# Preliminary Research on the Size Distribution of Aerosols in Beijing①

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ABSTRACT

Number concentration and size distribution of atmospheric aerosols were measured in Beijing by an optical particle counter. The relationship between aerosol size distribution and relative humidity is discussed. The results show that the size distribution, diurnal variation, daily variation of atmospheric aerosols have a good relation to relative humidity and Richardson number.

**Key words:** Atmospheric aerosol, Number concentration, Size distribution, Relative humidity, Richardson number

## 1. Introduction

Atmospheric aerosols play an important role in the radiative energy balance of the earth–atmospheric system. The effects of aerosols on climate depend on their concentrations, size distribution and chemical composition (Wang, 2000). Atmospheric aerosols influence climate in two ways, direct and indirect. They can scatter and absorb solar radiation, thereby directly changing the planetary radiation budget. In the whole, aerosols, especially soluble aerosols can modify the microphysics and optical properties of cloud by acting as cloud condensation nuclei (CCN) enhancing the reflectivity of low–level water clouds, and can also alter the development of precipitation by influencing the mean cloud drop size and affecting cloud lifetime and hydrological cycle, thereby indirectly affect global climate. Taken altogether, the estimated combined effects of atmospheric aerosols on the earth radiation budget today may be comparable in magnitude, but opposite in sign to those caused by greenhouse gases. Aerosols play an important role in radiative forcing and environment. Aerosol is also one of the major pollutants in big cities (Zhao and Wang, 1991). Long time chronic to high concentration of particle pollutants may do harm to humans, animals, vegetation, and buildings. Aerosols often originate from the ground, and their concentrations have a good relationship with meteorological condition. In the past, the size distributions of aerosols in Beijing were investigated (Wang et al., 1984, You et al., 1983, Zhou et al., 1983). At present, people pay much attention to atmospheric particles, while the mechanism about the formation, transformation, removal of urban aerosols is still not very clear. It is important to have a better understanding on the aerosol concentration, size distribution and their relationship to meteorological condition.

From February to May 1999, the size distributions of aerosols were observed

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continuously for about 30 days at the yard of 325m meteorological tower in the north suburb of Beijing by an optical particle counter. With synchronous meteorological data, the variations number concentration, size distribution of atmospheric aerosols and their relationship to the relative humidity and meteorological conditions are investigated and analyzed based on the measurement in this experiment. The variations of atmospheric aerosol concentration and size distribution near surface in relation to relative humidity and Richardson number are discussed on the basis of the above measurement.

## 2. The observation site and instruments

The experiment site is located on the top of a two floor building, which is to the east and 50 m far away from the 325 m Meteorological Tower (116°22′E, 39°58′N), outside the North Shanhuan Road in Beijing. It is about 6 meters high above the ground. The BCJ–1 optical particle counter made in Suzhou, was used to measure atmospheric aerosol concentration and size distribution. This counter has 6 channel, and its nominal ranges of aero–dynamic diameter is as follows: 0.3～0.5, 0.5～0.7, 0.7～1.0, 1.0～2.0, 2.0～5.0 and >5.0$\mu$m. The airflow rate is 5.66L per 2 minutes. About 30 days continuous data of aerosol size concentrations were collected on March 1–23, April 5–11 and April 26–28. The meteorological data including wind speed, wind direction, temperature and relative humidity were obtained at the different levels 8, 15, 32, 47, 63, 80 and 102 m at the Meteorological Tower.

## 3. Results and analysis

### 3.1 *Variation of atmospheric aerosol concentration*

The observed size distributions of number concentrations of atmospheric aerosols show a single–peak mode and the peak values appear at 0.5～0.7$\mu$m. The maximum and minimum concentrations (obtained on March 13 and April 27, respectively) are shown in Fig. 1. The day of March 13 was cloudy and day–averaged relative humidity was 81%, while the day of April 27 was clear and the day–averaged relative humidity was only 36%. The aerosol number concentrations have considerable diurnal variation. The concentration of fine particles (D< 1.0$\mu$m) varies distinctly and the maximum can be more than 10 times; but the

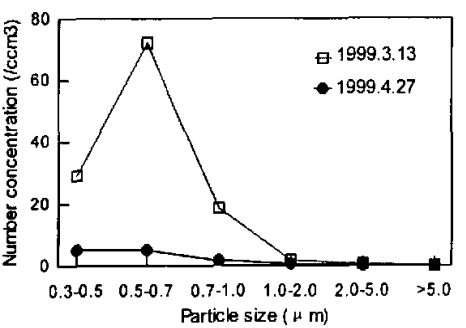


Fig. 1. The size distribution of number concentration of aerosol.

concentrations of big particles ($D > 1.0\mu m$) have small difference. This means that number concentrations have a good relationship to relative humidity, which will be discussed below.

3.2 *Aerosol size distribution*

Figure 2 gives the change of size distribution of aerosols number concentration with different relative humidity. With the increase of the relative humidity, the number concentration of fine particles increased when relative humidity was less than 75%, and decreased when relative humidity is higher than 75%. As an important physical–chemistry process in the field of atmospheric chemistry, gas–to–particle conversion plays an important role in forming aerosol particles. The increase of relative humidity will be beneficial to forming the fine particles (Wang, 1982). This suggests that the gas–to–particle conversion is one of the important sources of fine particles in high relative humidity. But the number of fine particles will decrease when the air humidity is too high, a large amount of fine particles will coagulate and convert to coarse particles and descend to the ground.

3.3 *The relationship between the daily variation of number concentration and relative humidity*

Concentrations of atmospheric aerosols have a good relation to the weather condition. The 30–day profiles obtained show that the number concentrations of atmospheric aerosols were high in cloudy days and low in clear days. In quality, the concentrations of atmospheric aerosols changed with the variation of relative humidity. In the situation of fairly low relative humidity, the aerosol particle concentration shows positive correlation to relative humidity. Fig. 3a gives the relationship between the aerosol particle concentration and the daily variation of relative humidity (the day–averaged relative humidity RH = 39%) from 6 p.m., April 26 to 6 p.m., April 28. The correlation coefficient between number concentration and relative humidity was 0.65. When relative humidity is quite high (RH = 81%), the number concentration and relative humidity have negative correlation and the correlation coefficient was −0.71 (Fig. 3b).

3.4 *The relationship between daily variation of number concentration and Richardson number*

Number concentrations of aerosols have diurnal variation. In the cloudy weather, the

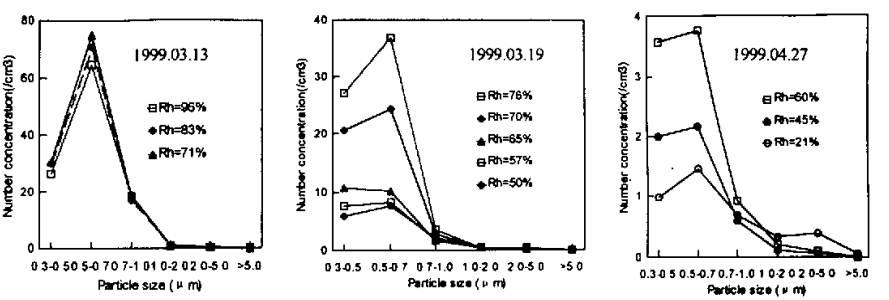


Fig. 2. The aerosol particle size distribution at different relative humidity.

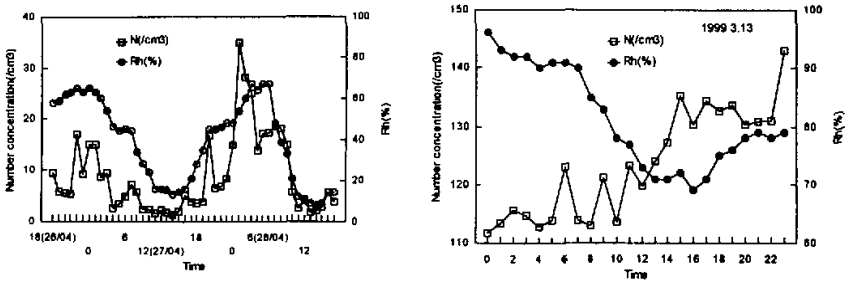


Fig. 3. The aerosol number concentrations and relative-humidity.

number concentrations were rather high and the daily variation was not considerable, while in clear days, the aerosol number concentration shows obvious daily variation. Meanwhile, the number concentrations are low in the daytime and high in the night time. Generally, aerosol concentrations reach minimum in the afternoon and maximum at midnight. It agrees with the past results (You et al., 1983). The reason for such variation can be due to the change of turbulence. In the daytime, atmospheric aerosols are easily transported upward because of the strong turbulence, hence the concentrations are low in the near-ground-level. While in the night time, turbulence is repressed and atmosphere near the ground level remains stable. Therefore, aerosols originating from the ground are not very easily transported upward, hence the concentrations are high near the ground. Here, the diurnal variations were studied using the relationship between aerosol number concentration and Richardson number.

The atmospheric gradient Richardson number is defined as

$$Ri = \frac{\frac{g}{\bar{\theta}_v}\frac{\partial \bar{\theta}_v}{\partial z}}{[(\frac{\partial U}{\partial z})^2 + (\frac{\partial V}{\partial z})^2]}. \tag{1}$$

According to the potential temperature formula, the following equation can be given:

$$\frac{1}{\bar{\theta}_v}\frac{\partial \bar{\theta}_v}{\partial z} = \frac{1}{T}(\Gamma_d - \Gamma), \tag{2}$$

where $\Gamma_d$ and $\Gamma$ denote the dry adiabatic lapse rate and the temperature lapse rate, respectively, $\Gamma_d = \frac{g}{C_p} = 0.0098$ K/m, $\Gamma = -\frac{\partial T}{\partial z}$.

According to the Richardson number criterion, when $Ri < Rc$ (typically within 0.2~0.25), lamella stream is unstable and turbulence occurs; when $Ri > Rt$ ($=1.0$), turbulence turns into lamella stream. A series of gradient Richardson numbers have been calculated out according to the meteorological data measured under 100 m level. When relative humidity is less than 75% (clear or clear-to-cloudy weather), particle number concentrations are positively correlated to the Richardson numbers, and the coefficient is 0.65. Typically, Richardson numbers are more than 0.2 at night when air laminar flow is stable, fine particles

originating from the surface cannot be dispersed upward quickly, hence there are high concentrations. But Richardson numbers are generally less than 0.2 in the daytime (especially at noon, this number is negative) when turbulence occurs near the ground and acts strongly. Therefore, the number concentrations of aerosols are low because of turbulent diffusion (Fig. 4a). When the relative humidity is higher than 75%, the calculated Richardson numbers are over 0.25 and have relatively poor correlation to the number concentrations; the coefficient is only −0.21 (Fig. 4b). Accordingly, turbulence will not grow up and atmosphere is stable.

## 4. Conclusions

The number concentrations and size distributions of aerosols are the key indexes for studying the physical features of aerosol. By analyzing 30 days data of size distributions of aerosol from this experiment, some results have been obtained as follows:

1) The number concentrations of aerosols show a large variation. For fine aerosols, the proportion of number concentrations between the maximum and minimum can be even more than 10.

2) The size distribution of aerosol number concentration shows a single peak mode. The peak of distribution locates at 0.5～0.7 $\mu$m and its concentrations have a closely relationship to relative humidity. With the increase of relative humidity, the concentrations increased when RH is less than 75%, and decreased when RH is higher than 75%.

3) The number concentrations of aerosols have evident diurnal variations and are closely related to relative humidity. The number concentrations were low in the daytime and high in the night time when relative humidity is smaller than 75%; they are positively correlated to relative humidity and the coefficient is 0.65. When relative humidity is higher than 75%, the aerosol number concentrations are negatively correlated to relative humidity and the coefficient is −0.71.

4) The diurnal variation of number concentrations of atmospheric aerosol is related to the atmospheric stability. When relative humidity is smaller than 75%, the particle number concentrations are positively correlated to the Richardson number, the coefficient is 0.65. When relative humidity is higher than 75%, and the number concentrations are poorly correlated to the atmosphere stability.

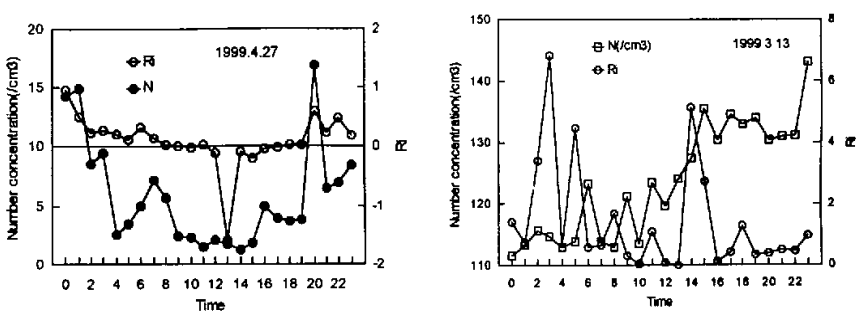


Fig. 4. The number concentrations of aerosol and Richardson number.

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# 北京地区气溶胶粒度谱分布初步研究

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**摘　要**

本文对北京地区气溶胶数浓度及其谱分布特征进行了初步研究．重点探讨了气溶胶数浓度分布与相对湿度的关系．研究结果表明，气溶胶浓度和谱分布存在明显的日变化和逐日变化，并在很大程度上受空气相对湿度和理查森数影响．

**关键词：** 气溶胶，粒度谱分布，相对湿度，理查森数