International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 12 Issue 1 ǁ January 2024 ǁ PP. 182-186

Experimental study on indoor pollutant PM2.5 concentration in public buildings

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Abstract
As the environmental pollution caused by urbanization and industrialization becomes more and more serious, the indoor air pollution of public buildings should also attract the attention of all walks of life. Literature [1] shows that indoor particulate matter concentration is correlated with indoor pollution in public areas, and it is necessary to study the impact of indoor PM2.5 on indoor air quality. As the place where students gather and stay for the longest time, the classroom is where students spend more than 80% of their time every day. Therefore, the air quality in the classroom has an important impact on the healthy growth of students. In this paper, through the field test of PM2.5 concentration in a classroom of a school in Shanghai at different times and under different conditions, the distribution and variation characteristics of PM2.5 concentration are obtained, and the PM2.5 concentration level and source are compared and analyzed, so as to have an in-depth understanding of relevant standards and prevention measures of PM2.5, and make corresponding health risk assessment. It not only puts forward improvement measures for indoor PM2.5 concentration control, but also helps to improve the air quality inside the classroom.
Keywords:*PM2.5,Control concentration standard, Health risk assessment.*

Date of Submission: 05-01-2024 Date of acceptance: 17-01-2024

I. INTRODUCTION

PM2.5 is a lung accessible particulate matter with particle diameter ≤ 2.5 μm. It is a complex mixture composed of inorganic and organic substances, mainly including water-soluble inorganic ions, elemental carbon (EC), organic carbon (OC), heavy metals, etc. Affected by regional, seasonal, energy structure, industrial level and other factors, its chemical composition varies greatly in different regions [2]. Domestic atmospheric PM2.5 has a wide range of sources, both primary and secondary sources, and its composition has the characteristics of composite pollution. The complex chemical composition of PM2.5 can cause a variety of health hazards [3]. At present, the main research methods used at home and abroad include population epidemiological investigation and toxicology study. The World Health Organization (WHO) pointed out in the 2005 edition of the "Air Quality Guidelines" that when the average annual concentration of PM2.5 reaches 35μg/m^3, the risk of human death is about 15% higher than that of 10μg/m3 [4]. PM2.5 is rich in a variety of organic compounds, among which polycyclic aromatic hydrocarbons (PAHs) are carcinogens with strong toxicity, among which benzopyrene is the most carcinogenic [5]. An analysis of data from 14 cohort studies in eight countries found that an increased risk of lung cancer was associated with concentrations of elements such as copper, iron, potassium, sulfur, silicon, nickel, and zinc in the air, particularly sulfur and nickel, which are typically attached to particulate matter.

PM2.5 pollution not only seriously endangers people's health, but also has a great impact on climate and atmospheric visibility. The impacts of particulate matter on climate include both direct and indirect effects. Direct impact means that particles can directly block sunlight from reaching the Earth's surface, increasing the optical thickness of visible light. Among them, carbon black particles can absorb solar short-wave radiation and emit infrared radiation, thus affecting solar radiation transmission, heating the atmosphere, reducing the surface temperature and affecting the earth's long-wave radiation. This dual effect on the surface and atmosphere will affect the temperature stratification of the tropospheric atmosphere, causing the stagnation of air convection, which is extremely unfavorable to the diffusion of pollutants [6]. The indirect effect mainly refers to that particulate matter, as cloud condensation core and ice core, plays an important role in the formation and growth of cloud rain, which not only enhances or weakens rainfall, but also changes the type of cloud rain. The change of particle concentration affects the formation of clouds, and the change of clouds in turn has a great impact on the climate, for example, non-descending clouds can be converted into descending clouds [7]. Higher concentrations of particulate matter can change the color of the sky and reduce visibility.

1.1 Site profile

There is a school in Shanghai with a construction area of 42,500 m^2, with several teaching buildings, one of which is taken as an example. The teaching building has five floors on the ground, with each height of about 3.2m. The tested classroom is 8.5m long, 7.2m wide and 3.2m high. On the south wall, there are two aluminum alloy sliding Windows with 3.6m long and 1.2m wide, which can be opened in half. The classrooms are equipped with split winter and summer air conditioning equipment and fresh air system. The air supply mode is top air supply, and the exhaust outlet is set on the roof of the classroom.

1.2 Main measurements

1.2.1 Test method

This test mainly conducted continuous monitoring of indoor and outdoor PM2.5 in the classroom, and the test time was May 2022. Based on natural ventilation conditions, the test was conducted on a weekend to study the impact of changes in PM2.5 concentration in the air outside the classroom on indoor PM2.5 concentration. The doors and Windows were opened on the first day and closed on the second day. Using outdoor environment values as comparative data, the change of PM2.5 concentration in the classroom was analyzed when the doors and Windows were opened and closed. Keep the classroom unattended during the test to ensure the true reliability of the test data.

1.2.2 Point arrangement

Three indoor measuring points are evenly arranged along the diagonal direction of the classroom. The measuring points are positioned as far as possible away from doors and Windows and split air conditioning outlet, and the instruments are placed on the classroom desks, so as not to hinder students' normal activities. The average data of the three measuring points are taken as the representative data of the indoor test. The test points outside the classroom are arranged in a shady place outside the windowsill of the classroom to avoid inaccurate test data caused by direct sunlight. The selection of the location of the test point refers to the sampling code for the detection of hazardous substances in the air of the Workplace and other standards.

1.2.3 Analytical method

At present, there are many studies on the correlation between indoor and outdoor particulate matter, which are mainly divided into two types: I/O value and linear regression analysis. The I/O value is the concentration ratio of indoor and outdoor pollutants, and the I/O ratio is usually used to determine whether indoor particles come from indoor or outdoor sources. When I/O≤1, indoor particulate matter in the classroom is dominated by outdoor sources, when I/O > 1, indoor pollution in the classroom is dominant, and in the absence of obvious long-term indoor pollution sources, the I/O ratio is about 1. Linear regression analysis is a method to study the influence relationship, and the correlation coefficient r2 is used to judge the correlation between the two. The higher the r2, the stronger the correlation between the two [8]. This paper uses these two methods to analyze the correlation between indoor and outdoor PM2.5 concentration during natural ventilation and when fresh air system is turned on in class, and compares the change of indoor PM2.5 pollutant concentration after fresh air system is turned on.

1.3 Comparison of indoor PM2.5 concentration standards

The U.S. Environmental Protection Agency (EPA) first issued the National Ambient Air Quality Standards (NAMBIENT Air Quality Standards) on April 30, 1971. NAAQS. The U.S. Environmental Protection Agency (EPA) divides standards into two levels: primary standards to protect public health, including the health of sensitive populations such as asthma patients, children, and the elderly; secondary standards protect the material wealth of society, including visibility and the protection of animals, crops, vegetation and buildings

Table 1 PM2.5 standard values established by EPA, AQI, air quality and health warnings.

PM2.5/(μ g/m^3)	AQI	Air quality	Health warning
≤15	0～50	Good	None
16～40	51～100	Moderate	People with unusually sensitive constitutions should consider reducing prolonged or intense exercise
41～65	101～150	Unhealthy for Sensitive Groups	People with heart or lung disease, the elderly, and children should avoid prolonged or strenuous activity
66～150	151～200	Unhealthy	People with heart or lung disease, the elderly, and children should avoid prolonged or strenuous activity; Others should reduce prolonged or strenuous activity
151～250	201～300	Very Unhealthy	People with heart or lung disease, the elderly and children should avoid all outdoor activities; Others should avoid prolonged or strenuous activity
≥251	301～500	Hazardous	People with heart or lung disease, the elderly and children should stay indoors and reduce their activity levels; Others should avoid all physical activity outside the

			home

China's GB 3095-1982 "Ambient Air quality standards" was first published in 1982, and was revised three times in 1996, 2000 and 2011, each revision and improvement have better adapted to the level of social and economic development and environmental management requirements in different periods, and played an important role in guiding atmospheric environmental quality.

The Ambient Air Quality Standard GB3095-2012 [9] sets new requirements for outdoor air quality exposed to people, plants, animals and buildings, which will be officially implemented on January 1, 2016. Compared with the current standard, the new standard has three breakthroughs: first, adjust the environmental air quality functional zone classification scheme, the current standard in the three zones into the second zone; Second, improve pollutant projects and testing specifications, including adding annual average and daily average PM2.5 concentration limits in basic monitoring projects, and tightening PM10 concentration limits. Third, the requirements for the validity of data statistics are improved, as shown in Table 6. In the basic monitoring items, the new standard adds the annual average and daily average concentration limits of PM2.5.

Table 2Ambient air quality standard outdoor particulate concentration limit table

Project	Average Time	New	Old	New	Old	Remark
PM	annual mean	40	40	70	100	tighten
PM10/(μ g/m^3)	daily mean	50	50	150	150	unchanged
PM	annual mean	15	-	35	-	Increase
PM2.5/(μ g/m^3)	daily mean	35	-	75	-	increase

II. RESULT AND DISCUSSION

2.1 Analysis of test results of natural ventilation conditions

The main source of PM2.5 in classrooms is personnel activities, which will cause fine particles deposited on the ground or other surfaces to levitate again, thereby increasing the indoor PM2.5 content. Considering that students did not move around during the actual class and closed the doors and Windows due to outdoor noise, we chose to observe and analyze the change of indoor PM2.5 concentration under natural ventilation on Saturday and Sunday when no one was in the classroom.

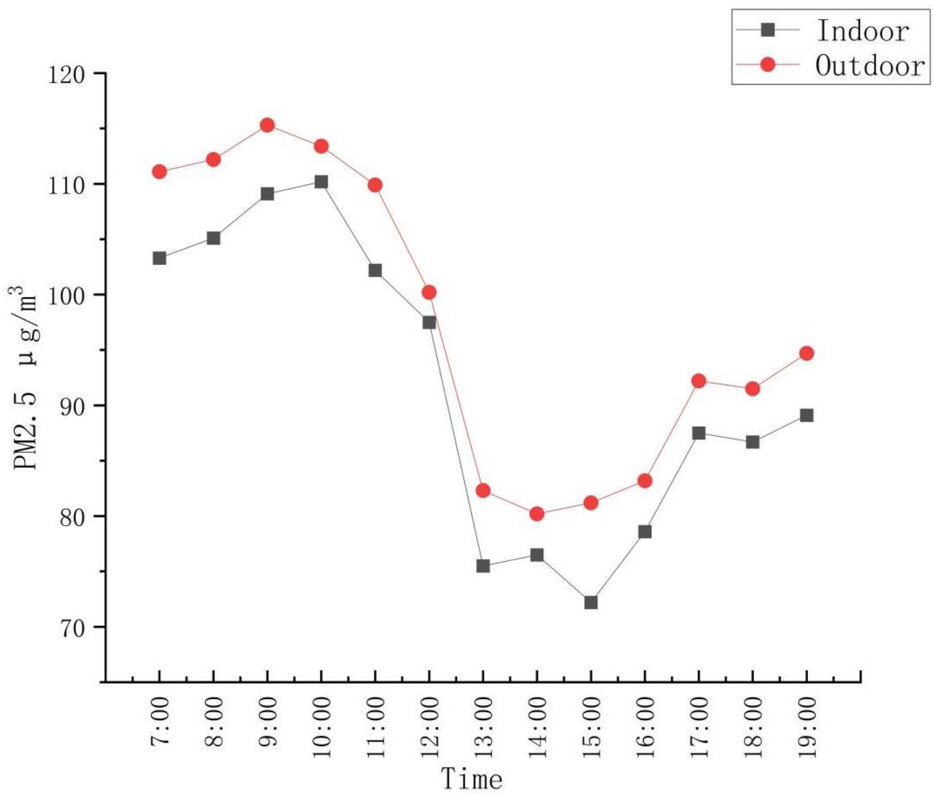

Fig.1: Indoor and outdoor PM2.5 concentration when doors and Windows are opened

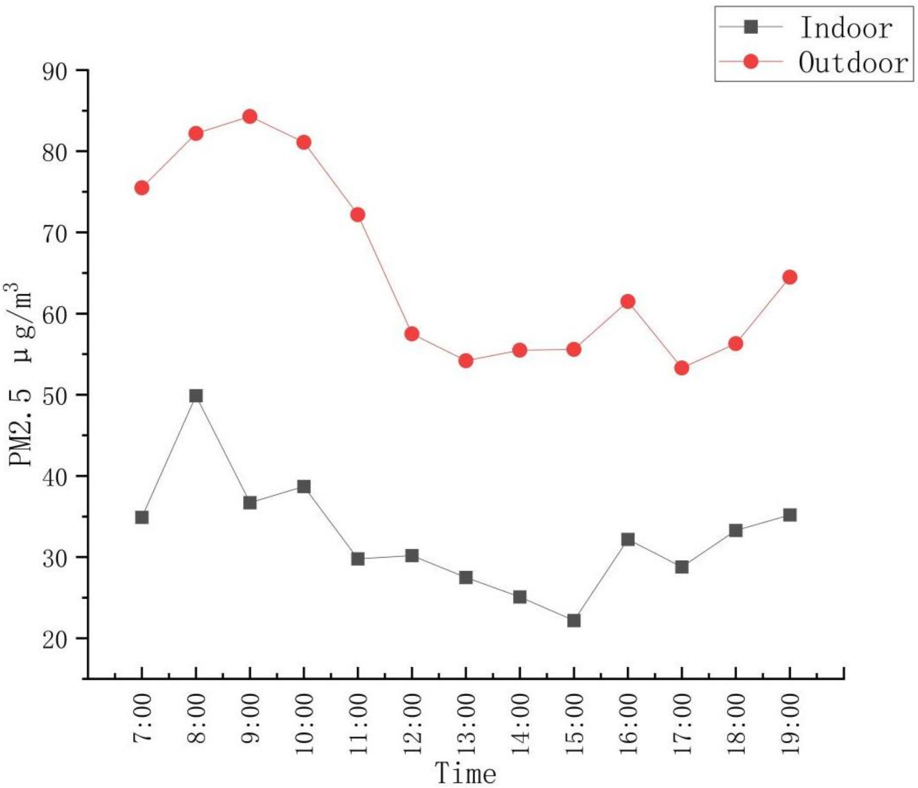

Fig.2: Indoor and outdoor PM2.5 concentration when doors and Windows are closed

Figure 1 shows the effect of the change of PM2.5 concentration in the air outside the classroom on the indoor PM2.5 concentration when no one is in the classroom and the doors and Windows are open. The results show: Under the condition of natural ventilation in the classroom, the mass concentration ratio of indoor and outdoor PM2.5 reaches above 0.9. The PM2.5 concentration in the classroom changes significantly with the outdoor PM2.5 concentration, but the indoor PM2.5 concentration is always lower than the outdoor level, and the I/O ratio is always less than 1. In the classroom, the concentration of PM2.5 generated by indoor sources is relatively low, while indoor PM2.5 mainly comes from the outdoor environment .

Figure 2 shows the change of PM2.5 mass concentration inside and outside the classroom when the doors and Windows are closed. As can be seen from the figure, even if the doors and Windows of the classroom are closed, the PM2.5 mass concentration in the classroom still has a tendency to change with the outdoor, but compared with the doors and Windows, the indoor PM2.5 mass concentration changes greatly, and the high value area of indoor PM2.5 mass concentration does not rise significantly when the doors and Windows are opened. This indicates that closing doors and Windows can reduce indoor PM2.5 concentration to a certain extent. However, the indoor and outdoor PM2.5 average concentration ratio is still high, and the indoor and outdoor concentration ratio is between 0.4 and 0.6, indicating that under the conditions of closed doors and Windows, PM2.5 penetration is strong, and it can penetrate into the classroom through the gaps in the doors and Windows, and outdoor PM2.5 pollutants can still greatly affect the indoor PM2.5 concentration.

2.2 PM2.5 prevention and control

There are many sources of indoor air pollution, and air conditioning and ventilation system, as a medium of internal and external air exchange, is an important means and way to improve indoor air quality. At present, the control technology of PM2.5 is mainly based on ventilation dilution, interception or adsorption filtration.

2.2.1 The pollution source is ventilated and diluted

Ventilation can increase the mobility of the air, so that the pollutants in the air can be diluted to a certain extent with the flow of the air, so it is necessary to enhance the ventilation of the indoor environment and introduce clean fresh air to dilute the pollutants. However, while diluting pollutants through ventilation, it should also be noted that if the temperature difference between indoor and outdoor air is large, it is not recommended to directly introduce outdoor air for indoor ventilation dilution, because this will lead to an increase in air conditioning energy consumption and a decline in indoor environment comfort.

2.2.2 Filter indoor PM2.5 pollution

The filtration of pollutants in the air is mainly through the air filter set at the return air port or the supply air port of the indoor end equipment, in order to achieve the filtration of pollutants in the air, which is the most common way in the current HVAC air purification technology. According to the efficiency of its purification, the air filter can be divided into high efficiency filter, medium efficiency filter and low efficiency filter, and the specific selection needs to be designed according to the degree of outdoor air pollution and indoor environmental status.

In the process of use, it should be noted that the filtration effect of the air filter is affected by many factors, and a good filtration effect can effectively reduce the particles in the air and improve the quality of the air. The air filter also needs to be replaced in time to avoid the accumulation of fine dust on the filter, causing secondary pollution to the air leading to the room.

III. CONCLUSION

At different test times, indoor PM2.5 concentration varies greatly, and both outdoor particulate concentration and indoor source will affect the change of indoor PM2.5 concentration. Generally, outdoor source dominates.

Factors affecting indoor PM2.5 concentration: outdoor particle concentration, opening of doors and Windows, test period, etc. Compared with FIG. 1 and FIG. 2, it can be seen that there are obvious differences in indoor PM2.5 concentration in classrooms with Windows on and off. When the Windows of the classroom are opened for ventilation, the correlation between indoor and outdoor PM2.5 is higher, which is significantly higher than that when the Windows are closed, and most indoor PM2.5 comes from the outdoor. On the contrary, when the classroom is closed, the indoor PM2.5 concentration and correlation decrease significantly, indicating that the window area of the classroom and the infiltration effect of PM2.5 may be important factors affecting the entry of outdoor particulate matter into the classroom.

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