

황사의 물리·화학적 성상 및 특성

Physical and Chemical Characteristics of Asian Dust

202 - 3

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Abstract

The frequency record of sand storm occurrence in spring season has been renewed continuously along with its intensity and extended duration from the year 2000 to 2002 period. The airborne sand transported from long distance practically reduces visibility and influences atmospheric radiation energy balance. It can further affect the ecological system through the deposition on the earth's surface while offering the buffer effect to acid substance, because of its alkali content such as calcium. It is known that no chemical reaction proceeds between elemental components contained in transporting particles during sand storm period. The elements originating from soil sources and some cations increased with the occurrence of sand storm. However the elements of anthropogenic origin(Pb, Se and Zn) and anions(NH_4^+ and NO_3^-) decreased, possibly because of the dilution effect by the strong air flow from westward direction.

Keywords : **Sand storm; Visibility; Ecological system; Anthropogenic**

: ; ; ; ;

(PAH s)

가 가

. 1991
UNEP(United Nations Environment Programme)

‘ ,
() ,
(水蝕), ,

(2).

가 .

UNEP

1/4,

70%

36 ha가

1/6

.

가

가 .

가

가

,

pH 0.2

가

가

(3).

.

30 $\mu\text{g}/$ m^3

1,300 mm

가

(1).

pH=4.7

(4).

가

가

가

1998

4

~

(5, 6).

가

, 2001 4

1,000~2,000 m

(IGAC)

100

가가 가

(

)

(ACE - Asia ; Asian - Pacific

Region Aerosol Characterization Study)

(7, 8).

1. (, ,)

Year	Annual mean			Average value except sand storm			Affected rate		
	PM _{2.5}	PM ₁₀	TSP	PM _{2.5}	PM ₁₀	TSP	PM _{2.5}	PM ₁₀	TSP
2000	26.5	65	99	26	64	98	1.9%	1.6%	1.02%
2001	43	73	111	42	66	99	2.4%	10.6%	12%
2002	40	76	114	36	64	100	11.1%	18.7%	14%

PM_{2.5}, PM₁₀, TSP 3

沙塵暴(dust or sand storm), 揚沙(blowing sand), 浮塵(floating dust) 3가 . , , , 11

沙塵暴 , 가

50 沙塵暴 가 가 가 . 가

50 5 , 60 8 , 70 13 , , 1

80 14 , 90 23 沙塵暴 2002 TSP 14%,

2000 8 (9). PM₁₀ 18.7%, PM_{2.5} 11.1% . 2000

50 ~ 60 沙塵暴 1 ~ 2%

가 가 가 . 2003

가 2004 3 가

가 가

PM₁₀/TSP 2000 2001

가 52.8% 61.4% 2002

沙塵暴 가 71.5%

. 5 53 ~ 71%

PM_{2.5}/TSP 15 ~ 29% , PM_{2.5}/PM₁₀ 27 ~ 47%

(2).

Al Ca 3 Al Ca

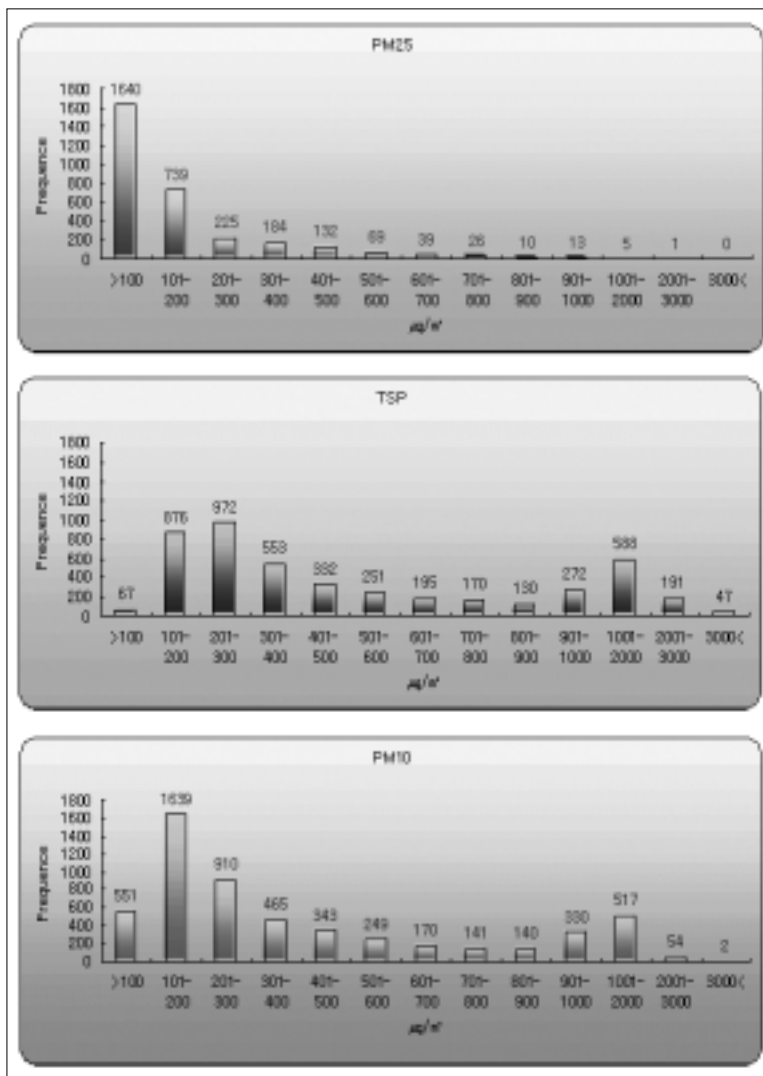
(Ca/Al) 가

0.73 ~ 1.04 , 0.83 ±

2.		(2000 ~ 2004)						
Year	days		TSP($\mu\text{g}/\text{m}^3$)	PM ₁₀ ($\mu\text{g}/\text{m}^3$)	PM _{2.5} ($\mu\text{g}/\text{m}^3$)	PM ₁₀ /TSP(%)	PM _{2.5} /TSP(%)	PM _{2.5} /PM ₁₀ (%)
2000	11	mean \pm sd	257.5 \pm 255.7	135.9 \pm 135.3	-	52.8	-	-
		max*	2,565	993				
2001	28	mean \pm sd	238.6 \pm 178.4	147 \pm 106.5	69.7 \pm 41.1	61.4	29.1	47.4
		max*	1,748	950	282			
2002	17	mean \pm sd	444.5 \pm 544.4	317.7 \pm 390.4	114.6 \pm 145.9	71.5	25.8	36.1
		max*	4,394	3,311	1,239			
2003	2	mean \pm sd	156.2 \pm 102.8	96.7 \pm 56.3	39.8 \pm 26.4	61.9	25.5	41.2
		max*	686	356	179			
2004.3	5	mean \pm sd	253.4 \pm 218.3	135.2 \pm 99.7	37 \pm 26.9	53.4	14.6	27.4
		max*	1,530	618	194			

max* : hourly maximum date in Seoul

3.			Al		Ca		Al	
Concentration ratio(Ca/Al)								
Date	Normal period		Date	Sand storm period		6.8%		
	PM ₁₀	TSP		PM ₁₀	TSP	(10),	6.6%	
Jan. 10	0.98	1.21	Jan. 12	-	-	(10),		
11	0.73	0.85				8.3%(7)		
14	1.04	0.99	Mar. 16	0.50	0.51	(11)	Al	
15	-	1.43	18	0.53	0.60			
Mar. 12	0.77	0.82	19	0.72	0.77		가	
13	0.88	0.82	20	0.59	0.61		Ca Al	
14	0.92	1.06	21	0.60	0.59			
15	0.76	0.67	22	0.45	0.50		,	
25	0.83	0.93	23	-	0.56			
26	0.77	0.84				1.9%		
Ave±SD	0.83±0.11	0.93±0.22	Ave±SD	0.58±0.13	0.59±0.09		5.6%	
							Ca 가	
0.11(mean±sd)							(
Ca 가 Ca/Al							(CaCO ₃)	
가 (10).							가	
0.45~0.72							가	
0.58±0.13							Ca	



1. (2000 ~ 2002,)

Ca

가

Ca

가

PM₁₀

TSP

Ca/Al

PM₁₀, TSP

Al Ca

PM_{2.5}, PM₁₀

TSP

1

(2000 ~

2002. 11)

PM_{2.5}, PM₁₀,

TSP

PM₁₀ TSP

bi - modal

PM_{2.5}

. PM₁₀ 500

μg/m³ 4,608

15.2% 700 ,

TSP 21% , PM_{2.5} 3,064

가 144 4.7%

. PM₁₀ 500 μg/m³

4,608

15.2% 700 , TSP

21% , PM_{2.5} 3,064 가

4.7%

4. PM ₁₀ TSP (μg/m ³)											
Sampling period	Size	Dust	Na ⁺	Mg ⁺⁺	Ca ⁺⁺	NH ₄ ⁺	K ⁺	F ⁻	Cl ⁻	NO ₃ ⁻	SO ₄ ²⁻
Jan. 10' ~`11/02	PM ₁₀	106±	0.60±	0.17±	1.34±	7.8±	1.05±	0.17±	4.3±	20.8±	17.8±
14' ~`15/02		27	0.43	0.10	0.75	3.2	0.88	0.17	1.5	8.9	7.7
Mar. 12' ~`15/02	TSP	152±	0.86±	0.26±	2.74±	8.1±	1.22±	0.35±	5.3±	22.9±	19.9±
25' ~`26/02 (N : 10 days)		40	0.54	0.12	1.35	2.9	0.80	0.31	1.9	10.5	7.6
Jan. 12/02	PM ₁₀	343±	1.98±	0.47±	3.44±	4.2±	1.25±	0.24±	5.3±	15.0±	17.2±
Mar. 16/02			1.0	0.27	2.01	4.4	0.84	0.13	2.1	13.2	12.5
18' ~`23/02 (S : 8 days)	TSP	634±	2.68±	0.63±	4.57±	4.1±	1.35±	0.34±	7.0±	15.3±	21.5±
			1.93	0.48	3.13	3.8	0.86	0.24	2.9	12.7	17.5
sand storm / normal	PM ₁₀	3.2	3.3	2.7	2.6	0.5	1.2	1.4	1.2	0.7	1.0
	TSP	4.2	3.1	2.4	1.7	0.5	1.1	1.0	1.3	0.7	1.1

4 가 .

PM₁₀

3.2 , TSP 4.2 , PM₁₀ .

Na⁺, Mg⁺⁺, Ca⁺⁺ / 3.3 , PM₁₀, TSP

2.7 , 2.6 . TSP 3.1 , 2.4 , 5 .

1.7 가 Ca⁺⁺ Al, Ca, Fe, Mg

. 9.1 , 6.2 , 7.3 , 7.5

NH₄⁺ PM₁₀ TSP 0.5 (PM₁₀ base), Cr, K, Mn, Sr V

, CaO 2.6~6.1 (PM₁₀ base)

. As, Ba, Cd, Cu, Ni

(SO₄²⁻) ,

(NO₃⁻) , Pb, Se, Zn 0.77, 0.61, 0.82

. (NH₄⁺) (NO₃⁻) 가

. , (SO₄²⁻) 1998 4 1999 1 ,

가 SEM EDX ,

가 3.6 μm .

5.		PM ₁₀ TSP (μg/m ³)								
Sampling period	Size	Al	Ca	Cr	Fe	K	Mg	Mn	Na	Sr
Jan. 10'~'11/02 14'~'15/02	PM ₁₀	1.68±	1.41±	0.007±	1.66±	0.87±	0.51±	0.05±	0.73±	0.008±
Mar. 12'~'15/02		0.97	0.74	0.002	0.63	0.34	0.29	0.02	0.32	0.004
25'~'26/02 (N : 10 days)	TSP	3.16±	2.84±	0.010±	2.93±	1.30±	0.89±	0.07±	0.98±	0.014±
		1.55	1.27	0.002	1.02	0.50	0.48	0.03	0.48	0.007
Jan. 12/02 Mar. 16/02	PM ₁₀	15.17±	8.79±	0.017±	12.05±	3.74±	3.82±	0.246±	1.87±	0.051±
18'~'23/02 (S : 8 days)		18.14	10.82	0.016	14.6	4.43	4.08	0.257	1.22	0.060
	TSP	26.19±	15.53±	0.029±	21.4±	5.65±	5.73±	0.38±	2.69±	0.082±
		35.6	20.9	0.031	29.28	6.02	0.48	0.44	2.20	0.109
S.S normal	PM ₁₀	9.1	6.2	2.6	7.3	4.3	7.5	5.2	2.6	6.1
	TSP	8.3	5.5	2.9	7.3	4.4	6.5	5.3	2.7	5.8
Sampling period	Size	As	V	Ba	Cd	Cu	Ni	Pb	Se	Zn
Jan. 10'~'11/02 14'~'15/02	PM ₁₀	0.010±	0.005±	0.07±	0.003±	0.10±	0.007±	0.11±	0.01±	0.21±
Mar. 12'~'15/02		0.006	0.002	0.02	0.001	0.04	0.002	0.06	0.01	0.06
25'~'26/02 (N : 10 days)	TSP	0.011±	0.007±	0.09±	0.003±	0.32±	0.01±	0.11±	0.011±	0.25±
		0.006	0.003	0.02	0.001	0.06	0.003	0.06	0.01	0.06
Jan. 12/02 Mar. 16/02	PM ₁₀	0.011±	0.022±	0.10±	0.003±	0.11±	0.013±	0.08±	0.006±	0.17±
18'~'23/02 (S : 8 days)		0.008	0.023	0.07	0.002	0.05	0.010	0.06	0.007	0.09
	TSP	0.014±	0.036±	0.15±	0.002±	0.31±	0.020±	0.09±	0.006±	0.21±
		0.008	0.044	0.13	0.002	0.10	0.019	0.06	0.009	0.09
S.S normal	PM ₁₀	1.12	4.6	1.39	0.95	1.13	1.17	0.77	0.61	0.82
	TSP	1.26	5.0	1.57	0.90	1.00	2.10	0.75	0.54	0.83

Na, Mg, Al, Si , Na, Al, Si 가 가 PAH
(12) . 14

15

Na - Si - Al - Mg .

6.	PAH	(ng/m ³)
Date	PM ₁₀	TSP
Mar.28/02	21.99	18.38
Apr.6/02	20.23	19.01
Apr.7/02	17.18	14.62
Apr.8/02	16.65	13.8
Apr.11/02	21.12	13.8
mean	19.43	15.92
sd	2.14	2.29
the period exposed to the dust storm		
Mar.29/02	19.69	14.16
Mar.30/02	15.63	13.73
Apr.3/02	16.54	12.79
Apr.4/02	11.31	10.93
Apr.10/02	6.71	7.2
Apr.12/02	15.78	12.33
Apr.14/02	13.61	10.93
mean	14.18	11.72
sd	4.18	2.35
during intermediate period		
Apr.19/02	8.67	7.79
Apr.21/02	6.15	4.23
Apr.22.02	9.38	6.55
mean	8.07	6.19
sd	1.70	1.81
Rainy day		
total mean	14.71	12.02
sd	5.21	4.18

PAHs

chrysene, benzo(b)fluoranthene, benzo(k) flu-
oranthene 3 10

6

PAHs TSP
15.92 ng/m³, PM₁₀ 19.43 ng/m³

TSP
PAHs 6.19
ng/m³, PM₁₀ 8.07 ng/m³

PAHs TSP 11.53 ng/m³,
PM₁₀ 13.82 ng/m³

PM₁₀, TSP
PAHs 가
140% 가
, 250%

가
PM₁₀

PAHs
TSP 120%

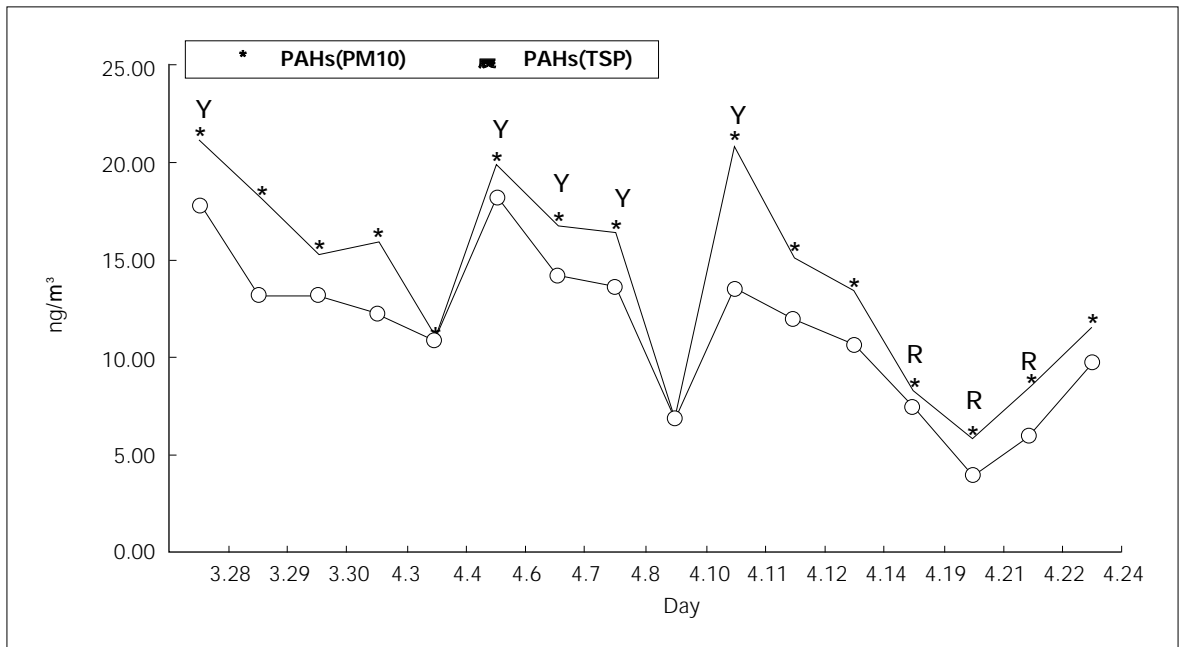
16 15
TSP PM₁₀ 가

PAHs 90~95%가
3 μm

PAHs
PM₁₀

2 PM₁₀
PAHs 가

가 4 6~8



2. PM₁₀ TSP PAHs ()

PAHs 3

50.9%

4 7 53.2 % 가 200 ng/m²/h

PAHs

(13).

(Emission)

(Deposition)

2001 3 20 3 27

가 -

가

3 ng/m³

5

(60%) 1~2 ng/m³

PM₁₀ 가 274 µg/m³ 가 가

7.

(2001 3)

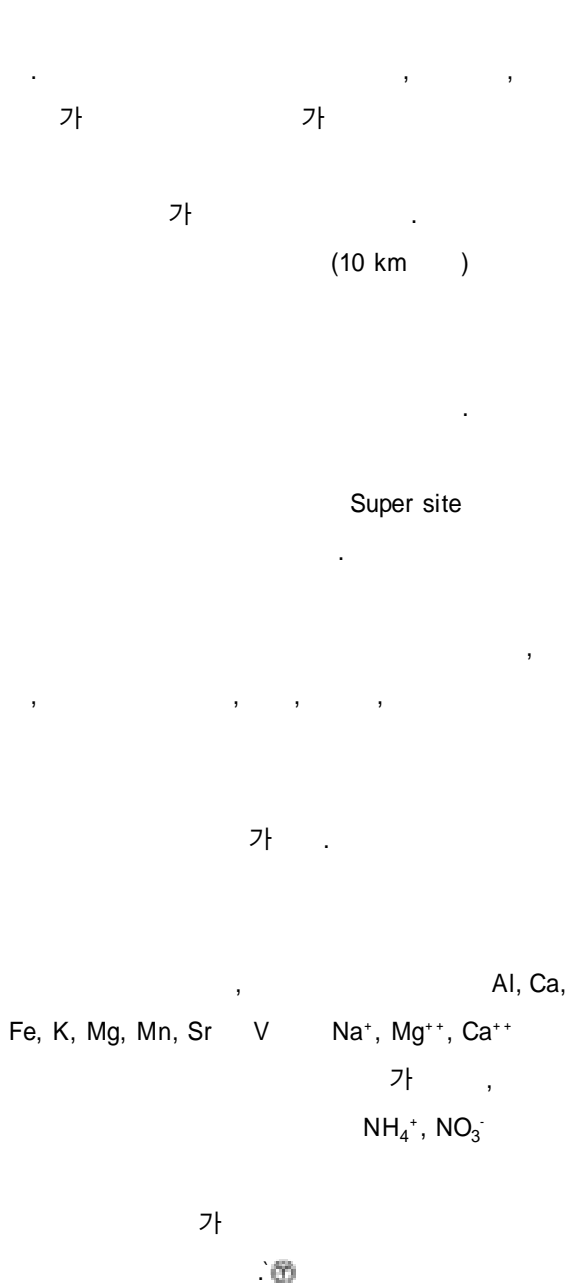
A. Hg - related

	Hg ¹ ng m ⁻³	Hg(L) ² ng m ⁻³	Hg(U) ³ ng m ⁻³	K ⁴ m ² s ⁻¹	Flux ⁵ ng m ⁻² h ⁻¹
A. All data					
Mean	0.45	3.72	3.26	0.42	196.95
Median	0.49	3.40	3.12	0.44	178.18
SD	0.59	1.10	0.93	0.18	150.23
Min	- 1.82	2.21	1.82	0.07	- 12.72
Max	2.14	8.35	7.72	0.76	562.34
N	164	164	166	36	32
B. Upward emission					
Mean	0.67	3.89	3.21	0.45	211
Median	0.60	3.58	2.98	0.46	187
SD	0.43	1.15	0.96	0.16	145
Min	0.03	2.21	1.82	0.10	14.9
Max	2.14	8.35	7.72	0.76	562
N	129	129	131	33	30
C. Downward deposition					
Mean	- 0.38	3.07	3.45	0.11	- 9.17
Median	- 0.28	3.05	3.23	0.11	- 9.17
SD	0.37	0.57	0.82	0.06	5.03
Min	- 1.82	2.39	2.49	0.07	- 12.7
Max	- 0.03	5.02	6.84	0.16	- 5.61
N	31	31	31	2	2

*Superscripts 1 through 5 denote Hg concentration gradient, Hg concentration at lower level (1 m), Hg concentration at upper level (5 m), turbulent transfer coefficient used for the derivation of flux, and Hg fluxes, respectively.

(14).

2000 2002 3



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4 ()	
1.	6.
2.	7.
3.	8.
4.	9.
5.	10.