A study on the correlation of the indoor and outdoor particulate pollution levels in the university premises

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Abstract. In recent years, haze weather happens frequently. PM2.5 and PM10 are the main factors that affect the haze weather, so they deserve to be studied. The study will help to propose better measures to improve the indoor air quality. This paper is to study the relevance of indoor and outdoor concentrations of particulate matter, the daily variation of indoor particulate matter concentrations and the horizontal distribution law of particulate pollution in campus buildings. Through the study, it can be seen that outdoor particulate pollutants is the main source of indoor particulate matter and there is no significant difference in the average particle concentration between the daytime and night.

Introduction

The harm of particulate matter in the air is becoming more and more obvious nowadays. High concentrations of particulate matter in the air will damage the respiratory system [1] and lead to cardiovascular disease, cancer [2], etc. However, the time of modern 70%-90% is spent indoors [3], so indoor air quality is particularly important. The study is helpful for us to understand the change of the concentration level of particulate matter and improve the indoor air quality.

Methods and materials

Experimental subjects. One of experiments was taken place in the girl's dormitory. The experiment was to find out the relationship between indoor and outdoor particle concentration and the daily variation of indoor particulate matter concentrations. The room was on the second floor, and the area of it is about $28m^2$. The length of the room is seven meters and the width of it is four meters. There is window, a door, six pieces of beds and tables, an air conditioner and a fan in it. For the comparison of particle concentration in campus buildings, a campus underground supermarket, canteens, teaching buildings, parks, computer rooms, toilets, wash rooms and a library were selected to be measured.

Experimental apparatus. In this experiment, the mass concentration of PM2.5 and PM10.0 was measured by DUSTTRAK 8520.

Experimental methods. The relationship between indoor and outdoor particle concentration levels: the experiment was conducted from 8:00am to 8:00pm. The data was measured every one hour. Particulate mass concentration in the girl's dormitory was measured firstly. Then outdoor particulate mass concentration was measured immediately. The change of particle concentration in the whole day: this experiment needs all day measurements. The concentration of particulate matter in the dormitory was measured every one hour. The comparison of the concentration of PM2.5 in typical places of Campus: the experiment was done nearly at the same time, and each place was measured for a minute.

The relationship between indoor and outdoor particle concentration levels

The concentrations of indoor and outdoor particulate matter are closely related to each other. However, what is the exactly relationship between them is unknown. Therefore, this section is to find out the relationship.

Indoor and outdoor particulate matter concentration ratio. There are two main methods for figuring out the concentration ratio of indoor and outdoor particulate matter [4].

Method one: integration method

We obtained 100 sets of data about indoor and outdoor particulate mass concentration through experimental measurements, so we can get 100 sets of instantaneous I/O values:

$$IO_t = \frac{C_i}{C_o} \tag{1}$$

Continuous stacking can be transformed into integral, so that the average I/0 value of a certain period of time can be calculated by integral formula (2), which is as follows:

$$IO_T = \frac{\int_T C_i(t)dt}{\int_T C_o(t)dt} \tag{2}$$

Method two: linear regression fitting

The method is to use the Outdoor particulate matter concentrationas the independent variable, and the indoor particulate matter concentration is the dependent variable. Then the value of the indoor and outdoor particulate concentration ratio can be obtained by linear regression fitting. If the fitting line is close to a straight line, it can be explained that the concentration of indoor and outdoor particles is closely related. Fig. 1 shows the indoor and outdoor particulate matter concentration linear regression.

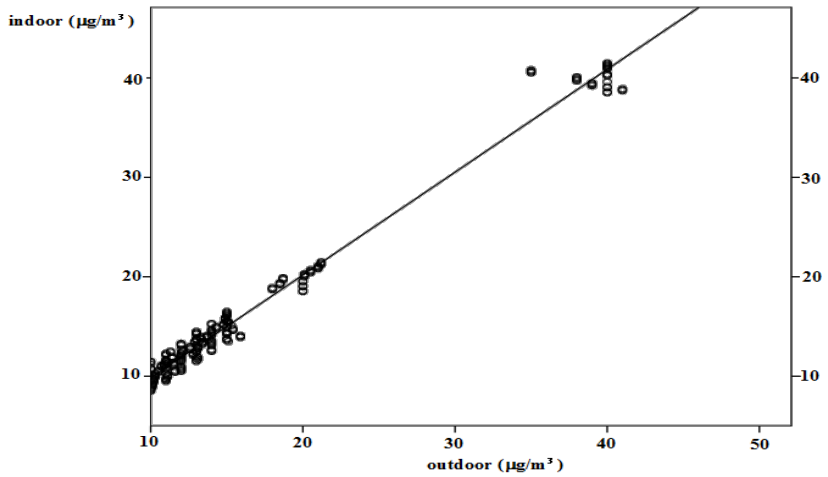

Fig. 1 Linear regression fitting of indoor and outdoor particulate matter

Correlation analysis of indoor and outdoor particle concentration. Pearson correlation coefficient is used to describe the linear correlation of two variables. The correlation coefficients are represented by R. The value of R is between -1 and 1. If R is positive, it indicates that the two variables are positively correlated. If R is negative, it shows that the two variables are negatively correlated. If R equals 0, it represents there is nocorrelation between the two variables.

Table 1 Indoor and outdoor particulate matter concentration ratio

	Indoor and outdoor PM2.5 concentration ratio	Indoor and outdoor PM10 concentration ratio
Integral method	0.910	0.922
Linear regression	0.921	0.942

As Table 1 shows, the I/O ratio measured by the two methods is all above 0.9. Therefore, a conclusion can be drawn that the concentration level of indoor and outdoor particles is very close, and the same as their relationships.

The results of correlation analysis by software SPSS are shown as Table 2 and Table 3:

Table 2 Correlation analysis of PM2.5

Pearson Correlation	Outdoor Pm2.5	Indoor Pm2.5
Outdoor Pm2.5	1	0.938
Indoor Pm2.5	0.938	1

Table 3 Correlation analysis of PM10

Pearson Correlation	Outdoor Pm10	Indoor Pm10
Outdoor Pm10	1	0.953
Indoor Pm10	0.953	1

As Table 2and Table 3 show, the indoor and outdoor correlation coefficient of PM2.5 and PM10 are 0.938 and 0.953. It can be seen that outdoor pollution sources has huge effects on indoor particulate matter concentration level. For further, outdoor pollution is the most important contribution of indoor pollution.

The change of particle concentration in the whole day

The mass concentration of particulate matter is one of the physical properties of particulate matter. It is an important standard to measure the level of particulate matter concentration and an important basis for judging the air quality. This section selects the students' apartments as the research sites.

The whole day was divided into two periods: the day is from 6:30am to 6:30pm, and the night is from 6:31pm to 6:29am of the next day. Indoor particulate matter concentration level is described by following values:

Table 4 Indoor particulate pollution levels

	Time slot	Minimal value	Maximum value	Mean	Standard deviation
PM2.5(μg/m³)	Night	5	163	65.48	43.219
	Day	4	155	65.51	50.295
	24h	4	163	65.50	46.947
PM10(μg/m³)	Night	8	341	110.63	82.158
	Day	6	336	119.09	100.212
	24h	6	341	115.06	92.091

From Table 4, it can be seen that the concentration of the night is lower than that of the day. However, the average concentration of daytime and night has no obvious difference by T test.

The comparison of the concentration of PM2.5 in typical places of Campus

Representative places in the campus were selected to draw the column chart. It reflects the concentration of particulate matter at different locations at the same time, as is shown in Fig. 2:

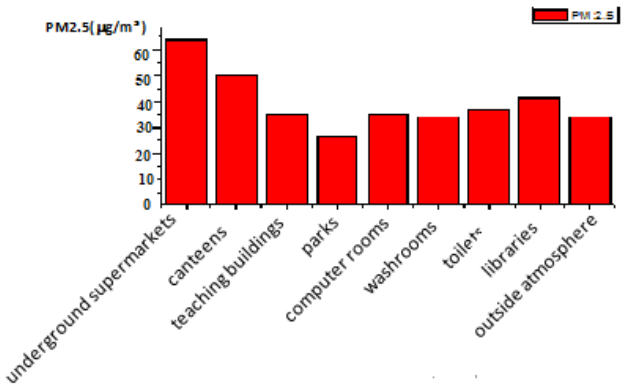

Fig. 2 Mass concentration of PM2.5 in typical places of campus

From Fig. 2, it can be seen that particulate matter concentration of the campus underground places and canteens are significantly high. It even can reach two to three times of the outdoor concentration of particulate matter. Therefore, it can be concluded that air without circulation sometimes increase the concentration of PM2.5, and cooking can become a new pollution source to some extent. Contrary to underground places and canteens, the concentration of particulate matter in the park has improved compared with the outdoor atmosphere. Maybe the park's flowers and trees have played a role in the purification of air.

Summary

Through the analysis of above three parts, some conclusions can be drawn as follows:

(1)In the building of no indoor pollution sources, indoor and outdoor particulate concentration level is closely related. The correlation coefficient reaches 0.9. Outdoor particulate pollutants are the main source of indoor particulate matter.

(2) Particles concentrations of underground places and cooking places are high and can reach two to three times of the outdoor concentration. Therefore, it is necessary to ventilate timely to reduce the content of particulate matter in the underground places and canteens.

(3) There was no significant difference in the average particle concentration between the daytime and night.

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