Correlation Analysis of Indoor and Outdoor PM2.5 and Exploration of Prevention Methods

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Abstract: In order to study the correlation of indoor and outdoor PM2.5 concentrations, five sampling points are selected in Hunnan New District of Shenyang City. The PM2.5 concentration inside and outside the five buildings were monitored in December 2018. After that, the writers analyze the variation characteristics and trends, and explore the prevention and control methods to indoor and outdoor PM2.5. The results show that there is a significant correlation between indoor and outdoor PM2.5 concentration, and the concentration is affected by opening or closing windows. When there is no indoor pollution source, indoor pollutants mainly come from outdoor infiltration. The prevention and control of PM2.5 pollution can be divided into indoor and outdoor aspects. Scholars often ignore the harm of PM2.5 to human body when they stay in the house. In indoor environment, PM2.5 is analyzed through aerodynamics. Due to the slow air flow, the inhalation volume of human body is more than that in the outdoor environment with fast air flow. In this paper, we will discuss how to reduce the harm of PM2.5 to human body and create a healthy living environment for residents.

1. Introduction
With the rapid urbanization development, people are enjoying a more convenient life brought at the cost of our environment. In recent 20 years, haze has occurred frequently in most areas of China, especially in North China, Northeast China, and other areas in winter heating period, coal and straw burning will produce a lot of atmospheric particles. According to the particle size, atmospheric particles can be divided into coarse particles (PM 10) and inhalable lung particles (PM2.5)\[1\]. PM2.5 is inhaled into the lungs through human respiration due to its small size, which poses a huge potential threat to human body. People who are exposed to high concentration of PM2.5 for a long time will be more likely to have pneumonia, lung cancer, heart disease and cerebrovascular diseases.\[2\]-\[4\]

The quality of living environment is related to people’s well-being, and people’s requirements for a healthy living environment gradually increase with the improving living standards. As the main pollutant of urban environment\[5\], the analysis and treatment research of PM2.5 should also be strengthened. In this paper, the writers mainly focus on the indoor and outdoor monitoring of PM2.5 in Hunnan New District of Shenyang City in winter, and explore its indoor and outdoor rules, correlation and prevention methods of PM2.5.

2. Research Methods

2.1 Sampling Time and Places
Located in Northeast China and the middle of Liaoning Province, and in the center of Northeast Asia economic circle and Bohai economic rim, Shenyang is an important central city and advanced equipment manufacturing base in Northeast China approved by the State Council. Hunnan District is a municipal district of Shenyang City, Liaoning Province. It is a special experimental zone of the reform and opening up in Shenyang, and also serves as the model performing Shenyang’ s reform and opening up. In this paper, the monitoring of PM2.5 fine particles’ concentration is carried out at five sampling sites in Hunnan District. The five sampling sites are selected through functional area distribution method, effectively representing the distribution of atmospheric PM2.5 in Hunnan. The specific points are shown in Figure 1, and the geographical coordinates are shown in Table 1.

Table 1 Distribution of sampling sites

| Number | Monitoring point                        | Geographical coordinates          |
|--------|----------------------------------------|-----------------------------------|
| 1      | Hunnan Industrial District              | Longitude:123.531464               |
|        |                                        | Latitude:41.689571                |
| 2      | Shenyang Urban Construction University | Longitude:123.420494               |
|        |                                        | Latitude:41.67371                  |
| 3      | Shenyang Taoxian International Airport  | Longitude:123.494949               |
|        |                                        | Latitude:41.639202                 |
| 4      | Dormitory building of Shenyang Jianzhu University | Longitude:123.515419 |
|        |                                        | Latitude:41.74361                  |
| 5      | Shenyang Olympic Sports Center         | Longitude:123.463676               |
|        |                                        | Latitude:41.74115                  |

2.2 Sampling Method

Using portable dust monitor to monitor the atmospheric PM2.5 at the sampling sites, and the test range is from 0.01 mg/m³ to 500 mg/m³. In the whole experiment, two PM2.5 dust monitors are used to record the indoor and outdoor PM2.5 concentration values of the buildings. At the same time, the temperature and humidity detector is used to monitor the indoor and outdoor temperature and relative humidity.

We selected 10 days in December (2018) to monitor PM2.5 particulate matter. To obtain the average PM2.5 concentration within the measurement range, the monitor is carried out three times a day (morning, noon and evening), and once every 10 minutes within an hour. The monitor of indoor and outdoor PM2.5 concentration should be strictly conducted in accordance with the determination
method of *Ambient air quality standard* GB3095 - 2012 and the quasi limit value of each index[6].

3. Results and Analysis

3.1 Changes of PM2.5 Inside and Outside the Sampling Sites

The variation curve of PM2.5 concentration at different sampling sites can be seen in Figure 2. (Hunnan Industrial District-1, Shenyang Urban Construction University-2, Shenyang Taoxian International Airport-3, Dormitory building of Shenyang Jianzhu University-4, Shenyang Olympic Sports Center-5)

![Figure 2 Changes of indoor and outdoor PM2.5 concentration](image)

December is the heating period in Shenyang, during which the indoor and outdoor air is seriously polluted. The average outdoor PM2.5 concentration is as high as 124 μg/m³, and the average indoor concentration is 95.656 μg/m³. The outdoor PM2.5 concentrations of the five sampling sites are higher than their indoor concentrations. From the curve trend, the indoor PM2.5 concentration changes with the outdoor concentration. The peak and trough trend of five indoor and outdoor PM2.5 concentration curves are basically same, but the change points of details are different. Compared with the other four groups of data, the outdoor PM2.5 concentration of the Olympic Sports Center Stadium is higher than the indoor concentration. The main reason is that the sports hall is relatively empty, and the windows are rarely open, thus more PM2.5 particles are blocked out of the window.
3.2 Correlation Analysis of Indoor and Outdoor PM2.5 Concentration

In order to obtain the relationship between indoor and outdoor PM2.5 mass concentrations, the measured data are analyzed by regression analysis. The relevant equation and data analysis are shown in the figure below. It is found that there is a significant correlation between indoor and outdoor PM2.5 concentrations, the correlation equation of indoor and outdoor PM2.5 concentrations is \( y = 0.6117x + 10.71842 \) and correlation coefficient \( r = 0.6412 \), which represents the permeability index of PM2.5 fine particles from outdoor to indoor. The positive correlation coefficient means that the outdoor PM2.5 concentration has positive correlation with the indoor PM2.5 concentration. This indicates that indoor PM2.5 is mainly affected by outdoor PM2.5 if there is no indoor pollution source. Under different sampling weather conditions and meteorological factors, PM2.5 infiltration are different. Indoor and outdoor PM2.5 particle concentration will be closely related to the gap of building maintenance structure or residents’ window opening.

![Figure 3 Regression of Indoor and Outdoor PM2.5](image)

4. Exploration of Prevention and Control Methods of PM2.5

4.1 Outdoor PM2.5 Pollution Source Control

1. In order to improve fuel combustion efficiency, it is essential that we should optimize the energy structure, promote the new energy development and the use of new clean energy, and reduce the use of coal and natural gas and other old-fashioned energy sources; vigorously strengthen the output of wind power, electrical energy and solar energy[7].

2. We should control energy using in rural areas, and strictly control straw burning[8]; in urban areas, controlling the mobile sources like cars, using centralized heating as far as possible, and control the emission of pollutant particles in the catering industry are of great significance. Besides that, we have to effectively reduce road dust, and comprehensively control and supervise it[9].

3. As for traffic, we should pay more attention to the real-time monitoring of PM2.5, increase the vegetation coverage, ensure the overall air quality of residential areas, and try to make the small particles deposit into large particles.

4.2 Indoor PM2.5 Control

Passive control: Passive energy-saving building comes from Germany. Due to the use of composite doors and windows and insulation materials, this kind of energy-saving building has good air tightness and greatly reduces the indoor air penetration. During the heating period, the building envelope
effectively blocks PM2.5 invasion\[10-11\]. To reduce the air leakage rate of the building and improve the air tightness of the enclosure structure, it is necessary to strengthen the supervision and optimize the design in the construction. All these measures are helpful to control the indoor PM2.5 penetration.

Active control:
1. In the office area, the organized ventilation system with filter structure can be used to replace the traditional one. Some studies show that natural ventilation can aggravate the indoor pollution of PM2.5\[12-16\].
2. Air purifier is used to filter PM2.5 particles in the residential area, and humidifier can be used to ensure indoor air humidity to settle the particles.

5. Conclusions
According to the 10-day experiment in Hunnan District, we can draw the following conclusions:

In December 2018, the atmospheric PM2.5 pollution was serious in Hunnan, with an outdoor average value of 124 ug/m³, and the secondary standard limit value of GB 3095-2012 is 75 ug/m³. The average indoor concentration of PM2.5 in main buildings is 95.656 ug/m³, and the secondary standard limit of PM2.5 in human inhalation air is 75 ug/m³. This district is assessed as mild pollution. There is an obvious correlation between the indoor and outdoor PM2.5 concentration, and the concentration is affected by the opening and closing of windows. When there is no indoor pollution source, indoor pollutants mainly come from outdoor infiltration.

If we want to control the PM2.5 concentration in the building more effectively in the short term, we can consider using air purification and humidification devices in the building. In the long run, we should optimize the energy structure, increase vegetation coverage and people’s awareness of environmental protection.

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