In situ measurement of atmospheric particles mass concentration in Anshan

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Abstract. The changes of the atmospheric particles mass concentration, their pollution condition, and their relationships to visibility have been studied by using the continuous concentration data of monitoring instrument GRIMM180 from Anshan air component monitoring station in 2014. The results show that the mean mass concentrations about PM10 and PM2.5 are respectively 0.077 mg/m³ and 0.049 mg/m³, and their daily average concentration has a large variation range. The daily variation of the mass concentration is characterized by a pronounced double-peak pattern, with peak concentration during 7:00~9:00 AM and 21:00~22:00 PM, and low during 3:00~5:00 and 14:00~16:00. The ratio above air quality standard about PM10 daily average concentration is 9.07%, and the atmospheric particles exist mainly in the form of fine particles. The atmospheric particles mass concentration and the visibility show negative correlation, and the finer the particles are, the more they affect visibility.

1. Introduction

With the rapid development of economy in China, the atmospheric particles have become the main atmospheric pollutants in many cities, and their existence has an important effect on atmospheric environment, human body health, visibility, climate change.1-4 The fine particles PM2.5 in the atmosphere do greater harm to the human body health than the coarse particles. They deposit in the pulmonary alveoli and directly enter into the blood cycle to cause the rising of disease and mortality rate. They are also the main factors to reduce visibility5,6. Therefore, the strengthening research of urban atmospheric particles concentration change is of significance to reveal the basic characteristics and the rule of variations about urban atmospheric particles. Some research on atmospheric particles had been done outside China in the 1950s, and it is deeper in recent years7,8. Many researches have also been done about the atmospheric particles from different Angles in recent years in China. For example, the characteristic of aerosol has been studied in Xiamen by Xuebin Li et al9. Using the observational data in Lanzhou area, the atmospheric particles mass concentration and spectrum distribution in different weather conditions have been studied by Xin Wang et al10. On the basis of atmospheric aerosol observations collected in Chongqing in winter of 2001—2002, the analysis of physical and chemical characteristics of aerosol, such as number concentration, mass concentration, size distributions,
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chemical compositions and the relations to meteorological factors have been conducted (Bin Zhu et al., 2006)\cite{17}. The relationship between the atmospheric particles concentration and meteorological conditions has been studied in semi-arid area by Zhenhai Wang et al.. The results show that precipitation is a very important factor scavenging particles with diameter larger than 1 µm\cite{18}. Size distribution of number concentration and chemical components of particulate matters have been analysed during Spring Festival in Shanghai suburb (Guanghua Wang et al., 2011)\cite{19}. The size distribution of particulate was analyzed by the FA-39 stage sampler in Northern-suburb of Nanjing from January to November in 2014 (Wu Dan et al., 2016)\cite{20}. The results show that Particulate pollution in Northern-suburb Nanjing was serious in which the annual average concentrations of PM1.1, PM2.1 and PM10 were (65.6 ± 37.6), (91.0 ± 54.7) and (168.0 ± 87.0) µg·m⁻³ respectively; fine particles dominated and most of them had a diameter of less than 1.1 µm. There have been some related reports about the research on atmospheric particles in Liaoning province\cite{21-24}, but very few systematic studies have been done, in Anshan, on the variation and pollution conditions of the atmospheric particles and the fine particles.

The changes of the atmospheric particles mass concentration and their pollution conditions have been analysed by using the observational data of GRIMM180 instrument from Anshan air component monitoring station in 2014. Meanwhile, Combining with the data of visibility their relationships to the atmospheric particles mass concentration have been studied.

2. Data

The observational site of Anshan is located in the air component monitoring station at the top of the building of Anshan Meteorological Bureau. Its geographical position is 122.60° E, 41.05° N and 77.3 metres above sea level and there is successive on-line monitoring over the atmospheric particles mass concentration and the visibility. The atmospheric particles mass concentration is measured by particles monitors GRIMM180, which is made by the GRIMM Company in Germany. GRIMM180 can measure the number concentration of the aerosol in 31 particle sizes and the mass concentration of PM10, PM2.5 and PM1 in real time once every 5 minutes. The visibility instrument FD12, made by Finland VAISALA company, is used to measure the atmospheric visibility. FD12 is a forward-scattering measuring Instrument controlled by a microprocessor and its observation elements include the average visibility every 1 minute, every 10 minutes and the change trend of the visibility.

The observation data of different frequency has been processed by deleting useless and wrong data due to instrument malfunction, blackout and so on. After sorting out and analyzing the data, we get the hourly mean data. Then the daily and monthly mean data are respectively calculated based on the hourly mean data.

3. Results and discussion

3.1 The daily and monthly mean mass concentration variation

The variations of PM10 and PM2.5 daily mean concentration in 2014 in Anshan are presented in Figure.1. Variation features of PM10 and PM2.5 are more identical, but the daily average concentration of the atmospheric particles has a large variation range. The annual mean mass concentrations of PM10 and PM2.5 are respectively 0.077 mg/m³ and 0.049 mg/m³. The lowest daily mean mass concentration value appears on September 4, 2014 in summer and the values of PM10 and PM2.5 are respectively 0.014 mg/m³ and 0.009 mg/m³. The highest value appears on February 23, 2014 in winter and the values of PM10 and PM2.5 are respectively 0.312 mg/m³ and 0.270 mg/m³. Analysis shows that the weather is sunny on September 4, 2014 in Anshan due to the weak cold air intruding, which had a good diffusing effect on atmospheric particles. Meanwhile the atmosphere was unstable or slightly unstable and it was advantageous to transport and diffuse of the atmospheric particles, which lead to the lowest concentration value appearing. The weather condition was stable, the average wind speed was about 0.86m/s, the inversion near the surface existed at the high level, and fog-haze weather appeared on February 23 2014 in Anshan, which caused serious atmospheric pollution.
Figure 1. The variations of PM10 and PM2.5 daily mean concentration in 2014

Figure 2 and Figure 3 separately shows the Monthly and seasonal variations of PM10, PM2.5 and PM1 mass concentration in 2014 in Anshan. The monthly mean mass concentration of the atmospheric particles has a large variation range, and the mass concentration varies with the season. There has been a low value of the atmospheric particles mean mass concentration in summer (from 6 to 8 months), which is the lowest in the four seasons with the values of PM10, PM2.5 and PM1 being separately 0.028 mg/m³, 0.022 mg/m³, and 0.020 mg/m³. The minimum monthly value of the atmospheric particles mass mean concentration occurs in June and the values of PM10, PM2.5 and PM1 are separately 0.047 mg/m³, 0.038 mg/m³, and 0.034 mg/m³. There has been a high value in winter (1, 2, and 12 months), which is the highest in the four seasons with the values of PM10, PM2.5 and PM1 being separately 0.107 mg/m³, 0.065 mg/m³, and 0.057 mg/m³. The maximum monthly value of the atmospheric particles mean mass concentration occurs in February. The seasonal mean values in Spring (from 3 to 5 months) and autumn (from 9 to 11 months) are in the middle of the values in the four seasons, with the values of PM10, PM2.5 and PM1 being separately 0.100 mg/m³, 0.053 mg/m³, and 0.046 mg/m³ in spring, and that being 0.057 mg/m³, 0.042 mg/m³, and 0.039 mg/m³ in autumn. Analysis shows that the atmosphere is unstable or slightly unstable generally in June of summer. The wind speed being large and precipitation’s scavenging effect on the atmospheric particles, which is advantageous to transport and diffuse of the atmospheric particles, leads to the appearance of low concentration value. The mass concentration of the atmospheric particles is the highest in Winter, owning to a large amount of coal-firing and the inversion and static wind near the surface appearing at a high level in Winter.

Figure 2. The variations of PM10, PM2.5 and PM1.0 monthly mean concentration in 2014
3.2 The hourly mass concentration variations of a day for PM10, PM2.5 and PM1
Figure 4 shows the hourly variations of a day for PM10, PM2.5 and PM1 mass concentration in 2014 in Anshan. The results show that the variations of PM10, PM2.5 and PM1 mass concentration are the bimodal characteristics. The daily variation trend of PM10 and PM2.5 PM1 is consistent. The daily variation of the mass concentration is characterized by a pronounced double-peak pattern, with peak concentration during 7:00 ~ 9:00 AM and 21:00 ~ 22:00 PM, and low during 3:00 ~ 5:00 and 14:00 ~ 16:00, which is the consequence of meteorological conditions and daily variation of pollution emission. The activities of people and the coal heating boilers have increased gradually since 5:00 AM. In addition, the number of the vehicles on road and the pollutants emissions becomes more and more, which leads to the increasing of PM mass concentrations and up to the maximum value at 7:00 ~ 9:00 AM. Later, because of the mixing layer developing up and the wind speed increasing, the pollutant concentration starts to decrease and down to a minimum value at about 15:00 PM when the layer of turbulent mixing has developed fully. The height of mixing layer has become lower and the wind speed smaller since 18:00 PM, which causes to form thin mixing layer and the increasing of PM mass concentrations. In addition the traffic emissions is also one of the reasons for high mass concentration.
3.3 The exceeding standard situation of the atmospheric particles and the ratio of the fine particles to the coarse particles

At present the national level 2 standard of daily mean mass concentration for PM10 is 0.15 mg/m³ and PM2.5 0.075 mg/m³ according to Technical Regulation on Ambient Air Quality Index (HJ633-2012) in China. There is no specific concentration standard for PM1. The exceeding standard situation of the atmospheric particles is analyzed according to the above standard. The available observation days are 364 and the annual mean mass concentration of PM10, PM2.5 and PM1 are respectively 0.077 mg/m³, 0.049 mg/m³, and 0.044 mg/m³. The results show that there are 33 days above national level 2 standard for PM10 and the exceeding ratio of PM10 is 9.07% in 2014 in Anshan. Number of days above level 2 standard of PM2.5 is 53, and the exceeding ratio of PM2.5 is 14.6%, and the ratios of PM2.5/PM10 and PM1/PM10 are respectively 63.9% and 56.8% in Anshan, which is roughly the same level as in Dandong and Fushun of Liaoning province. Through the above analysis, we find that the atmospheric particles exist mainly in the form of fine particles in Anshan. However, the fine particles can deposit in the pulmonary alveoli and directly enter into the blood cycle to cause the rising of disease and mortality rate. So the pollution degree of the fine particles is more serious than the coarse particles in Anshan and we need put more attention to the fine particles.

3.4 The relationship between the atmospheric particles mass concentration and the visibility

Figure 5 shows the monthly variations of the correlation coefficient between particles mass concentration and visibility from January to December in 2014 due to the limitation of the observational visibility data. The particles mass concentration and the visibility show negative correlation and the average correlation coefficients of PM10, PM2.5 and PM1 to visibility are respectively -0.57, -0.81 and -0.82, which shows that the finer the particles are, the more they affect visibility. The correlation coefficients of PM10, PM2.5 and PM1 to visibility are respectively -0.85, -0.93 and -0.93 in March, which is the highest. The correlation coefficients of PM10 to visibility are respectively -0.28, -0.44 and -0.48 in November, which is the lowest. The correlation coefficients of PM2.5 and PM1.0 to visibility are respectively -0.58 and -0.59 in October which is the lowest. In addition, though the change trends of the correlation coefficient of PM10, PM2.5 and PM1 to visibility are well identical, the values of the correlation coefficient are not equal. The correlation between PM10 and the visibility is lower than that of PM2.5, PM1 and the visibility each month. In addition to January, April and December, the correlation between PM1 and visibility is higher than PM2.5 and the visibility. So, it is also known that the finer the particles are, the more they affect visibility.

![Figure 5](image-url)
4. Conclusions

(1) The annual mean mass concentrations of PM10 and PM2.5 are respectively 0.077 mg/m3 and 0.049 mg/m3 in 2014 in Anshan. Variation features of PM10 and PM2.5 are more identical, but their daily average concentration of the atmospheric particles has a large variation range.

(2) The monthly mean mass concentration of the atmospheric particles has a large variation range, and the mass concentration varies with seasons. There has been a low value of the atmospheric particles mean mass concentration in summer, which is the lowest in the four seasons with the values of PM10, PM2.5 and PM1 being separately 0.028 mg/m³, 0.022 mg/m³, and 0.020 mg/m³. The maximum monthly value of the atmospheric particles mean mass concentration occurs in February.

(3) The hourly mean mass concentration of the atmospheric particles has a large variation range in a day. The daily variation of the mass concentration is characterized by a pronounced double-peak pattern, with peak concentration during 7:00~9:00 AM and 21:00~22:00 PM, and low during 3:00~5:00 and 14:00~16:00, which is the consequence of meteorological conditions and daily variation of pollution emission.

(4) The exceeding ratio of PM10 for the daily mean mass concentration is 9.07% in 2014 in Anshan and PM2.5 is 14.6%. The ratios of PM2.5/PM10 and PM1/PM10 are respectively 63.9% and 56.8%. The pollution degree of the fine particles is more serious than the coarse particles in Anshan and we need put more attention to the fine particles.

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