Investigation into the indoor and outdoor air pollution of PM2.5 and PM10 in a university of Zhengzhou during wintertime

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Abstract. In this paper, the particle mass concentrations of PM2.5 and PM10 are determined by a portable air particulate monitoring instrument in different places of the University of Zhengzhou; meanwhile, the temperature, the humidity, the ventilation condition, the indoor area and other indicators are observed in the sampling point. On the basis of the monitoring results, the concentration differences of PM10 and PM2.5 between the indoor environment and the outdoor environment are compared, and the influence factors of the dust content in the indoor air are analyzed and discussed. The results show that there is a negative correlation with indoor concentration of PM2.5/PM10 while ventilating and the humidity doesnot affect PM10/PM2.5 obviously.

Keywords: PM2.5, PM10, university, influencing factors

1. Introduction

Atmospheric particulate pollutants with small particle size and complex characteristics, will not only do harm to human health but also lead to many serious environmental problems; in addition, the issue of atmospheric particulate pollution has been getting more and more attention from the public and the government due to the persistent haze weather. Atmospheric particulates have become the primary pollutants to affect urban air quality in recent years, which have close relationships with health. Domestic and overseas a large number of researches on epidemiology and sanitary science show that the smaller the particle size of a particulate matter (PM), the greater the harm to human health; PM2.5 is harmful to some extent to human respiratory system, cardiovascular system and immune system. A person will spend about 70%~90% of his time indoor everyday, so that indoor particulate matters cause possible potential health hazards to human body shall need more attention.

In recent years, there are many researches on concentration distribution characteristics of outdoor PM2.5 and its influence factors, but the reports on indoor conditions are less relatively, especially the relevant researches on PM2.5 in universities which are densely populated areas are much less. In this research, we plan to monitor the mass concentration (hereinafter referred to as “concentration”) of PM2.5 in different zones, campuses and function rooms of a university in Nanjing City in order to assess the indoor PM2.5pollution level in universities and analyze the factors to affect the indoor concentration of PM2.5, and provide basis to the research and control of indoor PM2.5 and preparation of relevant standards.

2. Research method

2.1. Monitoring equipment

Handheld dust monitors JCF-200(CW-HAT200) are adopted to monitor the mass concentration of PM10 and PM2.5, which dust concentration testers launched for the increasingly serious haze pollution with social development, and which can test the concentration of dust fine particulate matters in air fast. The monitors are created independently with laser diode technique based on the foreign advanced miniature laser sensor technique with high sensitivity, which can record and store sample data automatically, so it can be taken back to the laboratory for analysis after downloading the data to the computer.

2.2. Research object and method

2.2.1. Monitoring sites

The experiments were carried out in different function rooms of the Campus of Henan University of Engineering in Zhengzhou city (the provincial capital of Henan province, an important integrated transport hub in China, located at 113° E and 34° N.), including classrooms,laboratories, dormitories, library, gymnasium and mess hall.

2.2.2. Research method

Measure indoor temperature, humidity, air pressure and area; and record number of people and condition of natural ventilation and air-conditioning switch. The concrete measuring time is from December 20, 2016 to December 26, 2016 for continuous 7 days monitoring 6 sites everyday. Take monitoring when the number of people is large as much as possible (because it is in the examination period, the people in classrooms and laboratories are less, but many people are concentratedin the library). As follows: classrooms (8:30—9:50), laboratories (10:00—11:20), dormitories (13:00—13:20),library(14:30—15:40), gymnasium(15:50—17:00)and mess hall(17:30—18:40).

Every instrument shall be cleaned and dried by zero settingfilter before measurement and shall begin to measure when data are stabile after turning on for 5 min. Read a group of numerical values every 60s and read continuous 5 values at every sampling points. Except the dormitory with one-point method because of small area, all other 5 indoor environments shall be arranged with five-point method. The instruments shall be installed in height of sitting respiratory zone over tables in classrooms, laboratories, dormitories, gymnasium, library and mess hall; the instruments installed in the gymnasium shall be in height of standing respiratory zone. The sampling points shall be more than 1.0m far away from indoor walls, and keep away from windows and doors. Outdoor sampling points shall be located at the places which are 10m far away from corresponding indoor environments.

3 Results

3.1. General features of monitoring sites

The average temperature during monitoring period is 17.6±1.2℃ and medial humidity is 34.4±2.4%. The difference of temperature and humidity between all monitoring points is not great, and meteorological conditions of monitoring points are stable. The number of people in library and mess hall are large relatively, the number of people in dormitories is normal, and the number of people in classrooms and laboratories are less. All ventilation conditions are same basically. The floor, indoor area and other specific conditions are shown in Table 1 Table 1.

3.2 Comparison of PM2.5 and PM10 concentration in different places

The monitoring period is in winter, and haze weather is the most common for a university in North China, so the haze weather has a strong impact on indoor PM value. The testing results show that the indoor PM2.5 and PM10 concentration of mess hall is highest （140 and 309μg/m^3） and the indoor concentration of laboratory is lowest (48 and 98μg/m^3). By comparison of ratios (I/O) of interior and outdoor PM2.5 and PM10 concentration in different sites, the I/O value in mess hall is largest and the I/O value in laboratory is smallest. See the specific results in Table 2.

3.3. The ratio relation between PM10 and PM2.5

The data in Table 3 are from all monitoring points and test data, and the statistical results are the proportional distribution of ratios of all points accounting for total samples in each range. BecausePM10 contains PM2.5, the mass concentration of PM10 must be more than the mass concentration of PM2.5. See the ratio distribution between indoor PM2.5 and PM10 in Table 3 and Figure 1.

It is known from Fig.1 that although the ratio relation doesn’t have a determined value, the ratios close to 2 are most among total samples, and the most proportion part is 2.13＜P≤2.20. The maximum value and minimum value of PM10/PM2.5 in statistical data are

2.28 and 1.5 respectively.

Table1 General features of monitoring sites

places	average temperature（℃）	average humidity（%）	floor	ventilation condition	average number of indoor people	area（m^2）
classrooms	18.2	47.5	the 1th floor	closed window	6	93
laboratories	17.8	49.2	the 2th floor	closed window	3	45
dormitories	17.5	51.5	the 3th floor	closed window	3	38
library	17.8	50.3	the 2th floor	opened window	108	450
gymnasium	18.6	49.7	the 1th floor	closed window	10	580
mess hall	19.5	62	the 1thfloor	opened window	192	1050

Table 2The comparison of ratios (I/O) of interior and outdoor PM2.5 and PM10 concentration in different sites

places	indoor average value of PM2.5	outdoor average value of PM2.5	I/O	indoor average value of PM10	outdoor average value of PM10	I/O
classrooms	54	74	0.73	109	152	0.72
laboratories	48	79	0.61	98	148	0.66
dormitories	65	90	0.72	135	170	0.79
library	36	78	0.46	72	156	0.46
gymnasium	83	90	0.85	153	185	0.83

mess hall	140	100	1.40	309	215	1.44

Table 3 The ratio distribution of PM2.5 to PM10

ratio range of PM10/PM2.5	sample number	proportion(%)
1.5≤P≤1.55	2	1.20%
1.55＜P≤1.60	0	0
1.60＜P≤1.65	0	0
1.65＜P≤1.70	2	1.20%
1.70＜P≤1.75	1	0.60%
1.75＜P≤1.80	1	0.60%
1.80＜P≤1.85	3	1.90%
1.85＜P≤1.90	3	1.90%
1.91＜P≤1.93	3	1.90%
1.93＜P≤1.95	4	2.50%
1.95＜P≤1.97	3	1.90%
1.97＜P≤1.99	8	5.10%
2.01＜P≤2.03	9	5.80%
2.03＜P≤2.05	12	7.70%
2.05＜P≤2.07	10	6.40%
2.07＜P≤2.09	12	7.70%
2.09＜P≤2.11	12	7.70%
2.11＜P≤2.13	11	7.10%
2.13＜P≤2.15	15	9.70%
2.15＜P≤2.20	22	14.20%
2.20＜P≤2.25	15	9.70%
2.25＜P≤2.30	6	3.80%

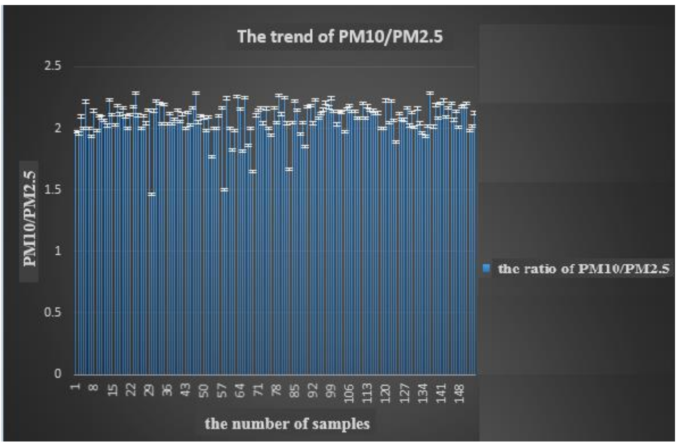

Figure 1 The trend of PM10/PM2.5

3.4. The Correlation between PM10 and PM2.5

As shown in figure 2, a result is obtained with regression equation by comparison of the ratio between the humidity and the ratio of PM10/PM2.5 that: correlation coefficient R^2=0.0016, which is less than 1 greatly, so there is no linear relation between them, which means the humidity doesnot affect PM10 or PM2.5 obviously.

Moreover, while researching the relation between humidityPM10 and PM2.5, we also monitor the influence of human activities on them. We can learn about that the number of population doesn't influence PM10 or PM2.5 obviously after comparing the two scatter diagrams with the numerical values of PM10 and PM2.5 when people are many and when people are less (hereby the diagrams are not listed for explanation).

3.5. The influence factor analysis of indoor PM2.5/PM10 concentration

Several factors that may influencePM2.5 and PM10concentration were analyzed with multivariate stepwise regression. Considering that the on-site frying in mess hall causing constant lampblack pollution will influence the indoor concentration ofPM2.5and PM10 to a large extent, the concentration in classrooms, laboratories, library, dormitories and gymnasium without obvious indoor activity pollution were analyzed at first. The analytical factors are: temperature, humidity, ventilation, heating, number of people, area and outdoor concentration of PM2.5and PM10. The results show that there is a negative correlation with indoor concentration of PM2.5 and PM10 while ventilating and there is a positive correlation with indoor area (the coefficient is 0.022). The regression equation is:

$$Y = 48.63 - 15.01X_1 + 0.022X_2 - 4.46X_3$$

Here, Y is the concentration of PM2.5 and PM10, X_1, X_2 and X_3 mean heating, area and ventilation respectively.

After bring the indoor frying activity in mess hall into analysis, the regression equation is:

$$Y = 139.17 - 17.67X_1 + 0.025X_2 - 91.38X_4$$

Here, Y means the concentration of PM2.5 and PM10, X_1, X_2 and X_4 mean heating, area and frying respectively.

The regression equation (2) shows it is a negative correlation between indoor frying activity and the concentration PM2.5 and PM10 (it is defined with statistical analysis that the value is 0 while frying and the value is 1 without frying or other obvious pollution), but the ventilation variable is removed in this regression equation, because it is possible that the constant indoor pollutant discharge covers up the ventilation.

3. Discussion

University campus is a special environment integrated of various public places and collective habitable rooms. University students will spend their over 90% of time in classrooms, laboratories, library, mess hall and dormitories, so the indoor concentration of PM2.5 and PM10 is closely related to students' health. The monitoring period of this research is in winter, so the temperature and humidity are low relatively, but the difference of temperature and humidity at every monitoring point is not large and the meteorological conditions of measuring points are stable relatively.

Based on the monitoring of indoor and outdoor campus environment, we discover that the I/O value in mess hall is largest, which means the PM2.5 and PM10 pollution is most serious, and indoor PM2.5 and PM10concentration is higher than outdoor; the I/O value of 1 in laboratory is smallest, which means the indoor concentration of PM2.5 and PM10 is lower than outdoor. The reason that the pollution in laboratory is the least is because there is a high-power fume hood working always in it; the main reason that the I/O value in mess hall is very high is because cooks will fry dishes on site in the selling area of mess hall, which is indoor cooking.

In order to further understand the environmental factors which will affect the indoor concentration of PM2.5 and PM10 in the sites where university students stay frequently, multivariate regression analysis is adopted. The results show that the indoor concentration of PM2.5 and PM10 in classrooms, laboratories, library, dormitories and gymnasium where there is no obvious pollution source can be reduced by natural or mechanical ventilation; however, the indoor concentration of

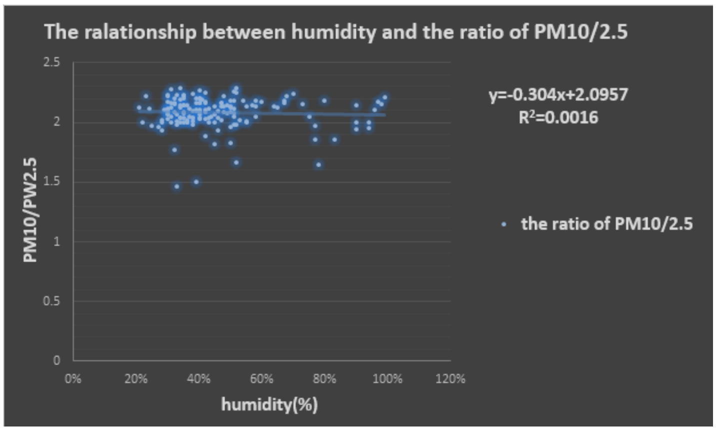

Figure 2 The relation between humidity and the ratio of PM10/PM2.5

PM2.5and PM10mess hall where there are some on-site frying activities to produce much lampblack will be increased. Moreover, the measuring period is just the dining time for students and the human activities such as come and go are many. What's more, the larger the area, the greater the indoor concentration of PM2.5and PM10, but the influence coefficient is small relatively, which remains to be confirmed in future researches.

4. Conclusion

This research has following limits: ①only the PM2.5 and PM10concentrationduring a period of time in winter is measured, but the concentrationat all seasons can be measured in future to obtain more typical data. ②It is simple and convenient to adopt portableair particulate mattermonitors to test PM2.5 and PM10concentration, but it is less correct than weighing method. ③The number of students in classrooms and laboratories is small, so the typical analysis of influence of number of students on indoor PM2.5 and PM10concentration is not strong.

The PM2.5 and PM10concentration in student activity sites will be influenced by indoor activities, air-condition, ventilation and outdoor environment. The larger data size and analysis of other pollution sources are needed to further research PM2.5 and PM10 conditions in universities. The indoor cooking lampblack in a mess hall which is an integral part of student life shall be controlled to reduce PM2.5 and PM10concentration.

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