J. KOSAE Vol. 22, No. E 1 (2006) pp. 45~48
Journal of Korean Society for Atmospheric Environment

Technical Information

Size Distributions of Atmospheric Particles in Cheonan, Korea

Sewon Oh*

Major in Environmental Engineering, College of Engineering, Sangmyung University, Cheonan, Chungnam 330-720, Korea

(Received 28 February 2006, accepted 28 April 2006)

Abstract

Mass size distributions of atmospheric particles in Cheonan were determined using a high volume air sampler equipped with a 5-stage cascade impactor. Bimodal distributions that are typical for urban atmospheric particles were obtained. A MMD of the fine particle mode was 0.47±0.05 μm with a GSD of 2.72±0.21, and those of the coarse particles were 5.15±0.18 μm and 2.09±0.09, respectively. The annual average concentrations of TSP, PM10, PM2.5, and PM1 were 74.1, 67.5, 54.2, and 42.3 μg/m^3, respectively. Although the daily PM10 concentrations were under the current National Standard, the daily PM2.5 concentrations frequently exceeded the US Standard even in non asian dust periods. The fractions of PM10, PM2.5, and PM1 in TSP were 0.905±0.013, 0.723±0.022, and 0.572±0.029, respectively, and fine mode particles occupied 57~72% of the total particle mass. The results indicate that fine particles were at the concerning level, and should be the target pollutant for the regional air quality strategy in Cheonan.

Key words : Mass size distributions, Fine particles, PM10, PM2.5, MMD, GSD

1. INTRODUCTION

Particles are emitted to the atmosphere by both natural sources, such as wind-borne dust, sea spray, and volcanic eruptions, and anthropogenic activities, such as the combustion of fuels. In addition, the chemical processes such as the oxidation and condensation of a number of gaseous compounds can lead to the formation of the particulate products. Once emitted or formed in the atmosphere, particles undergo several physical and chemical processes including condensation, coagulation, and deposition. Thus, particles in the atmosphere can change their size and composition, and the residence times of particles vary only from a few days to a few weeks. As a result, atmospheric particles lie in wide size ranges, from a few nanometer to around 100 μm in diameter. Generally, atmospheric particles are described as a trimodal distribution consisting of a nuclei mode by gas-to-particle conversion; an accumulation mode by condensational growth and coagulation of the nuclei mode; and a coarse mode by direct mechanical generation at the Earth's surface. However, atmospheric particles show a bimodal distribution based on the mass concentration, since the mass of particles in a nuclei mode is negligible. A fine mode is being used to indicate both nuclei and accumulation modes. The boundary separating fine and coarse modes is not precise, but lies approximately between 1~2.5 μm in particle

* Corresponding author.
Tel : +82-41-550-5310, E-mail : sewonoh@smu.ac.kr

diameter (Seinfeld and Pandis, 1998). Since many researchers mentioned the effect of particle size on human health, the determination of particle size distribution is a basic element in characterizing atmospheric particles.

Recent epidemiological studies have indicated that fine particles have the greater impacts on human health than coarse particles (Spengler *et al.*, 1990), and the regulations on particles have been changed to focus on fine particles. The US EPA has strengthened not only PM10 (particles less than 10 μm in diameter), but also PM2.5 regulations. Future legislative intentions are expected to be more focusing on fine particles, PM2.5 and even PM1. Therefore, the determination of particle size distribution focusing on fine particles is essential to set up the air quality strategy. Currently, Korea has only PM10 regulation, and National Air Quality Monitoring Stations measure only PM10 concentrations for atmospheric particles. There have been some studies on atmospheric fine particles in Korea (Park and Kim, 2005; Park and Kim, 2004; Kim *et al.*, 2003). However, most of these studies focused on the metropolitan areas, and measured only PM2.5 concentrations. Thus, relatively little data are available on concentrations, trends and size fractions of fine particles. The purpose of this study is to characterize the size distributions of atmospheric particles in Cheonan, Korea. The results of this study will provide the data concerning trends and concentrations of atmospheric fine particles for the urban areas representing typical mid-size cities in Korea.

2. EXPERIMENTAL METHODS

Mass size distributions of atmospheric particles in Cheonan were determined using the measured data for two years between January 2003 and December 2004. Cheonan is a mid-size city with about 500 thousand people, located on the northeast of Chungnam. The sampling site was located on the rooftop of the Administration Building in Sangmyung University, about 1,000 m away from a heavy traffic highway. A high volume air sampler (Andersen, GV 2360) equipped with a 5-stage cascade impactor (Andersen, Model 235) was used for the sampling. The aerodynamic cutoff diameters of the five impactor stages were 7.2, 3.0, 1.5, 0.95, and 0.45 μm, respectively. Ambient air containing atmospheric particles were sampled for 24 hrs, at a flow rate of 1.16 m^3/min. Particles were collected on a glass fiber filter (Andersen, SAC 230-GF) at each stage of the impactor, and the filter samples were weighed with an electronic balance (Sartorius, Model CP225D) before and after sampling. The electronic balance has 0.01 mg accuracy. Filters were equilibrated in the desiccator for 24 hrs prior to weighing. Total 74 samplings were conducted in the study.

3. RESULTS AND DISCUSSION

3.1 Mass size distributions of the particles

The mass size distributions of atmospheric particles in Cheonan were characterized based on 74 sampling data. Most sampling data (68 out of the total 74) showed the bimodal distribution with a saddle point in 1.5～3.0 μm range in diameter separating coarse and fine particle modes. A typical size distribution of atmospheric particles obtained in this study is shown in Figure 1. As shown in Figure 1, two peaks for the normalized mass concentrations lie at 0.45～1.5 μm and 3.0～7.2 μm in particle diameter. A bimodal distribution is typical for most

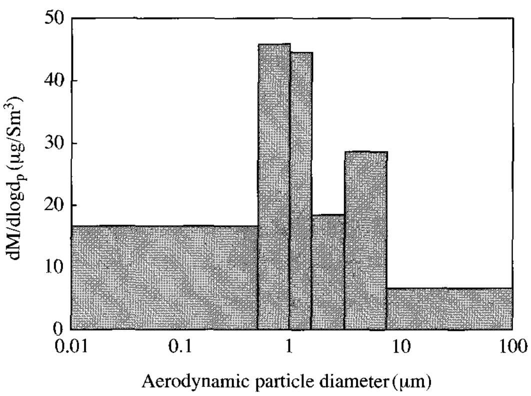

Fig. 1. A typical mass size distribution of atmospheric particles measured in Cheonan.

urban atmospheric particles, since the fine mode particles are generally produced by coagulations and photochemical reactions of combustion products from anthropogenic sources such as automobiles and boilers. Thus, atmospheric particles in Cheonan can be described as urban aerosols. Although, the total mass size distribution is not lognormal, each mode can be fitted to a lognormal distribution and the statistical values for each mode are used to represent the characteristics of size distributions. Mass median diameter (MMD) and geometric standard deviation (GSD) of the each particle mode were obtained from a log-probability plot. In a log-probability plot, diameters corresponding 50% and 84% cumulative mass were located. MMD is the diameter of 50% cumulative mass, and GSD is the ratio of diameters corresponding 84% and 50% cumulative mass ($d_{84\%}/d_{50\%}$). A MMD of the fine particle mode was 0.47±0.05 μm with a GSD of 2.72 ±0.21, and those of the coarse particles were 5.15 ±0.18 μm and 2.09±0.09, respectively. Error limits represent 95% confidence intervals. Seasonal variations in MMDs and GSDs were not obvious and within the error limits. Detailed values of MMDs and GSDs are listed in Table 1.

3.2 Mass concentration and size-segregated fraction of the particles

The mass concentrations of TSP, PM10, PM2.5, and PM1 were estimated from the size distribution data. The TSP concentration was calculated by summing the particle mass of all stages, and the PM10, PM2.5, PM1 concentrations were estimated assuming the even distribution within the size intervals of each stages. The annual average concentrations of TSP, PM10, PM2.5, and PM1 were 74.1, 67.5, 54.2, and 42.3 μg/m^3, respectively, and the annual average PM10 concentration were below the National Annual Average Standard (80 μg/m^3). The highest mass concentration for all size-segregated fraction of particles was observed in spring due to asian dust event. Seasonal values of TSP, PM10, PM2.5, and PM1 concentrations are listed in Table 2. In the asian dust period, the daily average PM10 concentration was over 200 μg/m^3, and exceeded the National Daily Average Standard (150 μg/m^3). Except this period, all the measured daily average PM 10 concentration was below the National Standard. This result shows that ambient air quality due to particles in Cheonan satisfies the current National Standard excluding asian dust periods. However, even in non asian dust periods, the daily average PM2.5 concentration frequently exceeded the current US Standard, 65 μg/m^3. Daily average PM2.5 concentrations for 18 days out of 70 sampling days (25.7%) were higher than the US Standard. The distributions of PM10 and PM2.5 concentrations are shown in Figure 2. The most frequent concentrations of PM10 and PM2.5 were at 50～75 μg/m^3 and 25～50 μg/m^3, respectively.

Table 1. MMDs and GSDs of atmospheric particles in Cheonan.

Season	No. of samplings	Fine mode		Coarse mode	
		MMD (μm)	GSD	MMD (μm)	GSD
Spring	21	0.44 ±0.08*	2.91 ±0.44	5.24 ±0.29	2.11 ±0.07
Summer	18	0.46 ±0.11	2.69 ±0.43	5.04 ±0.45	2.21 ±0.29
Fall	12	0.39 ±0.11	2.76 ±0.62	5.21 ±0.39	2.07 ±0.19
Winter	17	0.58 ±0.10	2.51 ±0.31	5.11 ±0.41	1.96 ±0.14
Annual	68	0.47 ±0.05	2.72 ±0.21	5.15 ±0.18	2.09 ±0.09

*Errors represent 95% confidence intervals.

Table 2. Mass concentrations of TSP, PM10, PM2.5, and PM1 in Cheonan. (unit: μg/m^3)

Season		Spring	Summer	Fall	Winter	Annual
TSP	Average	105.0	58.0	46.9	73.8	74.1
	Highest	246.5	145.2	101.4	181.2	246.5
	Lowest	31.4	4.8	9.3	18.0	4.8
PM10	Average	96.2	53.2	43.6	65.3	67.5
	Highest	235.8	139.2	93.0	160.3	235.8
	Lowest	29.4	4.7	8.0	16.8	4.7
PM2.5	Average	78.7	44.3	36.2	47.5	54.2
	Highest	207.0	126.5	78.2	110.1	207.0
	Lowest	24.0	4.2	5.7	13.3	4.2
PM1	Average	61.7	34.9	31.0	34.1	42.3
	Highest	184.3	121.0	67.3	71.4	184.3
	Lowest	17.2	3.8	4.7	11.4	3.8

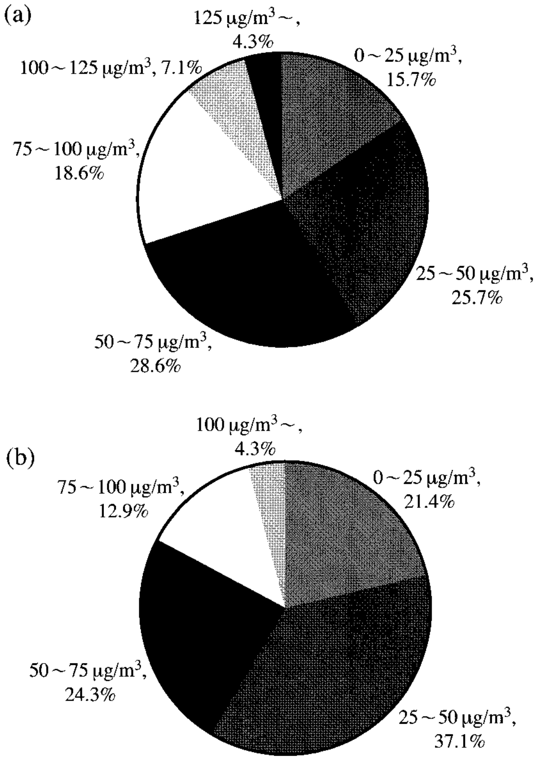

Fig. 2. Distributions of the particle mass concentrations. (a) PM10, (b) PM2.5.

Using the estimated concentrations of TSP, PM 10, PM2.5, and PM1, the concentration fractions of each size particles were calculated. The fractions of PM10, PM2.5, and PM1 in TSP were 0.905±0.013, 0.723±0.022, and 0.572±0.029, respectively. Considering that the boundary separating fine and coarse mode particles is between 1~2.5 μm in diameter, fine mode particles were more abundant than coarse particles. Fine mode particles occupied 57~72% of the total particle mass. The results show that atmospheric particles in Cheonan was mainly fine mode particles from anthropogenic sources. Despite the fact that the air quality for atmospheric particles satisfied the National regulations, fine particles were at the concerning level, and should be the target pollutant for the regional air quality control strategy in this area. In addition, the value of PM2.5/PM10 was 0.796±0.016, and this can be used as an index for estimating PM2.5 based on the available PM10 data.

4. CONCLUSIONS

Physical characteristics of atmospheric particles in Cheonan were investigated. Mass size distributions were biomdal with a saddle point in the 1.5~3.0 μm range, representing urban atmospheric particles. Fine mode particles occupied 57~72% of the total particle mass, and 25.7% of the measured daily PM2.5 concentrations were above the current US standard. These results indicate that fine particles are the major concerning air pollutants in Cheonan. Thus, further studies such as chemical analyses and source profiles of particles are needed to set up the effective air quality control strategy.

REFERENCES

Kim, K.H., G.H. Choi, C.H. Kang, J.H. Lee, J.Y. Kim, Y.H. Youn, and S.R. Lee (2003) The chemical compostion of fine and coarse particles in relation with the Asian Dust events. Atmospheric Environment 37(6), 753-765.

Park, J.S. and S.D. Kim (2005) The characteristics of secondary carbonaceous species within PM10 and PM2.5 in Seoul and Incheon area. Journal of Korean Society for Atmospheric Environment, 21(1), 131-140.

Park, S.S. and Y.J. Kim (2004) PM2.5 particles and size-segregated ioninc species measured during fall season in three urban sites in Korea. Atmospheric Environment, 38(10), 1459-1471.

Seinfeld, J.H. and S.N. Pandis (1998) *Atmospheric Chemistry and Physics*, pp. 507-510, John Wiley & Sons: New York.

Spengler, J.D., M. Brauer, and P. Koutrakis (1990) Acid air and health. Environmental Science and Technology, 24(7), 946-956.