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The Effect of the air change rates on the deposition rate of particles matter in the room

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Abstract
In this paper, the influence of the settling rate of particles of different particle sizes in a room was investigated using a method that detects the concentration of particles in the room under different working conditions. The effect of the number of air changes in the room on the settling rate of different particle sizes is analysed, and a numerical relationship between them was fitted. The results show that the settling rate of particulate matter increases with the number of air changes, and the larger the particle size (PM10), the greater the settling rate and the greater the effect of changes in the number of air changes; the settling rate is fitted linearly and logarithmically to the number of air changes, and the standard deviation between the measured and calculated values of the two relationships were found to be similar to the actual situation.

Keywords: *particles, deposition rate, air change rate*

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I. INTRODUCTION

With the development of society, people are spending more and more time indoors [1-2]. Moreover, studies have shown that indoor particulate matter pollution can seriously affect human health [3-4]. The sources of indoor particulate matter generally come from fumes, cigarettes, and indoor human activities [5]. When there are no human activities in the room and other activities that can produce large amounts of particulate matter, the movement of particulate matter in the room is mainly sedimentation. The deposition of particulate matter is a critical way to reduce the concentration of particles in a room, and the percentage of particulate matter deposited per unit time is called the deposition rate K. In an earlier study, Kulmala M [6] and others found that the deposition rate of particulate matter was an important factor affecting the ratio of indoor to outdoor particulate matter concentrations. In 2006, D.H. Bennett and P. Koutrakis [7], based on indoor and outdoor particle concentration and the number of room air changes, used a method derived from calculating the particle penetration coefficient and deposition rate. Several other scholars abroad have shown after research [8-10] that the deposition rate of PM2.5 is close to 0.4h-1, and that of PM10 is close to $1h^{-1}$.

This study investigated the magnitude of the settling rate of different particle sizes (PM10, PM2.5) under different indoor air exchange conditions. It also investigated the effect of the number of air exchanges on the settling rate of different particle sizes and compared it with the measured values by fitting.

II. EXPERIMENTAL PRINCIPLES

The settling of particulate matter is one of the main modes of movement of particulate matter. The main factors affecting the settling of particulate matter in a room are gravitational settling, Brownian action and inertia. When the doors and windows of a room are closed, the settling of particulate matter is the most critical factor in decreasing particulate matter concentration. So the settling rate of particulate matter can be obtained from the falling curve of particulate matter. As an example, take Figure 1:

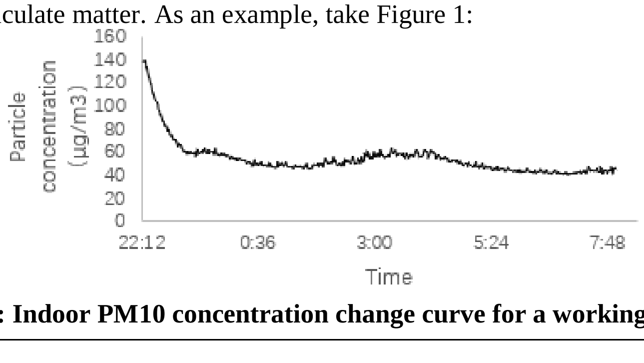

Figure1: Indoor PM10 concentration change curve for a working condition

Figure 1 shows the variation curve of indoor PM10 concentration in a specific working condition. According to Figure 1, it can be found that after closing the doors and windows, the concentration of particulate matter goes through a significantly decreasing section before entering the stable section, and the average slope of the decreasing section is the settling rate in this working condition.

In order to determine the decay time of the falling section, it is necessary to define the instability： S。

$$S = \sqrt{\frac{\sum_{i=1}^{n}(C_{in,i} - \bar{C}_{in})^2}{n-1}} / \bar{C}_{in} \tag{1}$$

Where Cin is the average indoor particulate concentration during the set period, μg/m3; n is the number of samples; Ci is the indoor particulate concentration value at each sampling moment during the set period, μg/m3.

The start moment of particle settling is positioned at τ0, the end moment of rapid decay is τ1, and the time interval of Δτ backward, when the instability of each measurement point satisfies $|S_{\tau 1+\Delta\tau}| \leq 2\%$ at the same time, τ1 is judged to be the decay stability moment. The decay start moment to the decay stability moment is the stable decay time τ1-τ0, and Δτ is set to 10min in this experiment when the decay stability of particles is judged.

The equation for the settling rate of particulate matter is as follows.

$$K = \frac{C_{\tau 0} - C_{\tau 1}}{C_{\tau 0}(\tau_1 - \tau_0)} \tag{2}$$

Where Cτ0 is the concentration at the initial moment of particle settling, τ0; Cτ1 is the concentration at the end of particle settling, τ1.

III. EXPERIMENTAL PROGRAMME

3.1 LABORATORY INTRODUCTION

To investigate the effect of the number of air changes in a room on the settling rate of particulate matter. The experiment was carried out in a laboratory in Shanghai with a room size of 4 m × 3 m × 3 m.

3.2 Air Change Rate

The settling of particulate matter is one of the main modes of movement of particulate matter. The main factors affecting the settling of particulate matter in a room are gravitational settling, Brownian action and inertia. When the doors and windows of a room are

The tracer gas method for measuring room ventilation can be divided into the following three methods: pulse, rising, and falling. By comparing the advantages and disadvantages of the three methods [11], the falling method, which is more economical and easier to control, was chosen as the method for measuring room ventilation in this experiment.

During the experiment, the tracer gas was released into the closed room. The most commonly used tracer gases are CO_2 and SF_6. The most significant advantage is that SF_6 is not present in the air and can still be easily detected at low concentrations, so SF_6 was chosen as the tracer gas for this experiment.

When releasing SF_6, a fan distributes the gas evenly around the room. The release is stopped when the concentration of SF6 gas reaches a particular value. At this point, the room is ventilated by natural infiltration, and the decay rate of the tracer gas can be measured to obtain the amount of ventilation in the room and, therefore, the number of air changes in the room. The tracer gas decay method for measuring room ventilation is calculated as follows：

$$\alpha = \left[\ln C_1 - \ln C_\tau\right] / \tau \tag{3}$$

Where α is the average air exchange rate, h^{-1}; C_τ is the tracer gas concentration measured at the moment of τ, mg/m3; C_1 is the tracer gas concentration at the beginning of the measurement, mg/m3; τ is the measurement time, h.

When measuring tracer gas concentrations, they can be divided into diagonal and plummet methods according to national standards. The room area of this experiment is small, and the gas mixture in the room is homogeneous, so the diagonal arrangement method, which is simple to operate and easy to control, is used to determine the room's ventilation.

As the number of ventilation changes in the natural permeability state of the room cannot be set by humans, this experiment is based on the measured number of ventilation changes in the room during a specific time as a known variable for different experimental working conditions.

3.3 PARTICLE CONCENTRATION

This experiment requires the investigation of the settling rate of particulate matter under different air exchange conditions, so the indoor particle concentration under different working conditions needs to be measured. The measurement of particle concentration is based on the relationship between the physical properties of the particles (including mechanical, optical and electrical) and the quantity or mass of the particles, which is detected by the appropriate instruments and methods [12].

Table 1: Rerun Column, Specification.

Work conditions	1	2	3	4	5	6	7	8
α (h^{-1})	0.26	0.32	0.36	0.43	0.48	0.55	0.61	0.64
K(PM10)(h^{-1})	0.32	0.41	0.44	0.54	0.60	0.65	0.73	0.76
K(PM2.5)(h^{-1})	0.32	0.39	0.43	0.48	0.58	0.64	0.65	0.67

According to Table 1, the settling rate of particulate matter increases gradually with the number of air changes in the room, where the settling rate of the larger particle size (PM10) is somewhat more significant than that of the particulate matter (PM2.5).

A linear and logarithmic fit of the settling rates of PM2.5 and PM10 to the number of air changes for the eight operating conditions is shown in Figure 2:

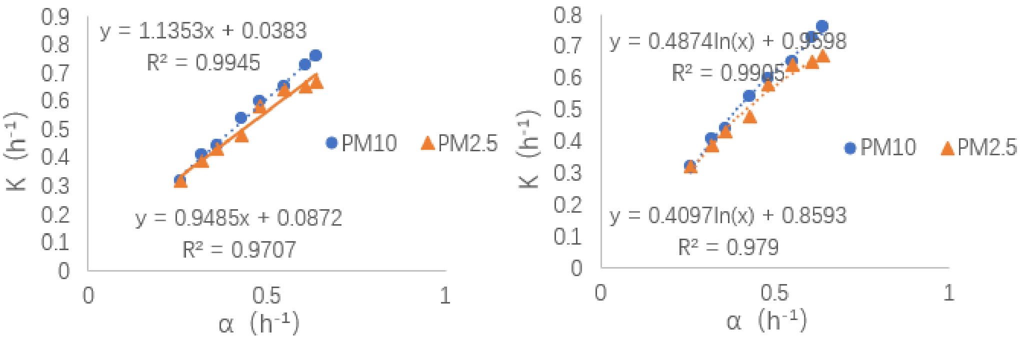

Figure 2: Fitting curves for indoor PM2.5 and PM10 deposition rates versus the number of air changes (linear fit on the left, logarithmic fit on the right)

A linear fit of the settling rate to the number of air changes is obtained from Figure 2 (left), as shown in Equation 4:

$$PM10 \cdots K = 1.1353\alpha + 0.0383$$
$$PM2.5 \cdots K = 0.9485\alpha + 0.0872 \tag{4}$$

The standard deviation between the measured and fitted values of the settling rate for PM10 is calculated to be 0.015, and the standard deviation between the measured and fitted values of the settling rate for PM2.5 is 0.019. The logarithmic fit between the settling rate and the number of air changes is obtained from Figure 2 (right), as shown in Equation 5:

$$PM10 \cdots K = 0.4874\ln(\alpha) + 0.9598$$
$$PM2.5 \cdots K = 0.4097\ln(\alpha) + 0.8593 \tag{5}$$

The standard deviation of the measured and fitted values for PM10 is 0.012, and for PM2.5 is 0.023. The linear and logarithmic fit of the settling rate to the number of air changes is very close to the measured values. It is clear from both fits that the larger the particle size (PM10), the more it is affected by the number of air changes. In other words, the higher the number of air changes, the faster the concentration of particles of larger size decreases due to the effect of settling.

IV. CONCLUSION

In this paper, a model was developed to calculate the settling rate of indoor particulate matter by measuring the number of air changes in a room, the concentration of particulate matter in the room, and the relationship between the settling rate of indoor particulate matter and the number of air changes in a room was analysed by combining the model with experiments.

In this paper, the relationship between the measured and calculated indoor PM10 and PM2.5 deposition rates and the number of room air changes were fitted linearly and logarithmically. The standard deviations between the two fits and the measured values were slight and less than 0.025, implying that both fits show the numerical relationship between the deposition rates and the number of room air changes.

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