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Characteristics According to the Size Distributions of Respirable Particulate During Yellow Sand Episode in Kosan, Jeju Island

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황사기간동안 제주, 고산지역에서 호흡성 분진의 입자 분포 특성

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ABSTRACT

This study was intended as an investigation of characteristics of background site atmospheric respirable particulate matters(RPM), and fine particles(<2.5 μm). The particle size distributions during the phenomenon of Yellow Sand(YS) occurs from April, 2001. Atmospheric aerosol particulate matter was directly collected on the Jeju island between 1 to 30, April, 2001 using an eight-stage cascade impacter(particle size range : 0.43~11 μm), and cyclone separator(cut size : 2.5, 10 μm). The episode of YS observed in background monitoring site, Kosan and appeared 2 times at sampling period. The mass concentrations of fine and coarse particles for YS episode were 34.2 and 59.6 $\mu g/m^3$, respectively, which were significantly increased amounts compared to 13.3 and 13.0 $\mu g/m^3$ for Non-YS(NYS). Most size distributions had two peaks, one at 0.43~.65 μm and the other at 3.3~4.7 μm. The result of analysis of water-soluble ion component indicated that sulfate was mainly ion component, but nitrate and calcium ion was significantly increased at the YS episode.

Keywords : RPM, Yellow Sand, Size distribution, Water soluble, Ion component

I. Introduction

In general, human beings come into direct contact with atmospheric aerosols by breathing or their skin. The major route for RPM to enter human body is the respiratory system.[8] These areosol particles were directly and/or indirectly related to climate change and prevailling north-westerly winter-monsoon wind from central Asia entrain the bulk of the Chinese desert dust delivered to inland China, Korea, Japan and the Pacific Ocean.[1,4] Specially, at spring time, yellow sand (YS) is often occurred to be widely from Asian continent which is affected on various types; adverse to public health, visibility impairment, increasing of industrial badness products and so on. A large number of studies on YS aerosols have been reported. However, only a few studies on YS aerosols as ion composition of separated particle size distributions can provide detailed information about composition and component of YS aerosols.

China emits most of the sulfur dioxide and major fraction of the nitrogen oxides, Chinese desert dust delivered to inland China, Korea, Japan, the Pacific Ocean and beyond. Iwasaka *et al.* (1998) reported that some particles were coated by water or soluble containing sulfate from the electron microscopic observation of YS particles sample.[3] Lee *et al.* (2001) did field measurements during 1996 and 1997. As that results, the major

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components of fine were sulfate, organic carbon, and ammonium in Kosan, and sulfate, ammonium and nitrate in Kangwha.[7]

Therefore, in this paper, to determine the YS aerosols from China continent to Korea peninsular, we measured not only mass concentration but ion components of particle size distributions for YS aerosols in background site of Korea.

II. Materials and Methods

1. Aerosol sampling site

For sampling of ambient aerosols, 1-stage filter pack sampler and Cascade impactor sampler were operated at a height of 74 m above sea level of the Kosan site located in Jeju, Korea in Asian dust storm episode during April, 2001. The Kosan site is located at the western tip of Jeju Island, Korea. Locations of sampling site are given in Table 1.

Kosan is one of the cleanest areas in Jeju Island in which emission amounts and concentrations of anthropogenic air pollutants are quite low compared to those of urban areas in Korean peninsula.

2. Cyclone filter pack for fine and RPM measurements

Cyclone preseparator designed to cut-size 50% removal with a diameter(aerodynamic) each of 2.5 μm and 10 μm or greater. Air is drawn through a cyclone, and into a single-stage filter assembly. the single-stage filter assembly contains a 47 mm Teflon filter supported by a stainless steel screen. The filter is a 2 μm pore-size Teflon membrane filter, Zefluor (Gelman Sciences). A pump unit maintains a flow of 16.7 Lpm, and dry gas meter allows checked start and end volume.

3. Cascade impactor for RPM size distributions measurements

A cascade impactor (Andersen, An-200) was used to identify the particle size distribution of aerosol at the Kosan monitoring site in Jeju. It is a particle sampling unit by aerodynamic impactor system having multi-stage with multi-jet nozzles so as to measure the particle size distributions. It has 8 size-fractionated stages with the nominal cut size of 11.0, 7.0, 4.7, 3.3, 2.1, 0.65, 0.43 μm, and backup filter. Each part was connected with the 3/8-inch polyethylene tube. The substrates used in the impactor were teflon membrane filters 80 mm in diameter and 0.22 μm pores, but quartz filter for the backup filters. A pump unit maintains a flow of 28.3 Lpm, and dry gas meter allows checked start and end volume.

4. Gravimetric determination

The Filter is weighed(after moisture equilibration) before and after use to determine the net weight gain. The total volume of air sampled corrected to EPA standard conditions(25°C, 760 mmHg) is determined from the measured flow rate and the sampling time. The particulate matter in the ambient air is computed as the mass of collected particles divided by the volume of air sampled (corrected to standard conditions) and expressed in μg/stdm^3.

5. Chemical component analysis

The anions, Cl^-, NO_3^-, and SO_4^- were analyzed using ion chromatography (Dionex-500). The preconcentration was used for the particulate material, immediately after desorption from the sampling filters into deionized water via agitation on a ultra sonic bath.

The cations, K^+, Ca^{2+}, Na^+, and Mg^{2+} from the sampling filters were determined via atomic absorption spectroscopy (Perkin-Elmer, Analyst 800). Particulate NH_4^+ was determined by indophenol colorimetric method (Perkin-Elmer lambda 20).

Table 1. Description of aerosol sampling site

Station	Latitude	Longitude	Sampling items	Aerosol Sampling	
				Measuring system	Collection principle
Jeju Kosan	33°17'	126°10'	Fine(dp<2.5 μm) RPM(dp<10 μm)	Cyclone filter pack system (URG-2000)	Cyclone separation
			Size distribution (0.43~11 μm)	Cascade impactor (An-200)	Multi nozzle direct impaction

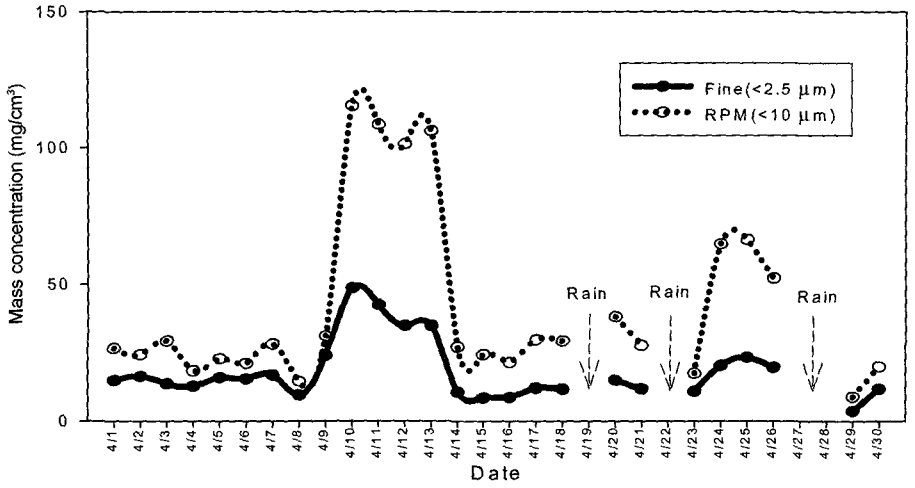

Fig. 1. Variations of fine and RPM concentrations in Kosan, Jeju.

III. Results and Discussions

1. Mass concentration

The episode of YS observed in Kosan and appeared 2 times at sampling periods. The first dust plume was detected on 10 April with RPM concentration of 115.5 μg/m^3. The second was detected on 26 April with RPM concentration of 66.5 μg/m^3. Include sampling periods, averages of fine and RPM concentration was 18.1 μg/m^3 and 41.4 μg/m^3, respectively (Fig. 1).

The mass concentrations of fine and coarse particles on YS episode were 34.2 and 59.6 μg/m^3 respectively, which were significantly increased amounts compared to 13.3 and 13.0 μg/m^3 on NYS (Table 2). The increasing rate of RPM concentration to compared YS and NYS, YS is about 3 times higher than the NYS. These conditions suggest that YS were very higher than that of the NYS.

Particle size distribution of RPM concentrations according to the episodes of YS phenomena have been measured and analyzed by using an cascade impactor sampler and were shown in Fig. 2.

Table 2. Average concentrations of fine and coarse particle concentrations(μg/m^3)

	YS(%)	NYS(%)	Average
Fine(<2.5 μm)	34.2(36.4)	13.3(50.4)	18.1
Coarse(2.5~10 μm)	59.6(63.6)	13.0(49.6)	41.4
RPM(<10 μm)	93.8	26.2	59.5

RPM size distributions can be considered as the sum of two modes, each characterized by a log-normal size distribution. RPM distributions curve showed bi-modal, in Fig. 2. Most RPM distributions had two peaks, one at 0.43~0.65 μm and the other at 3.3~4.7 μm. In most cases, particles with diameters smaller than 1 μm did not increase during the YS episode, indicating a lesser influence of YS on the masses of fine particles.[10] These results were good correlation with Kim *et al.* (1998) report that the particle size distributions showed bi-modal distribution peak with 4.0 μm at Kosan.[5] Also, the aerosol size distribution of coarse narrowed up to 4.0 μm, but fine was not variable amplitude peak change.

The comparison of YS episode and Non-YS with mass size distribution were summarized in Table 3. The comparison of YS/NYS ratios showed that increasing of coarse mode(2.1~11 μm) was higher than those of fine mode between YS and NYS.

2. Water soluble ion component

Most ion components increased for all sizes during the YS period, compared to the NYS period (Table 4, Table 5). The dominant ion components were SO_4^{2-}, NO_3^-, Na^+ and Ca^{2+} with the total sum of 8 stage cascade impactor filter concentration of

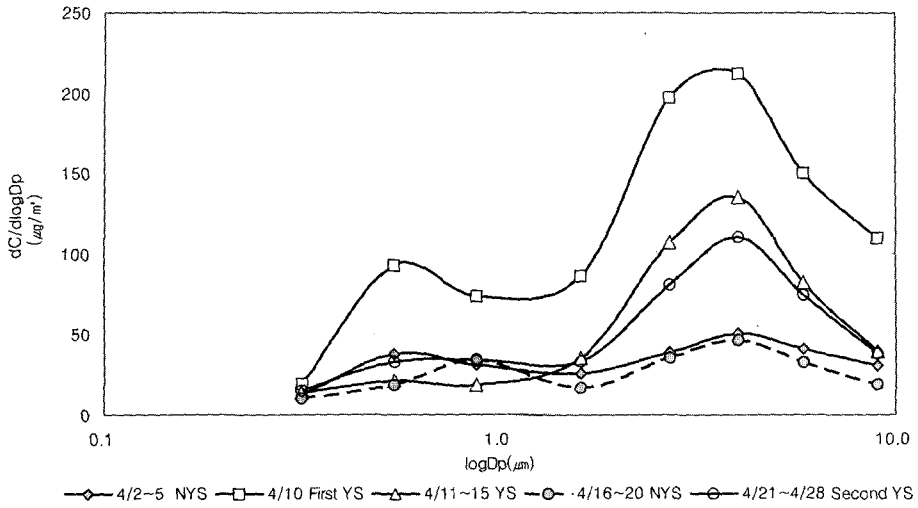

Fig. 2. Particle size distribution curves of mass loading in RPM.

Table 3. Comparison of YS episode and Non-YS with mass size distribution

Size range	YS episode (μg/m³)	NYS (μg/m³)	YS/NYS
<0.43 μm	5.37	3.82	1.4
0.43~0.65 μm	8.83	5.12	1.7
0.65~1.1 μm	9.68	7.44	1.3
1.1~2.1 μm	14.45	5.88	2.5
2.1~3.3 μm	25.10	7.23	3.5
3.3~4.7 μm	23.40	7.42	3.2
4.7~7.0 μm	17.68	6.31	2.8
7.0~11.0 μm	12.21	4.77	2.6
Total	116.72	47.98	

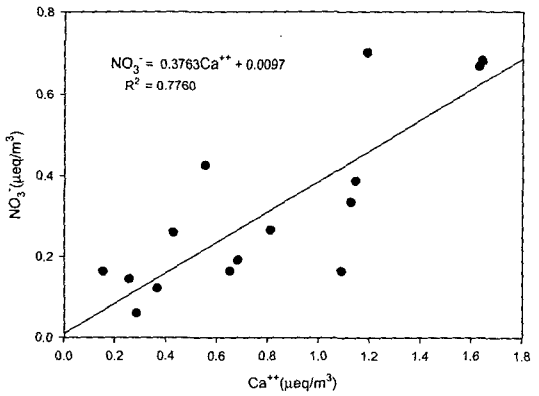

Fig. 3. The relationship between NO_3^- and Ca^{++} equivalent molar concentration.

10.86, 6.12, 2.36 and 1.94 μg/m³ respectively during the YS period, compared to the corresponding concentrations of 4.92, 2.19, 1.53 and 0.13 μg/m³ in Non-YS periods. Sulfate was mainly in the fine mode, at the 0.43~0.65 μm size fraction of NYS, and at the 0.65~1.1 μm size fraction of YS. Particulate sulfate formed over the continents from anthropogenic SO_2 may be transported to marine areas.[3] Therefore, the sulfate formation in Kosan area was associated with continentally transported material. Nitrate concentrations of samples peaked in the coarse mode. The size distribution pattern of nitrate showed good correspond with Ca^{2+} (Fig. 3).

The nitrate mass size distribution for coarse particles was associated with the surface area distribution of the sea-salt aerosol in sampling site. Willeke and Whitby (1975) reported that fine particles did not interact appreciably with coarse particles in the atmosphere, which indicates that coarse nitrate originates probably from atmospheric reactions of gaseous nitrogen species with coarse particles.[9] Nitrate was not a major component of Asian desert soil and loess which are thought to be origins of YS aerosol and Zhang *et al.* (1999) found that YS particle surfaces were important for particulate nitrate formation.[10] Thus, it was reasonable to consider that the nitrate detected in the coarse particle range had a different origin than YS particles. The size distribution of Ca^{2+} peaked

in the coarse mode. On the basis of aerosol observations in the ground-level atmosphere over Korea, the concentration of Ca^{2+} in aerosols increases in the aerosol due to transport the YS aerosols originating from dust storms on the Chinese desert. Coarse particles are generally comprised of soil elements over the continents and sea salt elements over the oceans. Kim *et al.* (1999) measured aero-

Table 4. Particle size distributions of ion concentrations during NYS

Dp (μm)	μg/m³								
	Mass	Cl^-	NO_3^-	SO_4^{2-}	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}
0.32	3.82 (0.445)[1)]	0.289 (0.254)	0.025 (0.035)	1.439 (0.118)	0.499 (0.319)	0.099 (0.093)	0.069 (0.098)	0.018 (0.017)	0.094 (0.133)
0.54	5.12 (2.444)	0.061 (0.010)	0.102 (0.022)	0.842 (0.143)	0.039 (0.029)	0.271 (0.081)	0.018 (0.013)	0.002 (0.001)	0.014 (0.016)
0.88	7.44 (0.486)	0.068 (0.041)	0.169 (0.136)	0.790 (0.069)	0.081 (0.056)	0.207 (0.027)	0.034 (0.015)	0.003 (0.001)	0.019 (0.027)
1.60	5.88 (1.716)	0.065 (0.007)	0.082 (0.030)	0.908 (0.183)	0.109 (0.038)	0.174 (0.023)	0.033 (0.009)	0.011 (0.002)	0.034 (0.020)
2.70	7.23 (0.555)	0.139 (0.183)	0.609 (0.063)	0.281 (0.089)	0.258 (0.122)	0.012 (0.015)	0.015 (0.004)	0.022 (0.012)	0.097 (0.107)
4.00	7.42 (0.424)	0.241 (0.110)	0.669 (0.003)	0.239 (0.050)	0.241 (0.070)	0.005 (0.001)	0.015 (0.000)	0.024 (0.006)	0.113 (0.101)
5.85	6.31 (0.982)	0.171 (0.130)	0.420 (0.050)	0.179 (0.028)	0.188 (0.028)	0.005 (0.007)	0.003 (0.004)	0.016 (0.004)	0.078 (0.073)
9.00	4.77 (1.630)	0.184 (0.003)	0.093 (0.063)	0.123 (0.029)	0.075 (0.029)	0.007 (0.000)	0.007 (0.010)	0.004 (0.002)	0.034 (0.014)
Total	47.98	1.218	2.168	4.801	1.490	0.779	0.194	0.100	0.482

[1)]( ) : standard deviation.

Table 5. Particle size distributions of ion concentrations during YS

Dp (μm)	μg/m³								
	Mass	Cl^-	NO_3^-	SO_4^{2-}	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}
0.32	5.37 (0.922)[1)]	0.230 (0.064)	0.024 (0.041)	2.137 (0.424)	0.380 (0.061)	0.442 (0.073)	0.129 (0.104)	0.014 (0.012)	0.097 (0.080)
0.54	8.83 (6.864)	0.081 (0.040)	0.184 (0.160)	1.042 (0.523)	0.169 (0.237)	0.343 (0.259)	0.060 (0.047)	0.004 (0.003)	0.018 (0.016)
0.88	9.68 (6.449)	0.095 (0.021)	0.278 (0.302)	1.236 (0.903)	0.104 (0.027)	0.333 (0.312)	0.091 (0.074)	0.008 (0.003)	0.025 (0.023)
1.60	14.45 (8.447)	0.170 (0.130)	0.724 (0.382)	1.085 (0.623)	0.201 (0.081)	0.181 (0.176)	0.084 (0.014)	0.038 (0.021)	0.216 (0.108)
2.70	25.10 (11.994)	0.768 (0.423)	1.453 (0.316)	0.814 (0.452)	0.408 (0.046)	0.045 (0.031)	0.029 (0.023)	0.077 (0.038)	0.505 (0.295)
4.00	23.40 (8.190)	0.894 (0.697)	0.828 (0.586)	0.553 (0.437)	0.320 (0.277)	0.025 (0.027)	0.017 (0.013)	0.054 (0.040)	0.417 (0.269)
5.85	17.68 (7.241)	0.914 (0.416)	0.670 (0.130)	0.382 (0.173)	0.363 (0.123)	0.076 (0.020)	0.018 (0.019)	0.035 (0.022)	0.285 (0.131)
9.00	12.21 (7.995)	0.571 (0.284)	0.322 (0.092)	0.208 (0.111)	0.150 (0.070)	0.058 (0.022)	0.008 (0.007)	0.013 (0.009)	0.155 (0.100)
Total	116.72	3.724	4.484	7.457	2.094	1.503	0.434	0.242	1.719

[1)]( ) : standard deviation.

sol size distribution in Kosan in April 1998 and reported that NO_3^- was mainly in the coarse mode while SO_4^{2-} and NH_4^+ were mainly in the fine mode.[6] Particulate NH_4^+ is formed from gaseous NH_3 emitted from various natural and anthropogenic sources. Most of NH_4^+ existed in the fine mode, regardless of the periods of YS or NYS.

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