH: The values of both followed Table 2.

2.2.3. Testing procedures and method

Prepared work: Firstly, the air duct must be cleaned by scrubbing the inner of the air duct with75% medical alcohol and sterilizing by the UV-lamp (the UV-lamp could produce the ozone so as to kill the microorganisms which are difficult to remove by scrubbing with medical alcohol). Then, the air duct was sealed for 30 min sterilization. The requirements of different working conditions could be obtained by the controlling the air velocity, temperature and the RH.

Rules of delivering the original dust: 10 g original dust was delivered to the duct through sample delivering hole. Test section was divided into 18 sampling locations by 5 cm space (see Fig. 1) numbered successively from ①–⑱ and each area was 50 cm^2. We sampled 9 times in each working condition and we got two samples in one time. The sequence, time and location of sampling were showed in Table 3; the sampling locations ① and ⑱ were taken as background level after 10 min of delivering the original dust;