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Based on Light Scattering Method Online Monitoring and Evaluation of PM10 in Public Places from Qinhuangdao, China

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Abstract

Abstract: Different indoor air inspirable particle concentrations in public places affect human health. So the real-time detection and analysis of particle concentration is very necessary. The author regards the inhalable particles that the particle equivalent diameter less than 10 μm (PM10) as detecting objects, and conducted the PM10 detection in three places, including a kindergarten classroom, a commercial building, a university's teaching building classroom in Qinhuangdao, Hebei, China. According to the test results, it analyzes that the inhalable particles in air in the three public places are all in accordance with the national indoor air quality standard; respectively analyzes the correlation between the inhalable particles and the indoor conditions when indoor heating, the windows and doors closed and when no heating, natural ventilation; respectively analyzes the correlation between the inhalable particles and the outdoor air conditions in the outdoor haze condition and outdoor sunny condition; According to the potential exposure value, through calculations, it obtained the potential exposure dose of the inhalable particle pollutants with different gender in different situations. The conclusions indicate that the men have higher potential exposure dose than the women; Adults have higher potential exposure dose than children; indoor personnel's potential exposure is beyond the limited value in the fog haze days.

***Keywords**: Public places; PM10; PM2.5; Detection; Exposure value*

1. Introduction

With the acceleration of global industrialization, air pollution problems became even more dominant. In China, the phenomenon of related air pollution has become more and more serious in recent years. It was reported that seven of the China's 10 most pollution cities are in Hebei in 2013 [1]. The major reason for air pollution problem is excessive levels of the inhalable particle pollutants. The inhalable particulates (Particles with diameters of 10um or less, PM10) refers to the particulates that suspended in air and the aerodynamic equivalent diameter is less than or equal to 10um [2].

Therefore, it can harm people's health, because the human respiratory may inhale small size particles. There are usually three cases that can lead to respiratory diseases, birth defects and mutagenicity [3,4]. After PM10 is inhaled, particles of 5μm~10μm can accumulate in the nose and upper respiratory tract; particles of 2μm~5μm enter into the lower part of the respiratory tract, and the particles below 2μm can enter into the bronchiole and alveolar [5]. Not only the respiratory system but also the particles adhered many kinds of harmful substances, which can cause chronic pulmonary disease and cardiovascular diseases [6]. Especially young children, who are in the lung function growth period, the inhalable particulates in air that the lung inhaled is a major cause that can lead to child small airway ventilation dysfunction ventilation, ventilation function dysfunction, child birth defects, child asthma and other diseases[7, 8].

Qinhuangdao is a coastal city located in the northeaster of Hebei, the city is adjacent to Bohai, and the oceanic climate significantly. It is the ideal vacation travel for people. But in recent years due to coal dust of the port, industrial waste gases, exhaust of vehicles and other gas pollutants in life and production, it has caused the environmental pollution in the city, and the problems are very serious. It is reported that [9], from January to September 2013, in the detection time for a total of 271 d, air quality qualified days is 164d, pollution days is 107d, the unqualified rate is nearly 40%. The problems of the inspirable particle concentration in air cannot be ignored.

The common methods used for measuring the indoor air inhalable particle pollutants include the gravimetric method, β ray absorption method, TEOM method and light scattering method. The measurement procedure of the weighing method is complicated. As the filter membrane used in the process of measurement need to reach the weight gain more than 0.5~1 mg, it often needs to obtain samples for 2~4h, later the samples still need to be sent to the lab for membrane drying, constant weight , measuring work [10,11]. The β ray absorption method can realize the continuous on-line automatic detection of the air, but the cost is high, and it is not suitable for the detection of indoor particle pollutants. TEOM method has higher requirements on air temperature and humidity. When measured in a high humidity rainy day or hot weather, the data should be low [12]. Through the light scattering method to detect the inspirable particle concentration in air in public places, it has the advantages of fast, sensitive, good stability, small volume, light weight, no noise, simple operation, safe and reliable, real-time detection, *etc*. [13] According to “the determination method of inhalable particles in air in public places—the light scattering method WS/T 206-2001” issued by the Chinese Ministry of Health, the light scattering method is specified the standard method to detect the inhalable particles in public places.

Due to a long time stay in the public environment, the quality of indoor air quality can have a significant impact on human health. Factors that sprightly affect the quality of IAQ are temperature, relative humidity, air velocity, fresh air, volatile organic compounds and inhalable particle pollutants, *etc*. With the indoor inhalable particle pollutants as the testing object, the author selected three public buildings with different function in Qinhuangdao, through the inhalable particle pollutant concentration online detection system that designed by the author to analyze and compare the test results. Combined with the survey of the indoor living personnel’s working time, it assessed the health affect factors and provided the reference for the government to make more scientific public indoor air quality standards.

2. Design of the Online Detection System

2.1. Composition of the Detection System

Composition of the detection system is composed of the light scattering particle counter, router, coordinator, and upper computer. The structure diagram is shown in Figure 1.

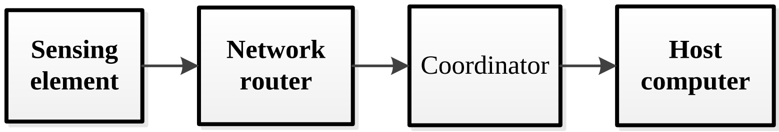

Figure 1. System Construction Drawing

Light scattering particle counting device is based on that when the light falls on the particles suspended in the air, it can produce the scattering light. Under the condition of unchanged particulate matter physical properties, the scattering intensity of the particles is proportional to the density of the particles [14, 15]. The light scattering particle counting device is composed of gas path and light path. The gas path system includes gas flow meter, air pump, air chamber and the photosensitive diode. And then it integrates A/D converter, final micro-controller and final Zig bee on the chip, and passes the signals to the router. The light source is a compact and low loss free light path semiconductor laser. The attenuation light beam is detected by the photoelectric diode. The gas flows through the chamber at a rate of 500mL/min. The air pump provides the power, and the flow meter conducts the measurement. The system structure diagram is shown in Figure 2.

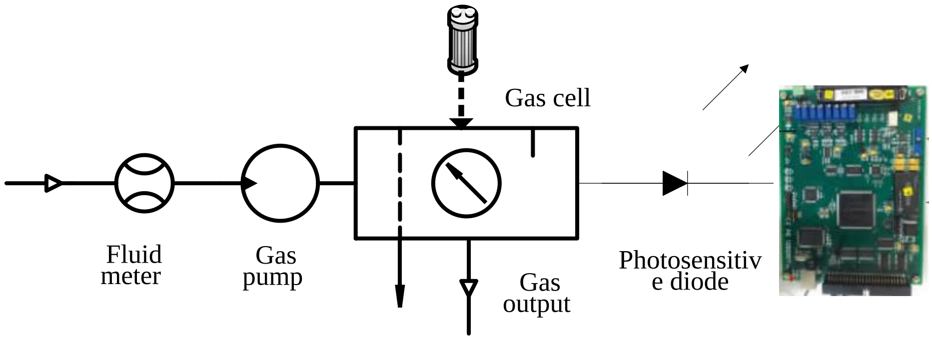

Figure 2. Light Scattering Particle Counting Device System Principle Diagram

The router is composed of the initial position node, the relay node, and Ⅰ、Ⅱ micro-controller. Router finishes the transmission of information through the communication function of Zig bee module. Finally, the information will be fed back to the data receiver.

The coordinator includes two micro controllers and two Zig bee transceivers. The first Zig bee transceiver realized the communication between the router and the first micro-controller. The second Zig bee transceiver realized the communication between the second micro-controller and upper computer. So, it can collect the real-time detection data of inhalable particle pollutions and upload to the upper computer model through the coordinator.

2.2. Design of Hardware Circuit

The hardware circuit is composed of data acquisition part and data transmission part.

The hardware circuit of data acquisition part includes sensor hardware circuit, micro-controller hardware circuit, power circuit and wireless transceiver module CC2430. CC2430 is a Zig bee TM chip based on the wireless standard in IEEE802.15.4 communications protocol, with Zig, which has the Zig bee RF in it, and the memory is 8051 microprocessor, including 32kB/64kB/128kB optional capacity and programmable flash and 8kBRAM. The power circuit is battery-powered, which can save the energy consumption. The module diagram is shown in Figure 3.

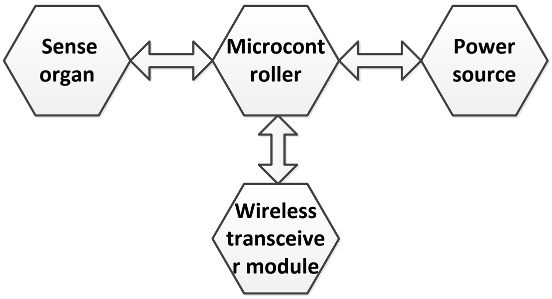

Figure 3. The Hardware of Data Acquisition Part

The hardware circuit of data transmission part includes router, coordinator and upper computer. The coordinator includes one micro-controller module circuit and CC2430 wireless data transceiver module that produced by TI Company. Through the different programming to its internal procedures, it can achieve the different functions of the router and the coordinator. Through the detection platform of upper computer, the processing, storage and display of the collected environmental data can be realized. Through the RS232 serial port of the upper computer, it realized the connection to coordinator. The data transmission part hardware composition diagram is shown in Figure 4.

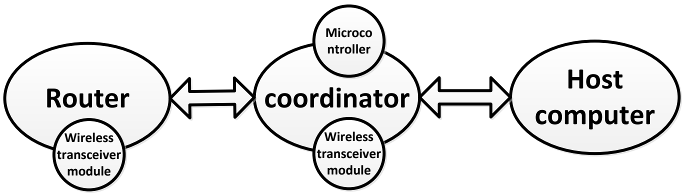

Figure 4. The Hardware of Data Receive Part

2.3. Detection System Software

The detection system software includes wireless Zig bee network transmission, sensor data acquisition, data transmission, micro-controller, upper computer real-time detection display. Among them, the flow diagram of sensor data acquisition program and data transmission program are shown in Figure 5, the flow diagram of the micro controller and upper computer real-time detection display program are shown in Figure 6.

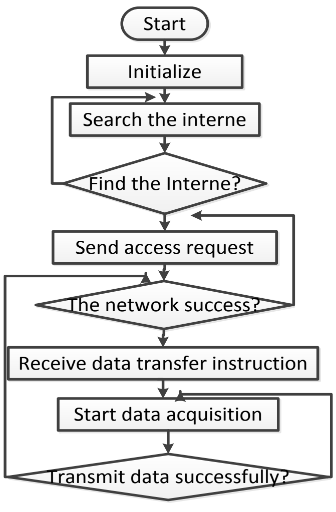

Figure 5. The Data Acquisition Program Flow

Figure 5 shows the sensor acquisition program, the process includes four steps: establish the wireless network by the controller and the router; add the sensor nodes into the network; begin to collect the data with the light scattering particle counting device; through the wireless transceiver module send the data to the coordinator by the router.

Figure 6 shows that through the coordinator, the data information will be sent to the upper computer to display, the upper computer then processes the data.

The software of the wireless data transmission module was developed by using IAR Embedded Workbench, and the detection platform of the computer was developed by using the Lab view. The development of the micro-controller module software adopts the ADS1.2 integrated development environment of ARM Company to design. Wireless data transceiver module requests to join the network. After received the response, it will send its address to the coordinator. It will automatically establish the bind with the coordinator. When received a data collection instruction, the sensor node starts to send the collected environmental data to the upper computer by the router and coordinator periodically.

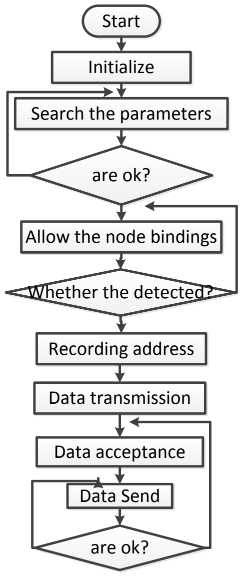

Figure 6. The Program Flow Data Receiving

3. Field Data Acquisition

Respectively, the test building is a kindergarten classroom, located on first floor, with windows, a building area of 16 m2; an ordinary office, located on the 4th floor, with windows, a building area of 25 m2; a university's classroom, located on the 2nd floor, with windows, the building area of 80 m2. Building all indoor areas have no air conditioners, and the ventilation conditions are good.

The test time is respectively on Nov 23, 2013 (the first test); Mar15, 2014 (the second test); Jul 26, 2014 (the third test). The three day was on a Saturday. There were no other human activities except the testers; when testing for the first time and the third time, it is sunny outside, and good air governance; when testing for the second time, it is haze outside. In the first test, indoor heating; In the second and third test, indoor without heating; According to the screening method to measure, namely close doors and windows for 12h before sampling, and obtain the sample once per hour.

The sampling point level setting scheme, the room less than 50 m2 should set 2 points; 80 m2set 4 points; the sampling point vertical setting scheme is roughly equal to the height of the breathing zone of people , setting a height of 1.0m.

4. Test results

Count the measurement data on Nov 23, 2013(heating, sunny, good outdoor air quality) and Jul 26, 2014(without heating, sunny, good outdoor air quality), and average them, then obtain the indoor air PM10 concentration in heating condition and non-heating condition and other statistical data, and then finishing in Table 1.

In order to study the specific changes of indoor air PM2.5 concentration and PM10, the related data in Table 1 will be drawn as shown in Figure 1. By statistical analysis, PM10 measurement average is 31.89μg•m-3 in the kindergarten when indoor heating, PM10 measurement average is20.627μg•m-3 in the kindergarten when no indoor heating; PM10 measurement average is 31.901μg•m-3 in the office when indoor heating; PM10 measurement average is21.964μg•m-3 in the office when no indoor heating; PM10 measurement average is30.128μg•m-3 in the university's classroom when indoor heating, PM10 measurement average is19.1484μg•m-3 in the university's classroom when no indoor heating. The related data in Table 1 will be drawn as shown in Figure 7.

Table 1. Statistical Data of Different PM10 Concentration in Indoor Environment

Building & weather		PM10(μg•m^{-3})									
		8.00	**9.00**	**10.00**	**11.00**	**12.00**	**13.00**	**14.00**	**15.00**	**16.00**	**17.00**
Kindergarten	Heating	30.25	32.10	32.10	32.17	32.54	31.17	31.25	32.55	32.56	32.21
	No heating	19.00	20.50	21.00	21.21	20.25	20.24	20.25	21.23	21.25	21.34
Office	Heating	34.14	35.15	35.12	35.16	35.20	34.10	34.78	35.10	35.12	35.14
	No heating	21.80	21.85	22.01	22.03	21.98	21.87	21.99	22.00	22.01	22.10
College	Heating	28.30	28.16	28.55	27.98	28.07	27.90	28.00	28.05	27.07	28.08
	No heating	15.45	15.17	15.36	15.42	15.23	15.26	15.35	15.25	15.40	15.44

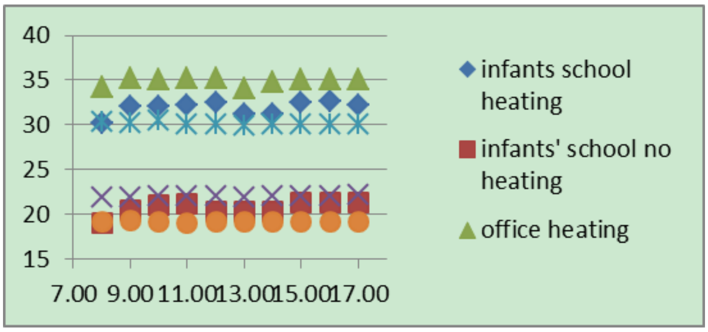

Figure 7. Analysis of Different Indoor Environment PM10 Concentration Data

$$r_{XY} = \frac{\sum_{i=1}^{n}(x_i-\overline{X})(y_i-\overline{Y})}{\sqrt{\sum_{i=1}^{n}(x_i-\overline{X})^2}\sqrt{\sum_{i=1}^{n}(y_i-\overline{Y})^2}} \quad (1)$$

Where, r_{XY} is the correlation coefficient; x_i is the heating when the concentration of PM10, μg•m-3; y_i is the indoor heating when the concentration of PM10, μg•m-3; $\overline{X}$ is the indoor heating when the average PM10 concentration, μg•m-3; $\overline{Y}$ is the no indoor heating when the average PM10 concentration, μg•m-3.

Conduct the correlation analysis by using Formula One, and obtain the correlation coefficient between them. In the kindergarten, PM10 correlation coefficient between the heating period and non-heating period is 0.83; in the office, PM10 correlation coefficient between the heating period and non-heating period is 0.69; in the university classroom, PM10 correlation coefficient between the heating period and non-heating period is 0.19. In addition to the University's classroom, during the heating period, the house is heated by using geothermal coil, and generally it has no ventilation indoor, so the content of PM10 all rose, namely it has a high correlation between different indoor PM concentrations and whether indoor heating. But the correlation coefficient of the college classroom is small, due to the flow of personnel, every two hours the personnel entering and exiting the classroom. Therefore, the correlation coefficient is smaller, but the indoor PM10 concentration still increases during the indoor heating period.

Count the measurement data on Mar 15, 2014 (haze, outdoor air quality is poor) and Feb 26, 2014 (sunny, good outdoor air quality), and average them, then obtain the statistical data of PM10, PM2.5 concentration in indoor air and other statistical data under the condition of heating and non-heating (as shown in Table 2).

Table 2. The Concentration of PM10 Statistical Data in Different Weather Conditions

Building & weather		PM10(μg·m^{-3})									
		8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00
Kindergarten	Haze	252.55	254.28	254.35	254.33	254.37	254.28	254.26	254.29	254.30	254.32
	Sunny	20.73	20.89	21.00	21.21	21.25	20.74	20.85	21.03	21.05	21.10
Office	Haze	253.19	255.15	255.18	255.18	255.03	255.20	255.19	255.18	255.16	266.14
	Sunny	20.80	22.02	21.95	22.01	22.03	21.98	21.97	21.99	22.03	22.06
College	Haze	256.37	258.86	258.89	258.75	258.78	258.72	258.80	258.83	258.85	258.87
	Sunny	20.45	21.37	21.39	21.36	21.38	21.23	21.26	21.30	21.32	21.36

By statistical analysis, when occurs the fog and haze outside, the PM10 measurement average is 254.13μg•m-3 in the kindergarten, when it is sunny outside , the PM10 measurement average is 20.905μ g• m-3 in the kindergarten; when occurs the fog and haze outside, the PM10 measurement average is 256.06μg•m-3 in the office, when it is sunny outside , the PM10 measurement average is 21.884μg•m-3 in the office; when occurs the fog and haze outside, the PM10 measurement average is 256.06μg•m-3 in the university's classroom, when it is sunny outside , the PM10 measurement average is 21.242μg•m-3 in the university's classroom. Calculate the correlation coefficient according to the formula 1. The related data in Table 2 will be drawn as shown in Figure8, Figure 9, Figure 10.

Perform the correlation analysis by using formula 1. In the kindergarten, PM10 correlation coefficient between the outdoor haze and outdoor sunny is 0.93; in the office, PM10 correlation coefficient between the outdoor haze and outdoor sunny is 0.95; in the university's classroom, PM10 correlation coefficient between the outdoor haze and outdoor sunny is 0.95. The indoor PM10 concentration not only affected by the indoor heating and ventilation technology but also by the outdoor air environment. In fog haze days, the tested indoor PM10 concentration is more than 100 times of the test value in sunny days. Thus it can be seen that the indoor PM10 value increased with the out door PM10 concentration in the fog haze weather. The relationship between them is almost linear.

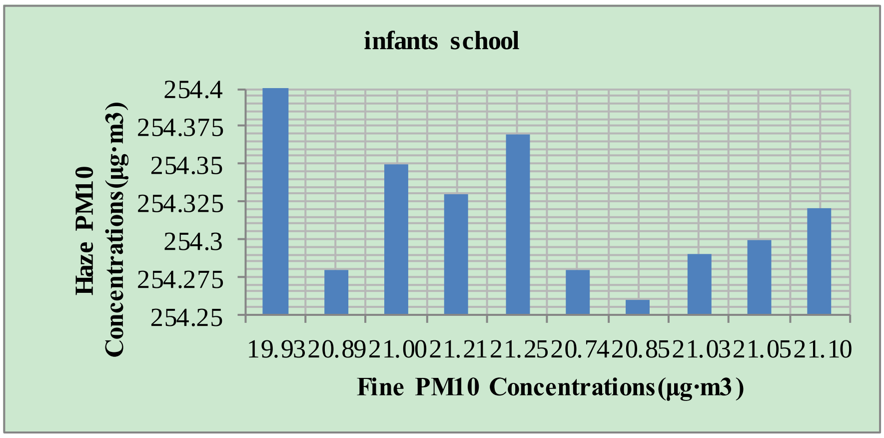

Figure 8. Indoor PM10 Concentrations Compared To the Kindergarten

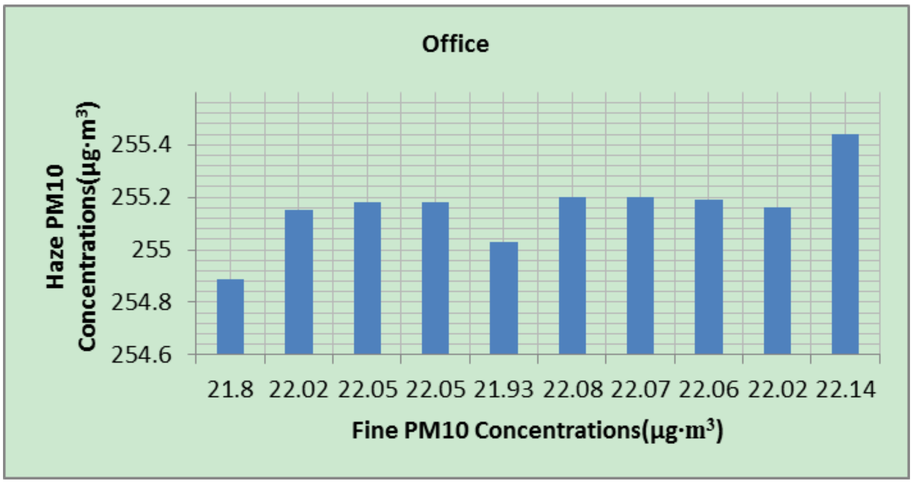

Figure 9. Indoor PM10 Concentrations Compared to the Office

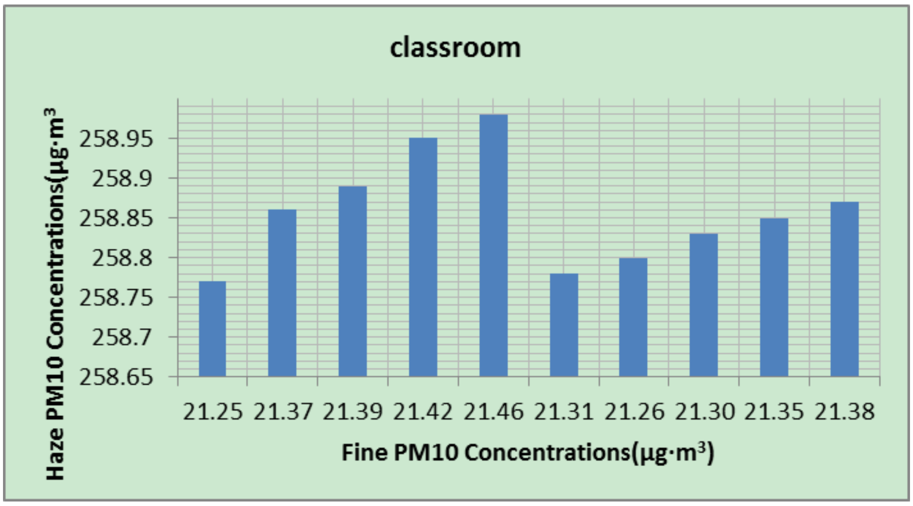

Figure 10. Indoor PM10 Concentrations Compared To the University Classroom

5. Assessment of Inhalable Particulates Exposure

Exposure assessment is an important parameter to assess the effect of the migration and distribution of the pollutants in the air on the body, and it provides the basic parameter [16] for the study of epidemiology and health risk assessment. The U.S. Environmental Protection Agency (EPA) proposed, according to the particle concentration absorbed by the body for some time, the potential exposure quantity (Potential Dose) can be obtained by calculation, and it can be used to assess the actual human exposure status [17]. The calculation formula is shown as follows:

$$D_{Pot} = \int_{t_1}^{t_2} C(t) IR dt \tag{2}$$

Where, D_{Pot} is the potential exposure, mg; $C(t)$ is the time variation of the particle concentration, mg·m-3; IR is the human respiratory morbidity, $m^3 \cdot h^{-1}$.

The author investigated the length of time that the living personnel of three kinds of occasions stay inside, the statistics are as follows:

Table 3. People in Indoor Schedule

Room	Member	Length
Kindergarten class	Become full grown	7.00-17.30
	Children	7.40-17.00
The college classroom	Schoolboys	8.00-10.00
	Schoolgirls	8.00-10.00
Office	Male	9.00-17.00
	Female	9.00-17.00

Table 4. Respiration Rate Statistics

Age	Gender	Respiration rate ($m^3 \cdot h^{-1}$)
Become full grown	Male	1.2
	Female	0.9
Children	Male or female	0.8

Table 5. Potential Exposure (mg·m-3)

The sampling period	The college classroom		Office		The college classroom
	Schoolboys	Schoolgirls	Male	Female	
Heating	1.11	1.01	1.35	1.25	1.04
No heating	0.56	0.45	0.87	0.79	0.35
Haze	1.68	1.52	1.88	1.75	1.46
Sunny	0.53	0.43	0.86	0.78	0.38
standard value	1.44				1.2

The size of respiratory rate is related to age, gender and activity. According to the related literature [18, 19], the different age and gender average respiration rates in different environments are shown in Table 4.

After calculation, data statistics can be obtained, as shown in Table 5.

From the data in the table, it concludes that the men have higher potential exposure dose that induced respiratory disease than the women in the same place; The children have higher potential exposure dose that induced respiratory disease than the adults under the same indoor and outdoor conditions; at the same time, under the same indoor and outdoor conditions, the students in university's classroom have higher potential exposure dose that induced respiratory disease than the staff in the office, this is because the personnel in university's classrooms flow every two hours. In addition, in the same place, when no indoor heating , the potential exposure dose that the personnel induced respiratory disease is high than that indoor heating; when outdoor occurs haze, the potential exposure dose that induced respiratory disease is higher than that in sunny outdoor. When outdoor fog haze occurs, the measured value is higher than the concentration limits of potential exposure dose, which can induce the respiratory disease. So the risk that induced respiratory disease is higher, we need to control the inspirable particle concentration.

6. Conclusion

This topic tests the indoor air inspirable particle concentration of the public buildings in Qinhuangdao during Nov 2013 to Jul 2014.

The indoor PM10 concentration is related to whether indoor heating. During the heating period, due to the poor indoor ventilation, the indoor PM10 and PM2.5 value is higher than the value tested in the non-heating period with good ventilation. The change ratio of PM10 concentration is 1.12~1.663, the change ratio of PM2.5 concentration is 1.29~2.1.

The indoor PM10 concentration is linearly associated with the outdoor PM10 concentration in the fog haze days, and it has no obvious correlation with outdoor PM10 concentration in sunny days.

The PM10 concentration in fog haze days is beyond our standard value (<0.15 mg/m3, GB/T 18883-2002 "indoor air quality standards"), other time is qualified; PM10 measurement data is beyond the standard (<0.035 mg/m3 American EPA). The indoor air PM10, PM2.5 concentration in the kindergarten is higher than the value measured in office and university. Therefore, it should arouse the relevant departments' great attention and proposes the solutions.

When outdoor fog haze occurs, the potential exposure dose that induced respiratory disease is higher than that in sunny days. When outdoor fog haze occurs, the measured value is higher than the concentration limits of the potential exposure dose that induced respiratory disease. Therefore, the risk that induced respiratory disease is higher, and we need to control the inspirable particle concentration.

Acknowledgements

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