# Analysis on mass concentration of $PM_{2.5}$ in Kunshan

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**Abstract**: The quality of ambient air has significant effect on the production and life of human beings, and the $PM_{2.5}$ is of great importance for the environment and heath. This paper presents the investigation on the regional, seasonal and daily characteristics of $PM_{2.5}$ in Kunshan, China in 2013 by setting 7 sampling points. The daily average value of $PM_{2.5}$ varies in a range of 4~366μg/m$^3$ while the annual average value reaches 57μg/m$^3$ with an over-standard rate of 63%. The mass concentration of $PM_{2.5}$ shows a small regional difference but great seasonal difference. This index is high in winter while low in summer, and is similar in spring and autumn. The total number concentration of particles ranging 0.3 ~10μm in the four seasons is 587/cm$^3$ of which the particles in 0.3~2.5μm account for 99.7%.

## Introduction

$PM_{2.5}$ represents the particles in the ambient air with aerodynamic equivalent diameters no more than 2.5μm. It consists of complex atmospheric pollutants produced by natural pollution sources and human activities. It can be generally divided into two groups: primary particles and secondary particles [1]. The $PM_{2.5}$, as the important index for estimating air pollution, is of great concern for countries and organizations in the world [2]. The USA is the first country to apply the $PM_{2.5}$ for environmental quality monitoring followed by WHO, Japan, Australia, etc [3]. In 2012, the "ambient air quality standard" was published in China which regulated the mandatory implementation of $PM_{2.5}$ as a monitoring index [4].

The mass concentration of $PM_{2.5}$ can represent the pollution level in a city or region. The global satellite retrieval distribution of $PM_{2.5}$ published by NASA in September 2010 showed the average global concentration of $PM_{2.5}$ during 2001~2006 [5]. PujaKhare et al. [6] monitored the $PM_{2.5}$ in the northeast of India and other cities. It was found that the concentration of $PM_{2.5}$ in India was higher than USA and Europe which showed obvious seasonal variations. There are growing interests in $PM_{2.5}$ in China. The pollution level, characteristics distribution and mechanism of $PM_{2.5}$ in Beijing, Lanzhou, Changsha, Xian were studied by Zhao et al. [7], Qu et al. [8], Zhu et al. [9] and Du et al. [10], respectively.

The city of Kunshan locates between 120°48′21″ E and 121°09′04″ E, and 31°06′ 34 ″ N and 31°32′36″ N. It is in the north Asia tropical monsson climate zone which is warm, humid, and has four distinct seasons, adequate sunshine, abundant rainfall, same period of rain and heat. The annual average rainfall, sunshine and temperature in Kunshan are 1200.4mm, 1789.2 hours and 17.6℃, respectively. The southeast and northwest winds are the primary winds. Kunshan is one of the most developed cities in China and ranks one of top 100 national comprehensive economic strength cities for many years. It has complete industrial categories and a typical environment condition in China.

## Data and Collection

Sample collection

A total of 7 sampling points were set in Kunshan, as listed in Table 1. The layout of these points including the height requirement of 3~15m met the technical requirements in relevant standards for the layout of ambient air quality monitoring points.

Table.1 Information of sampling points

| No. | Region characteristics | location | height | Influencing factors |
|---|---|---|---|---|
| 1 | suburban mixed area | 120.912°,31.402° | 5m | Transportation, industry, commerce |
| 2 | Urban commercial and residential mixed | 120.953°,31.388° | 15m | transportation, commerce, living |
| 3 | suburban commercial and residential mixed | 120.999°,31.381° | 8m | transportation, commerce, living |
| 4 | subtown commercial and residential mixed | 120.989°,31.468° | 5m | commerce, living |
| 5 | Large-scale planting area | 121.099°,31.337° | 5m | transportation |
| 6 | Rural community | 120.912°,31.181°, | 15m | living |
| 7 | Industrial park | 121.012°,31.277° | 15m | Industry, transportation |

Sampling and analysis

The automatic monitoring instrument of particles bam1020 produced by Met one was used to measure the concentration of $PM_{2.5}$. The beta ray attenuation method [3] was used for the measurement. The measurement was taken every hour with a sampling flow of 16.7L/min. The optical aerosol size spectrum OPS 3330 from TSI was used for the particle size sampling with a flow of 1L/min and duration of 24h. It is available for a maximum 16 channels ranging 0.3μm~10μm. The resolution ratio for 0.5μm particles is smaller than 5%. In this study, six channels were used, i.e. 0.3μm~0.5μm, 0.5μm~1.0μm, 1.0μm~2.0μm, 2.0μm~2.5μm, 2.5μm~5.0μm, 5.0μm~10μm. The concentration, mass, and surface area of each particle size range were automatically measured.

## Analysis of Results

Spatial characteristics

The monthly average value of $PM_{2.5}$ measured in 2013 varied in a range of 25~148μg/$m^3$ with the minimum value in the sampling point 6 in August and the maximum in point 7 in December. The annual average $PM_{2.5}$ ranged 53~60μg/$m^3$ with the minimum value in point 6 and the maximum in points 1 and 7, as shown in Fig. 1. The standard deviation between the maximum and minimum monthly average values was 7%~22%. There was a similar variation trend and small differences for the annual variation of $PM_{2.5}$. This may be due to the close distance between sampling points since a maximum distance of 30km between sampling points 4 and 6, and a minimum distance of 5km between points 1 and 2. This also means that there is extensive and universal distribution of $PM_{2.5}$ in a certain regional range. For the long sampling duration, the differences in local pollution and functional area were not obvious. For example, the annual average $PM_{2.5}$ of point 7 in a chemical industry area was the same as that in point 1 which was higher than that in other sampling points. The $PM_{2.}$5 also distributed extensively and universally in the vertical direction for the similar measured values along the height of the sampling (5-15m).

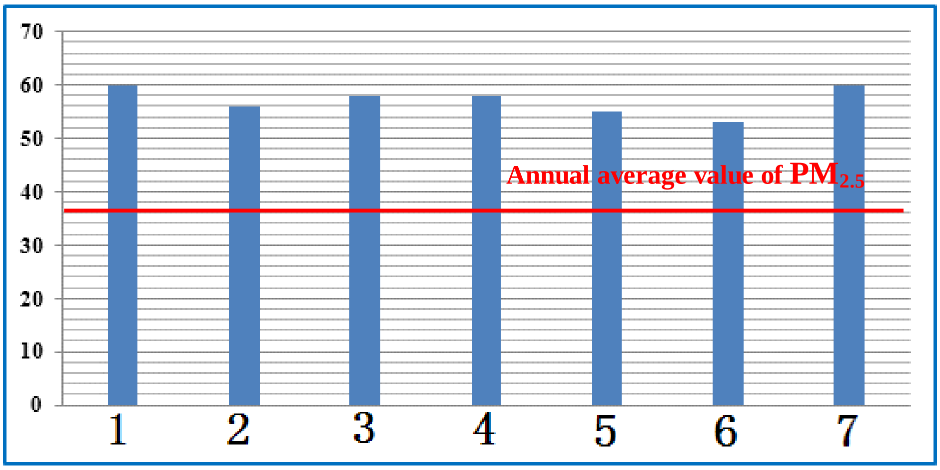


Fig.1 The variation of $PM_{2.5}$ at sampling points in 2013

Seasonal characteristics

Fig. 2 shows the variation of monthly average values of $PM_{2.5}$ in all the sampling points in 2013. It shows a smooth variation from February to September with a minimum value in August (28μg/m$^3$). From October, there was obvious increment of pollution and the $PM_{2.5}$ reached its maximum value of 134μg/m$^3$. From the perspective of seasons, the average concentration of $PM_{2.5}$ were 52μg/m$^3$, 33μg/m$^3$, 54μg/m$^3$, 94μg/m$^3$ for spring, summer, autumn and winter. There was obvious seasonal variation of $PM_{2.5}$ with an order of winter>autumn>spring>summer. The concentration of $PM_{2.5}$ in winter was larger than that in summer, and the spring has a similar $PM_{2.5}$ to autumn. Different from most of northern cities, there is no heating period in Kunshan that its pollution in spring is lower than that in the north. However, the winter is still the peak fuel consumption season and its $PM_{2.5}$ is higher than other seasons, considering the weather conditions and severe haze weather in the south of China in December, 2013. There is sufficient sunshine, strong solar radiation, obvious air convection in summer in Kunshan, and there is small possibility for temperature inversion phenomenon. The plenty rainfall also reduces the concentration of $PM_{2.5}$ [11]. Similar to other southern regions, the summer in Kunshan has the lowest $PM_{2.5}$.

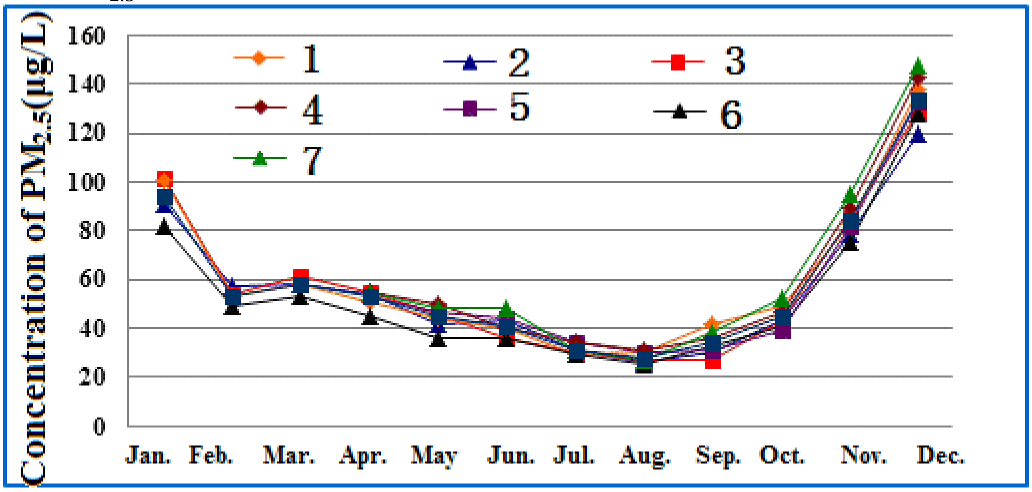


Fig.2 The variation of $PM_{2.5}$ at sampling points against months in 2013

Daily characteristics

For a similar variation trend of $PM_{2.5}$ in different sampling points, the point 1 was used to study the daily variation of $PM_{2.5}$ in different seasons. Figs. 3-7 show the timely average values of $PM_{2.5}$ from January to December, 2013. As shown in Fig. 3, there was peak-valley variation trend for the four seasons. There were obvious peaks in the morning and night, respectively. The variation was smooth in summer but fluctuation in winter. The concentration of $PM_{2.5}$ is affected by human activities, pollution emission, weather conditions, etc. During the morning 8am to 12 pm which was the rush hour, the atmosphere was primarily influenced by human activities and thus the $PM_{2.5}$ increased. Due to the increasing radiation, improved air convection and diffusion conditions, the $PM_{2.5}$ started to reduce after noon but increased again after dusk when the air became steady and the diffusion weakened. From the view of seasons, the first peak in spring and autumn occurred during 8am~10am while the peaks in winter and summer happened during 10am~12pm. The delay in the occurrence of peak $PM_{2.5}$ in winter was due to the latter occurrence of the peak of human activities in winter than that in other three seasons. The delay in summer was because that the $PM_{2.5}$ was governed by weather conditions that the atmospheric stability and wet deposition contributed to the reduction of $PM_{2.5}$. The lowest concentration of $PM_{2.5}$ occurred at 2pm~6pm due to the good diffusion conditions in the afternoon. However, in summer when the temperature at night was still relatively high, there was a relatively good diffusion condition and the lower area of $PM_{2.5}$ was not obvious.

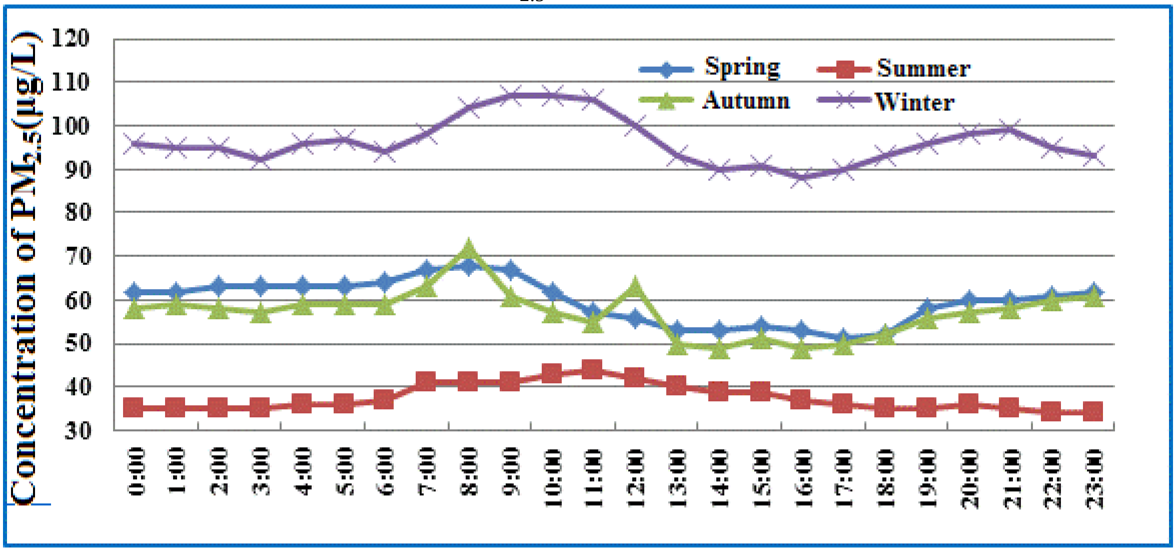


Fig.3 The daily variation of $PM_{2.5}$ in four seasons

Distribution of particle sizes

The effect of particles in different sizes on the environment and heath was studied by means of number concentration, mass, surface area of aerosol. The number concentration of particles at sampling point 1 during the whole year is listed in Table 2. The annual average values of $PM_{2.5}$ with particle sizes of 0.3 ~0.5μm, 0.5 ~1.0μm, 1.0 ~2.0μm, 2.0 ~2.5μm, 2.5 ~5.0μm, 5.0 ~10μm were 478, 98, 8.0, 1.6, 1.4, 0.4/$cm^3$ (587/$cm^3$ in total), respectively. The particles in a diameter of 0.3~2.5μm accounted for nearly 99.7% of the total particles. Figs. 4 and 5 show the mass and area percentages of particles in different seasons, respectively. Their variation was not obvious. The mass ratio of $PM_{0.3\sim0.5}$ accounted for 21.4%~27.0% (23.8% in average) while the area ratio varied in 40.6%~48.6% (43.4% in average). For $PM_{0.5\sim1.0}$, the mass and area ratios were 17.5%~18.1% (17.8% in average) and 29.4%~33.4% (31.4% in average), respectively. The mass and area ratios of $PM_{1.0\sim2.0}$ were 5.45%~6.74% (6.24% in average) and 6.54%~8.95% (7.60% in average), respectively. For $PM_{2.0\sim2.5}$, they were 2.46%~4.56% (3.23% in average) and 3.99%~6.01% (4.65% in average), respectively. The particles in 0.3~2.5μm accounted for 50% of the total mass which was similar to that of $PM_{2.5}/PM_{10}$. The area of $PM_{0.3\sim0.5}$ accounted for over 85% of the total area. This indicates that the smaller the particles, the greater harm they do.

Table 2 The number concentration of $PM_{0.3\text{-}10}$ in the second water plant

| Particle size (μm) | 0.3 ~0.5 | 0.5 ~1.0 | 1.0 ~2.0 | 2.0 ~2.5 | 2.5 ~5.0 | 5.0 ~10 |
|---|---|---|---|---|---|---|
| Season | Number concentration ( /$cm^3$ ) | | | | | |
| summer | 389 | 79 | 3.7 | 2.8 | 1.8 | 0.5 |
| autumn | 519 | 99 | 4.5 | 0.4 | 0.3 | 0.1 |
| winter | 587 | 127 | 12 | 1.0 | 0.7 | 0.2 |
| spring | 417 | 88 | 12 | 2.4 | 2.8 | 0.7 |
| average | 478 | 98 | 8.0 | 1.6 | 1.4 | 0.4 |

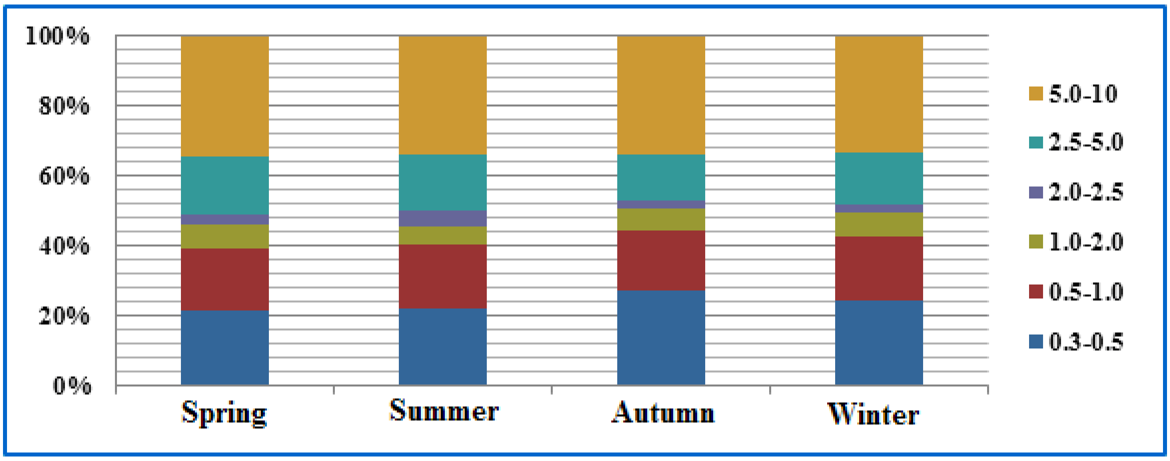


Fig.4 The distribution of mass of particles in different seasons

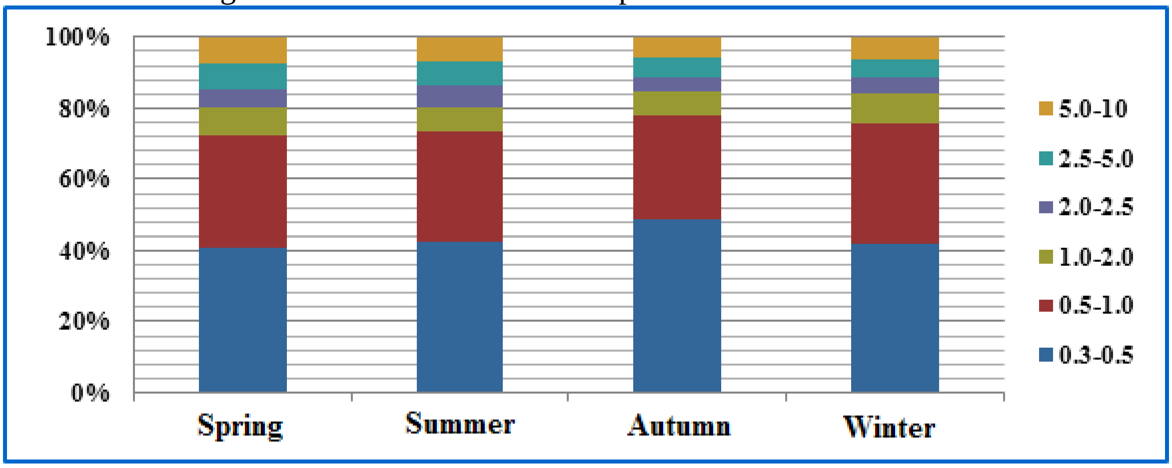


Fig.5 The distribution of surface area of particles in different seasons

## Conclusions

The daily average $PM_{2.5}$ in Kunshan in 2013 varied in a range of 4~366μg/m$^3$, compared to an annual value of 57μg/m$^3$, reaching an over-standard rate of 63%. The annual average $PM_{2.5}$ for different regions varied in 53~60μg/m$^3$. The small regional difference of $PM_{2.5}$ showed an extensive and universal spatial distribution of $PM_{2.5}$ pollutions. However, the concentration of $PM_{2.5}$ significantly depended on the seasons. The average number concentration of particles in 0.3~10μm reached 587/cm$^3$ of which 99.7% were particles in 0.3~2.5μm. This indicates that the $PM_{2.5}$ has become the main atmosphere issue in the developed areas in China.

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