한국환경과학회지 제14권(제5호), 463~471, 2005
Journal of the Environmental Sciences

PM$_{10}$ Concentration and Chemical Composition in a Western Region of Busan during the Spring 2003

Byung-Il Jeon* **and Yong-Sik Hwang**
**Department of Environmental Engineering, Silla University, Busan 617-736, Korea*
Institute of Industrial Medicine and Department of Environmental Occupational Medicine,
Inje University, Busan 614-735, Korea

(Manuscript received 4 March, 2005; accepted 18 May, 2005)

This study is designed to investigate the characteristics of PM$_{10}$ concentration and the chemical composition of heavy metallic components in the PM$_{10}$ sampled in western Busan from March to May, 2003. PM$_{10}$ measurement was done during springtime of 2003, totaling 29 days: 9 days in March, 10 days in April and 10 days in May. With a sampling time of 24 hours, it started 9:00 AM on that day and ended 9:00 AM the next day. The mean contribution ratio of soil during springtime was 10.3 %. Al had a significant correlation with Ca, Fe, Mg and Si and little correlation with Na, Ni and Zn.

Key Words : PM$_{10}$ concentration, Heavy metallic components, Contribution ratio of soil

1. Introduction

Atmospheric aerosols affect global climate both directly through scattering and absorption of solar radiation and indirectly acting as cloud concentration nuclei. A 2% increase in aerosol planetary albedo is sufficient to compensate global warming due to doubling of greenhouse gas emissions$^{1)}$. Aerosol particles of fine dimensions are recognized to have a strong impact on the environment and to be of concern in health-related effect. In urban areas, air particle pollution is of particular interest for the possible delayed health effects associated with continuous exposure of a high-density population$^{2)}$.

Airborne particulate matters, in general, fall into one of two categories; coarse particles with an aerodynamic diameter greater than 10 ㎛ and fine particles with an aerodynamic diameter less than 10 ㎛. Most coarse particles originate from natural sources, including soil dusts and seasalts flown and raised by wind. Fine particles are formed into ones originating from anthropogenic sources, such as combustion of fossil fuel, mobile exhaustion gas and the production process of chemical materials and secondary particulates converted from gaseous pollutants to particulate matters through condensation process of sulfur dioxide or volatile organic compound. Coarse particles, when introduced into human respiratory, do not penetrate the lung deeply since they are caught in the nose ciliation or the airway, while fine particles cause the human body harm in themselves, plus health damage because they turn into secondary pollutants in combination with metal, organic, acid, nitrogen dioxide and other pollutants, reach the bronchus or alveolus, when introduced into the human respiratory, and are easily subject to deposition. For instance, a study of 550,000 adults in 151 U.S. metropolitan areas found a 17 % higher mortality rate a cities with higher concentrations of fine particles than in cities with lower concentrations of fine particles. In California, an estimated 1,000 additional persons out of every 1,000,000 die of cancer annually because of fine particles from cars$^{3)}$.

Many of Korean studies on PM$_{10}$ have been made in metropolitan areas, including Seoul. In particular, Choi *et al.*$^{4\sim7)}$ studied the characteristics of heavy metals and ion components in PM$_{10}$ during the yellow sand periods in early spring in Seoul and Kim and Kim$^{8)}$ collected PM$_{2.5}$ and PM$_{10}$ samples in Suwon to study their chemical composition. Choi and Song$^{9)}$ measured PM$_{10}$ in Daegu to study the characteristics of sources of particulate trace metals and Choi and

---

Corresponding Author : Yong-Sik Hwang, Institute of Industrial Medicine and Department of Environmental Occupational Medicine, Inje University, Busan 614-735, Korea
Phone: +82-51-890-6875
E-mail: iimhys@inje.ac.kr

Baik[10)] researched the relationship between TSP and PM_{10} concentration in the ambient atmosphere. Oh and Kim[11)] investigated chemical composition trends of airborne particles at Kunsan and Kim[12)] researched the effects of climate factors on PM_{10} and metallic elements concentration at Kunsan. Na and Lee[13)] studied the characteristics of PM_{10} and airborne metallic elements produced at Ulsan. Triantafyllow[14)] studied synoptic climatology conditions during days when PM_{10} pollution episodes occur in a mountainous industrial area in Greece. MeKendry[15)] investigated high PM_{10} pollution episodes in the Lower Fraser Valley in Canada in his overview of spatiotemporal variations and meteorological controls. Yang[16)] provided a systematic study of spatial and seasonal variations of PM_{10} concentration in Taiwan.

In Busan, the area of this study, Choi *et al.*[17)] researched the characteristics of PM10 concentration by distributively sampling particulate matters into coarse particles and fine particles. Jeon[18)] collected $PM_{2.5}$ samples with particulate samplers to investigate the chemical compositions of ion and trace metallic elements. Cheong *et al.*[19)] provided an overview of daytime and nighttime concentration characteristics of chemical components in PM_{10}. Jeon *et al.*[20)] explained the effects of the January 1999 yellow sand outbreak on suspended particle concentration. Also, Jeon *et al.*[21)] studied the characteristics of heavy metallic elements in PM_{10} during yellow sand and non-yellow sand periods during springtime of 2002.

This study is designed to understand the characteristics of PM_{10} concentration and the chemical composition of heavy metallic components in it by sampling PM_{10} in western Busan from March to May, 2003.

2. Sampling and methods

Sampling was conducted in the rooftop of the six-floor Natural Science Building at Silla University, which was located in the foot of Mt. Backyang, Gwaebup-Dong, Sasang-Gu, Busan, as seen in Fig. 1. The sampling site, surrounded by Mt. Backyang, has a valley to the southeast and the Sasang industrial complex, about 3km away. Recently, many factories moving into other places has led to a significant diminishment in the influence of point sources, while the rise of large shopping malls has led to a distinct increase in automobiles, increasing influence by line sources. Many particular point sources surrounding the sampling site are distributed in the Sinpyeong · Janglim industrial complex, 5 km south of Sasang area and an influx of southwesterly may lead to advection of pollutants from the Sinpyeong · Janglim industrial complex and Sasang industrial complex, which could affect the sampling site. PM_{10} measurement was done during springtime of 2003, totaling 29 days: 9 days in March, 10 days in April and 10 days in May. Sampling was conducted on non-precipitation days alone, twice during weekdays(Monday to Friday) and once during weekends(Saturday and Sunday), 3 days a week. With a sampling time of 24 hours, it started 9:00 AM on that day and ended 9:00 AM the next day.

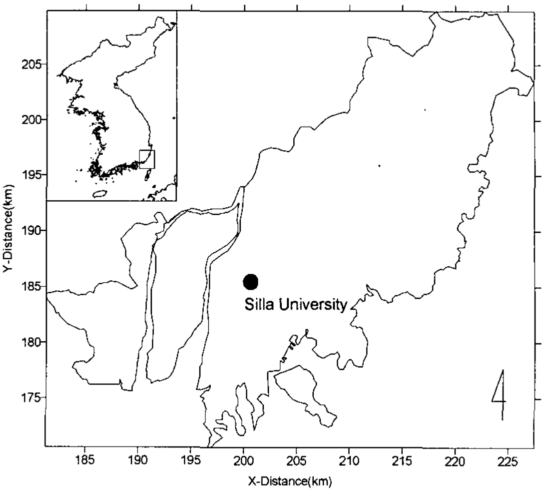

Fig. 1. Location of the PM_{10} monitoring site at Busan.

For measurement of PM_{10} concentration, we dried filter for 2 hours at a temperature of 105 ℃ and weighed it with a microbalance (Saritorious microbalance, Germany) with a sensitivity of 0.01 ㎎ to get PM_{10} concentration with the difference of mass before and after measurement. Measurement of trace metallic elements in PM_{10} required the analysis of Al, Ca, Fe, K, Mg, Na, Si and Zn with the use of ICP/AES (ICP-IRIS, ThermoJarrell Ash Colk USA) on the same conditions as Table 1, after pre-treating them using ultra-sonic extract method. Cd, Cr, Mn, Ni and Pb were analyzed with the use of AAS (Perkin Elmer 4100ZL, Flameless method).

Table 1. ICP/AES operating conditions

ICP/AES (ICP-IRIS)	
Maker	Thermo Jarrell Ash (USA)
Max power	2.0 KW
RF frequency	27.12 MHz
Wavelength range	174-800 nm
Detector	CID
Injection flow rate	2.035 mℓ/min
Nebulizer pressure	32 psi
RF power	1150 W

3. Results and discussion

3.1. Characteristics of PM_{10} concentration during springtime of 2003

Fig. 2 suggests the daily mean PM_{10} concentration measured from March 1 to May 31, 2003 at Gamjeon-Dong, one of Busan's automatic air pollution monitoring network, which is closest to this research sampling site and the precipitation measured at Busan Regional Meteorological Office. The 2003 yellow sand occurred twice, March 27 and April 12. While it primarily affected the central part of the country, Busan was unaffected by the yellow sand. Therefore, at Gamjeon-Dong, not a single day occurred when the daily mean PM_{10} concentrations exceeded 24 hour average 150 ㎍/㎥, Korea's air quality standard. Also, the maximum concentration occurrence day at Gamjeon-Dong during springtime of 2003 was April 13 with 137 ㎍/㎥, followed by March 26 with 131 ㎍/㎥ and May 20 with 127 ㎍/㎥. Overall, it shows 4 peaks, with high concentrations of PM_{10} occurring on a clear day with little precipitation, as seen in the figure. PM_{10} concentration, therefore, has very close relations with precipitation.

3.2. Mass concentration and chemical composition of PM_{10}

Table 2 shows the mass concentration of PM_{10} measured at Silla University, this study's sampling site and the monthly mean concentration of metallic element in the PM_{10}. The mean PM_{10} concentration during study periods was 53.8 ㎍/㎥, with the maximum concentration being 101.4 ㎍/㎥ of April 30, 2003 and the minimum concentration being 15.3 ㎍/㎥ of May 28. Monthly, the highest period was during April with 59.0 ㎍/㎥ and the lowest was during March with 46.3 ㎍/㎥. Monthly characteristics of heavy metal concentrations suggested Cr, K, Mn, Na, Pb, Si, Zn at the highest during March and Al, Ca, Fe, Mg at the highest during April, and Cd, Cu, Ni at the highest during May. In particular, heavy metal concentrations in March had many elements higher than during other months, which requires more studies to be done. The concentration distribution of heavy metal showed Cd<Cr<Ni<Cu · · · Ca<Si<K<Na in March and Cd<Cr<Ni<Cu · · · Si<K<Na<Ca in April and Cr<Cd<Ni<Cu · · · Ca<Si<K<Na in May. Both high-level concentrations and low-level concentrations showed the similar order. Therefore, the air that affected this study's area during springtime of 2003 is estimated to have been influenced by similar air current.

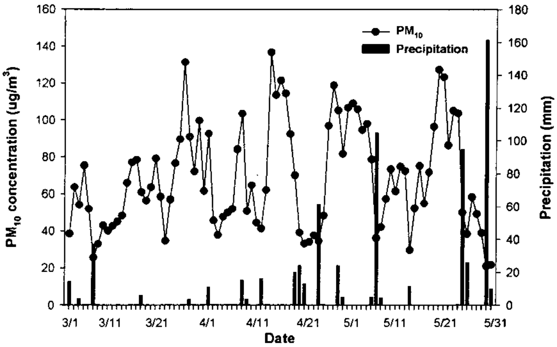

Fig. 2. Daily mean concentration (㎍/㎥) of PM10 at Gamjeondong (Busan) and precipitation (mm) from March 1 to May 31, 2003.

To provide a systematic understanding of the implication of the concentration distribution of metallic elements observed in this study, Table 3 suggests a comparison of the results of previous studies that analyzed the concentration distribution trend of heavy metallic elements and those of this study. The heavy metal concentrations of the springtime, 2003 were high except for Cd, Cr, Ni, Pb compared to those of the springtime 2002 that were measured at the same site[21].

Especially, elements from natural sources such as Al, Ca, Fe, Mg, Si, which do not originating from anthropogenic sources, were ten times high. It is estimated that many heavy metals transported from China after the 2002 yellow sand outbreak occurred on March 17, 18, 21, 22, 23 and April 8, 9, 10, 11, 17, 5 days during March and April, respectively. Elements from anthropogenic sources, including Cd, Cr, Pb, appeared quite high, heavy metal pollution

Table 2. Concentrations of major and trace elements in PM_{10} collected at Busan from March to May 2003

Mon./day	PM_{10}*	Al	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	Pb	Si	Zn
March 4	51.4	795.1	1250	11.6	8.6	31.3	541.7	1892	284.7	347.2	1340	16.3	308	1528	253.5
8	29.2	461.8	618.1	6.1	11.5	17.4	305.6	2736	197.9	13.9	4177	18.2	376	989.6	270.8
9	19.4	347.2	513.9	5.8	9.7	27.8	170.1	1247	197.9	10.4	2090	10.3	168.9	680.6	211.8
11	18.1	336.8	312.5	5.7	6.9	10.4	152.8	851	125	17.4	1517	13.7	108.7	538.2	194.4
13	51.4	510.4	743.1	16.2	14.6	24.3	482.6	1146	118.1	34.7	1750	22.8	304.3	989.6	1250
18	38.9	427.1	673.6	6	7.7	13.9	381.9	760	159.7	34.7	1177	14	166.8	1097	319.4
26	77.8	441	1122	7	12.8	27.8	638.9	1073	250	66	1233	19.3	443	1212	420.1
28	72.2	631.9	1163	12.4	25.7	31.3	916.7	934	281.3	69.4	1556	26.1	817.3	1372	545.1
30	58.3	506.9	739.6	6.9	11.7	17.4	392.4	1125	312.5	31.3	2149	10	161.3	798.6	298.6
April 2	25	201.4	385.4	1.9	5.3	10.4	34.7	1406	204.9	17.4	267	14.7	17	125	27.8
6	73.6	451.4	1385	11.6	5.9	27.8	496.5	823	72.9	74.2	205	8.3	273.9	399.3	163.2
9	33.3	218.8	447.9	4.2	4.3	10.4	225.7	392	128.5	13.9	1215	10.4	57.3	312.5	215.3
10	25	173.6	232.6	1	3.8	10.4	93.8	292	76.4	17.4	1003	4	20.1	131.9	177.1
13	84.7	1090	2712	9.1	6.3	62.5	871.5	910	465.3	52.1	406	8.6	215	1361	319.4
15	79.2	739.6	1840	9.3	12.7	20.8	850.7	569	416.7	66	698	19.2	219.5	944.4	385.4
17	59.7	395.8	1191	6.5	11	27.8	708.3	441	441	62.5	1816	22.5	264.9	642.4	572.9
21	16.7	211.8	416.7	4.5	5.9	13.9	218.8	365	180.6	17.4	1660	15.7	66.8	409.7	250
27	91.7	684	2083	4.3	6.9	3.5	670.1	1708	614.6	45.1	1024	8.5	400.3	1295	312.5
30	101.4	1108	2292	16	16.5	48.6	1017	1792	493.1	76.4	1111	21.5	242.2	1194	458.3
May 1	56.9	684	1361	9.5	8.5	27.8	704.9	736	322.9	66	1000	13.5	227.3	947.9	579.9
2	91.7	677.1	1372	15	11.4	24.3	812.5	1288	357.6	86.8	1417	21.2	384.7	1205	552.1
9	37.5	277.8	458.3	10	6.9	20.8	316	1003	156.3	31.3	1160	13.4	88.6	590.3	173.6
11	33.3	138.9	357.6	5	4.1	20.8	142.4	1094	114.6	10.4	1076	7.6	30.9	194.4	69.4
16	40.3	253.5	416.7	4.7	3.4	13.9	180.6	354	104.2	20.8	885	5.2	40.9	357.6	197.9
18	59.7	288.2	645.8	11.1	6.9	24.3	482.6	1378	180.6	31.3	250	25.4	288.8	520.8	284.7
20	100	527.8	1066	10.7	15.3	97.2	902.8	1031	253.5	336.8	1170	41.7	351	906.3	715.3
27	52.8	24.3	281.3	10.8	5.5	24.3	107.6	201	121.5	29.5	927	13.5	105.4	538.2	135.4
28	15.3	229.2	166.7	10.8	5.1	13.9	24.3	1007	79.9	10.4	837	4.9	11.8	239.6	72.9
31	65.3	204.9	413.2	10	6.1	45.1	302.1	628	166.7	69.4	1028	34.1	162	1479	142.4
March	46.3	495.4	792.8	8.6	12.1	22.4	442.5	1307	214.1	69.4	1889	16.8	317.2	1022.8	418.2
April	59.0	527.4	1298.6	6.8	7.9	23.6	518.7	870	309.4	44.2	941	13.3	177.7	681.6	288.2
May	55.3	330.6	653.8	9.8	7.3	31.3	397.6	872	185.8	69.3	975	18.1	169.9	697.9	292.4
Spring	53.8	449.6	919.3	8.4	9.0	25.9	453.3	1006	237.2	60.7	1246	16.0	218.0	793.1	330.0

*The unit of PM_{10} is μg/m³, while all the rest are ng/m³.

Table 3. Comparison of elemental components concentrations (ng/m³) of springtime PM_{10} among several city in Korea

Elements	This study	Busan[a)]	Seoul[b)]	Seoul[c)]	Daejeon[d)]
Al	449.6	3658.1	1800	2490	
Ca	919.3	668.0	1280	2336	
Cd	8.4	1.42	2.4	7.66	2.78
Cr	9.0	8.34	8.6	18.8	18.3
Cu	25.9	26.26		50.1	33.2
Fe	453.3	3706.9	1320	2321	2171
K	1006.3	776.9		1038	
Mg	237.2	2222.9	460	806	
Mn	60.7	173.7	42.0	94.2	55.7
Na	1246.4	3235.5	510	699	
Ni	16.0	12.60	7.3	47.8	39.7
Pb	218.0	30.35	70.5	124	251
Si	793.1	8417.8			
Zn	330.0	571.8	202	302	208

[a)] Jeon[21)], [b)] Choi et al[6)], [c)] Kim et al[22)], [d)] Kim et al[23)]

worse than in the previous year. This study showed the concentrations of Al, Ca, Cu, Mg were lower than those in Seoul and Daejeon and the levels of Cd, Na, Zn were much higher than those in other cities, which was assumably attributed to the location of the study area, Busan bordering the sea. Cr an Pb was higher in Busan than those in Seoul and lower than those in Daejeon, industrial region. The 2003 this study results showed that Busan was lower in the concentrations of Al, Ca and Fe that are affected by natural resources. For Cr, Pb and Ni that are affected by artificial sources, Busan was lower than in industrial regions and slightly higher than in residential regions.

Fig. 3 suggests the PM_{10} concentrations measured by *B*-ray absorption at Gamjeon-Dong, one of Busan's

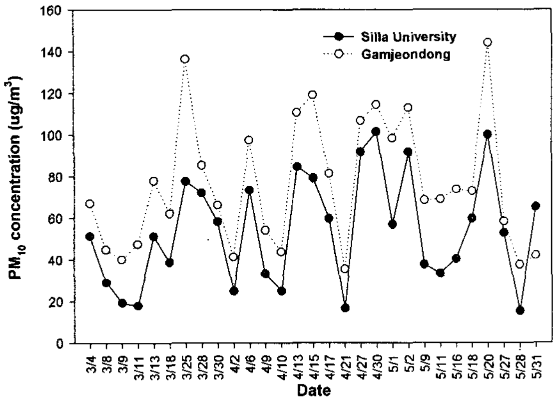

Fig. 3. Comparison of PM_{10} concentration ($\mu g/m^3$) between Gamjeondong and Silla University.

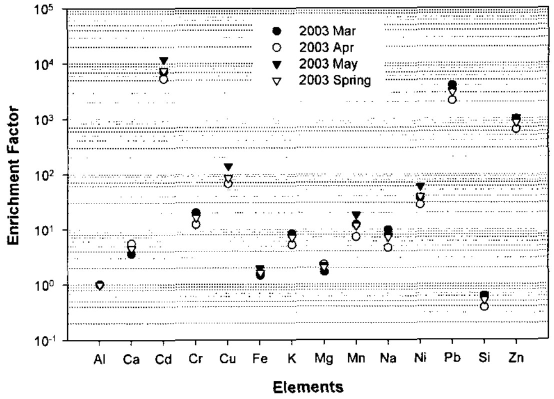

Fig. 4. Enrichment factor of each element relative to crustal composition and normalized by Al at Busan.

automatic air pollution monitoring network, and those measured by Mini-Vol on the rooftop of the Natural Science Building at Silla University by date. Overall, at Gamjeong-Dong, concentrations were higher than at Silla University. The two station's concentration variation trend was almost similar, with a correlation coefficient of 0.88 for the two groups. Thus, the sampling site, Silla University showed estimated lower PM_{10} concentrations than Gamjeon-Dong where an industrial area and a commercial area mix together, representing its local characteristics.

3.3. Crust enrichment factor

Fig. 4 shows the measured Enrichment Factor (EF) of elements in airborne suspended particles, based on their respective concentrations. With Al as standard matter, the crust composition ratio of each element was drawn using Formula (1).

$$EF = \frac{[x/Al]_{sample}}{[x/Al]_{crust}} \qquad (1)$$

[x/Al] means the concentration ratio of an element x and Al in airborne suspended particles or in soils. Since Al is a typical element originating from soil particles, the high EF of the elements point to an anthropogenic component. The elements with EF of less than 10 were identified as components such as Ca, Fe, K, Mg, Si, which are rich in most soils . In particular, Fe, Mg and Si whose EF were close to 1, which is almost similar to Al, are assumed to have originated from natural sources contained in a lot of soils.

Fig. 4 shows that Cd, Cu, Ni, Pb and Zn have originated from anthropogenic sources, with mean crust enrichment factors of 10 or more. In particular, Cd and Pb were very high with 7595.8 and 3032.7, respectively, and it is estimated to have been much influenced by the neighboring Sasang industrial complex and Sinpyeong, Janglim industrial complex. Analysis of the characteristics of EF by month, using data from this study, suggested Cr, Na, Pb at the highest crust enrichment factors, with Ca at the highest during April and Cd, Cu, Mn and Ni at the highest during May. It is estimated to have attributed to seasonal emission source effects and transportation, while it requires further study to be done.

To get a more detailed picture of differences in the EF that appeared according to the forms of emission sources in the study area, Table 4 compares the crust enrichment factors of metals obtained from PM_{10} in the study area with those in other cities. Ca was 4.6, higher compared to 2.1 in Jeju and 2.87 in Mt. Soback. Also, Na was 7.1, lower compared to 26.9 in Jeju, which was verifiably attributable to the location of Jeju that is affected by the ocean more than Busan, even though both of them are located in coastal area.

3.4. Contribution ratio of soil

To get the amount of soil particles suspended in the atmosphere, this study estimated the contributions of soil, using Al, an index element of soil, with Formula (2) used to get the contribution ratio of soil. C_{soil} means the concentrations ($\mu g/m^3$) of elements from soil in dusts and C_{PM10} the concentrations ($\mu g/$

Table 4. Comparison of crustal enrichment factors in various sites

Elements	This study	Daegu[a)]	Seoul[b)]	Jeju[c)]	Mt Soback[d)]
Al	1.0		1.0	1.0	1.0
Ca	4.6			2.1	2.87
Cd	7595.8	3696.2	3.8	1156	827
Cr	16.3	10303.9	25.4		
Cu	85.0		94.7		
Fe	1.6	2.4	2.39	1.9	0.94
K	7.0				
Mg	2.1			2.6	0.85
Mn	11.6	3.6	5.8	2.2	1.33
Na	7.1			26.9	1.02
Ni	38.6	106.7	244	4.1	2.5
Pb	3032.7	1175.3	294	621	675
Si	0.5				
Zn	852.4	426.5	184	62	50.0

[a)]Choi and Song[9)], [b)]Kim et al[22)], [c)]Choi and Barg[24)], [d)]Choi et al[25)]

m³) of suspended particles and C_{Al} the concentrations (μg/m³) of Al in suspended particles and 0.0813 the concentrations of Al in soil.

$$C = \frac{C_{soil}}{C_{PM10}} \times 100 = \frac{C_{Al}/0.0813}{C_{PM10}} \times 100 \qquad (2)$$

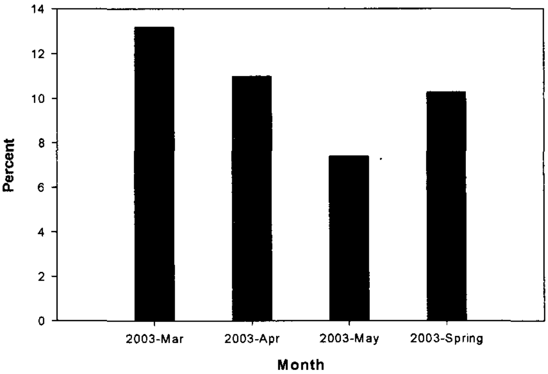

Fig. 5. Predicted contributions of soil to PM_{10} in Busan from March to May 2003.

Fig. 5 suggests the measured contribution of soil from March to May, 2003 in the study area. In the figure, the contribution ratio of soil was 13.2 % in March, 11.0 % in April and 7.4 % in May, showing a gradual declining trend. The average springtime contribution ratio of soil was 10.3 %. According to analysis of the contribution rate of soil during yellow sand/non-yellow sand periods in the study area during springtime of 2002[21)], compared to 21.7 % during yellow sand periods and 9.3 % during non-yellow sand periods, the average contribution ratio of soil in this study was very similar to that obtained during non-yellow sand periods and very lower than that obtained during yellow sand periods. In Seoul, Choi *et al.*[5~6)] found the contribution rate of soil at 58.5 % and 45.7 % during the yellow sand periods and at 28.8 % and 33.7 % during non-yellow sand periods in 1998. Another Shin and Kim[27)] found the contribution rate of soil at 60 % during yellow sand periods and at 28 % during non-yellow sand periods. In comparison with them, this study showed a very low value.

3.5. Correlation among metallic elements

Table 5 suggests correlations among metallic elements

Table 5. The correlation matrix between each metallic elements in PM_{10}

	Al	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	Pb	Si
Al	1.00												
Ca	0.92**	1.00											
Cd	0.49**	0.38*	1.00										
Cr	0.52**	0.38*	0.53**	1.00									
Cu	0.43*	0.41*	0.46*	0.39*	1.00								
Fe	0.84**	0.86**	0.56**	0.70**	0.58**	1.00							
K	0.41*	0.26	0.21	0.29	0.06	0.20	1.00						
Mg	0.77**	0.85**	0.17	0.39*	0.24	0.75**	0.30	1.00					
Mn	0.39*	0.30	0.36	0.31	0.65**	0.47*	0.22	0.22	1.00				
Na	-0.00	-0.19	-0.08	0.33	-0.11	-0.06	0.45*	0.01	-0.06	1.00			
Ni	0.17	0.12	0.47*	0.59**	0.65**	0.51**	0.14	0.18	0.52**	0.11	1.00		
Pb	0.51**	0.48**	0.46*	0.82**	0.30	0.72**	0.37*	0.44*	0.34	0.24	0.51**	1.00	
Si	0.71**	0.63**	0.50**	0.56**	0.42*	0.70**	0.38*	0.60**	0.45*	0.19	0.48**	0.69**	1.00
Zn	0.43*	0.34	0.54**	0.65**	0.36	0.60**	0.08	0.28	0.28	0.21	0.51**	0.53**	0.43*

* $P<0.05$, ** $P<0.01$

using statistical programs. Al showed a significant correlation ($P<0.01$) of 0.7 or more with Ca, Fe, Mg and Si and little correlation with Na, Ni and Zn. There were very high correlations between Ca and Fe and Mg; between Cr and Pb; and between Fe and Mg, Pb, Si. Also, there was a correlation coefficient of 0.65 or more between Cu and Mn and Ni; a correlation coefficient of 0.60 between Mg and Si; and a correlation coefficient of 0.69 between Pb and Si.

Ni that originates from anthropogenic sources, showed significant correlations ($P<0.05$) with Cd, Cr, Cu and Pb, suggesting that it originated in the neighboring Sasang industrial complex and having little correlation with other metallic elements. Pb showed significant correlations with Cd, Cr and Ni ($P<0.01$), with no correlations with other metal elements. Elements of anthropogenic origin had little correlation with elements originating from soil sources and there were high correlations among elements originating from soil sources. Therefore, it is found that metallic elements showed independent patterns of variation according to the types of emission sources.

3.6. Comparison of PM_{10} concentrations between weekday and weekend

This study, in principle, collected PM_{10} samples for 20 days during weekdays and 9 days during weekends (a total of 29 days) during springtime, 2003, twice during weekdays and once during weekends except for rainy days. For the impact of weekday and weekend on air pollutants concentration, most studies have been made on ozone[28]. However, recent studies on particulate matters during weekdays and weekends have been reportedly combined with gaseous matters[29~30]. Table 6 suggests PM_{10} concentrations during weekdays (Monday-Friday) and weekends (Saturday and Sunday) during springtime of 2003 at Gamjeon-Dong that automatic air pollution monitoring network in Busan. Weekday concentrations in March and April were higher than weekend ones, except for in May, Overall, they were 4.4 μg/m³ higher during weekdays than during weekends, with 69.5 μg/m³ for weekdays and 65.1 μg/m³ for weekends.

Table 6. PM_{10} concentration (μg/m³) of weekday and weekend at Gamjeondong in 2003

Week Month	March	April	May	Total
Weekday	65.1	71.5	71.7	69.5
Weekend	57.7	65.0	73.4	65.1
Total	63.5	70.0	71.4	68.3

Fig. 6 showed PM_{10} concentrations and heavy metal concentrations in PM_{10} during springtime of 2003 that were measured at Silla University, by dividing them into weekday and weekend. The concentrations of Cd, Fe, Mn, Ni, Zn were higher in weekday than those in weekend and Al, Ca, Cr, Cu, K, Mg, Na, Pb, Si were higher in weekend than those in weekday. Therefore, in the study area, there was no apparent influence of heavy metal elements of anthropogenic origin by an increase in traffic volumes and the operation of industrial facilities during weekdays. In a set of measurements carried out across Brisbane in Australia for 5 years, Morawska *et al.*[31] claimed that particle concentrations were higher during weekdays than during weekends. Also, in a six-year study in California in the United States, Qin *et al.*[32] suggested particle concentrations during weekdays higher than during weekends.

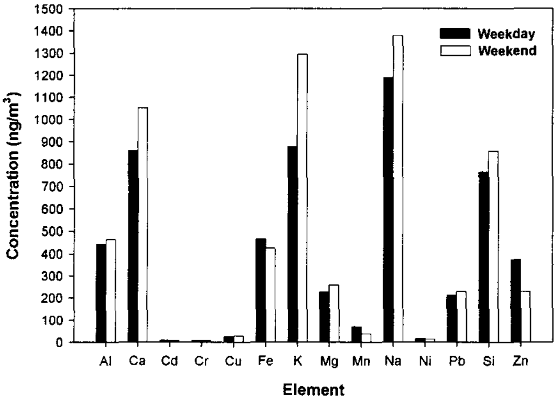

Fig. 6. Metallic component concentration of weekday and weekend at Silla university.

4. Summary and conclusion

As a result of analyzing PM_{10} concentrations measured on the rooftop of Silla University, Busan from March to May, 2003 and their chemical composition, the following conclusions were reached:

1) The PM_{10} concentrations at Gamjeon-Dong, Busan during springtime of 2003 showed 4 peaks, having close relations with rainfall.
2) The PM_{10} mass concentrations had a mean of 53.8

$\mu g/m^3$, highest in April and lowest in March. The concentration distributions of heavy metals showed Cd<Cr<Ni<Cu · · · Ca<Si<K<Na in March and Cd<Cr<Ni<Cu · · · Si<K<Na<Ca in April and Cr< Cd<Ni<Cu · · · Ca<Si<K<Na in May.

3) The PM_{10} concentrations at Gamjeon-Dong, one of Busan's automatic air pollution monitoring network, were higher than those measured at Silla University with the use of Mini-vol. The trend of variation was almost similar, with a correlation coefficient of 0.88 for the two groups.
4) Elements with EF of less than 10 were Ca, Fe, K, Mg and Si. Cd, Cu, Ni, Pb and Zn had a mean crust enrichment factor of 10 or more, originating from anthropogenic sources. The contribution ratio of soil in March was 13.2 % with 11.0 % for April and 7.4 % for May, a gradual declining trend. The mean contribution ratio of soil during springtime was 10.3 %.
5) Al had a significant correlation with Ca, Fe, Mg and Si and little correlation with Na, Ni and Zn. There were very high correlations between Ca and Fe and Mg; between Cr and Pb; and between Fe and Mg, Pb and Si.
6) Cd, Fe, Mn Ni, Zn were higher in weekday concentrations than in weekend concentrations and Al, Ca, Cr, Cu, K, Mg, Na, Pb, Si were higher in weekend concentrations than in weekday concentrations.

Acknowledgements

This articles was supported by the research grant 2004 of Silla University.

References

1) IPCC, 2001, Climate change 2001, The scientific basis, Summary for policy markers and technical summary of the working group 1 report, Cambridge University Press, Cambridge, 98pp.
2) Vedal, S., 1997, Ambient particles and health: lines that divide, Journal of Air & Waste Management Association, 47, 551-581.
3) Kim, W. S., 1997, A study for reducing and managing PM_{10} emissions in Seoul, Seoul Development Institute, 178pp.
4) Choi, J. C., H. M. Cho, J. Y. Kim, S. Kim and K. J. Kim, 1999, A comparison of chemical properties of TSP and PM_{10} during the spring of 1998 in Seoul, J. of the Korean Meteorological Society, 35(1), 38-46.
5) Choi, J. C., H. M. Cho, K. J. Park and S. Kim, 1999, A comparison of chemical properties of aerosols at Seoul and Anmyon-do, J. of the Korean Meteorological Society, 35(3), 396-404.
6) Choi, J. C., H. M. Cho, Y. S. Chun and K. J. Park, 1999, A study on metallic elements of aerosols in Seoul during the spring of 1998, J. of the Korean Meteorological Society, 35(2), 263-271.
7) Choi, J. C., S. N. Oh and K. J. Park, 2000, A study on ion components and metallic elements in aerosol during the spring, 1998 at Seoul, J. of the Korean Meteorological Society, 36(5), 551-560.
8) Kim, B. H. and D. S. Kim, 2000, Studies on the environmental behaviors of ambient $PM_{2.5}$ and PM_{10} in Suwon area, J. of Korean Society for Atmospheric Environment, 16(2), 89-101.
9) Choi, S. W. and H. D. Song, 2000, Source characteristics of particulate trace metals in Daegu area, J. of Korean Society for Atmospheric Environment, 16(5), 469-476.
10) Choi, J. S. and S. O. Baek, 1998, Relationships between TSP and PM_{10} concentrations in the ambient atmosphere, J. of Korea Air Pollution Research Association, 14(1), 1-10.
11) Oh, J. M. and D. S. Kim, 2001, Chemical compositions trends of airbone particles at Kunsan, J. of Korean Society for Atmospheric Environment, 17(6), 475-485.
12) Kim, S. C., 1999, Effects of climate factors on PM_{10} and metallic elements concentration, Korean J. of Environmental Health Society, 25(2), 39-47.
13) Na, D. J. and B. K. Lee, 2000, A study on the characteristics of PM_{10} and air-borne metallic elements produced in the industrial city, J. of Korean Society for Atmospheric Environment, 16(1), 23-35.
14) Triantafyllou, A. G., 2001, PM_{10} pollution episodes as a function of synoptic climatology in a mountainous industrial area, Environmental Pollution, 112, 491-500.
15) McKendry, I, G., 2000, PM_{10} levels in the Lower Fraser Valley, British Columbia, Canada: An overview of spatiotemporal variations and meteoro-

logical controls, J. Air & Waste Manage. Assoc., 50, 443-452.

16) Yang, K. L., 2002, Spatial and seasonal variation of PM_{10} mass concentration in Taiwan, Atmos. Environ., 36, 3403-3411.

17) Choi, K. C., S. Y. Yoo and B. K. Jeon, 2000, A study on the characteristics of concentrations of atmospheric aerosols in Pusan, Korean J. of Environmental Health Society, 26(2), 41-48.

18) Jeon, B. K., J. M. Suh and K. C. Choi, 2001, Chemical characteristics of ions and trace metallic element of $PM_{2.5}$ in Busan metropolitan area, Korean J. of Environmental Health Society, 27(4), 63-71.

19) Cheong, J. P., S. M. Yi and H. M. Yoon, 2001, The daytime and nighttime concentration characteristics of chemical components in PM_{10} measured in Busan, J. of Korean Society for Environmental Engineers, 23(3), 353-362.

20) Jeon, B. I., J. R. Bahk and J. K. Park, 2002, Characteristics of suspended particulate for yellow sand of January, 1999 in Busan, J. of the Environmental Sciences, 11(10), 1081-1087.

21) Jeon, B. I., 2003, Characteristics of heavy metallic elements of PM_{10} of yellow sand and non-yellow sand during springtime of 2002 at Busan, J. of Environmental Impact Assessment, 12(2), 99-108.

22) Kim, K. H., G. H. Choi and C. H. Kang, 2002a, The metallic composition of $PM_{2.5}$ and PM_{10} in a northeast region of Seoul during the spring 2001, Jour. Korean Earth Science Society, 23(6), 514-525.

23) Kim, K. H., J. H. Lee and M. S. Jang, 2002b, Metals in airbone particulate matter from the first and second industrial complex area of Taejon city, Korea, Environmental Pollution, 118, 41-51.

24) Choi, M. S. and E. J. Barg, 1999, Trace metals in airborne particulates collected at Cheju island, Korea, J. of Korean Society for Atmospheric Environment, 15(6), 727-738.

25) Choi, M. S., S. K. Lee, J. C. Choi and M. Y. Lee, 1995, Chemical characteristics of atmospheric particulate species in Mt. Soback, Korea(II)-The sources and seasonal variations of metallic elements, J. of Korean Society for Atmospheric Environment, 11(2), 191-198.

26) Shin, E., M. K. Choi, Y. Sunwoo and Y. S. Chung, 2002, Trace elements characterization of PM_{10} in Seoul area, J. of Korean Society for Atmospheric Environment, 18(5), 363-372.

27) Shin, E. S. and H. K. Kim, 1992, Influenced of yellow sand on TSP in Seoul, Korean Air Pollution Research Association, 8(1), 52-57.

28) Altshuler, S. L. and T. D. Arcado, 1995, Weekday vs. weekend ambient ozone concentrations : Discussion and hypotheses with focus on northern California, Journal of Air & Waste Management Association, 45, 967-972.

29) Diem, J., 2000, Comparison of weekday-weekend ozone : importance of biogenic volatile organic compound emissions in the semi-arid southwest USA, Atmospheric Environment, 34, 2445-3451.

30) Marr, L. C. and R. A. Harley, 2002, Spectral analysis of weekday-weekend difference in ambient ozone, nitrogen oxide, and non-methane hydrocarbon time series in California, Atmospheric Environment, 36, 2327-2335.

31) Morawska, L., E. R. Jayaratne, K. Mengersen, M. Jamriska and S. Thomas, 2002, Differences in airborne particle and gaseous concentrations in urban air between weekdays and weekends, Atmospheric Environment, 36, 4375-4383.

32) Qin, Y., G. S. Tonnesen and Z. Wang, 2004, Weekend/weekday differences of ozone, NO, CO, VOC_S, PM_{10} and the light scatter during ozone season in southern California, Atmospheric Environment, 38, 3069-3087.