Kor. J. Env. Hlth. Soc., Vol. 29, No. 4, pp 42~47(2003)

Study on Characterization of Deposition Flux of Dustfall in Kunsan, Korea

SeongCheon Kim†

School of Civil and Environmental Engineering, Kunsan National University, San 68, Miryong-dong, Kunsan, Chollapuk-do, Korea

(Received September 2, 2003/Accepted October 13, 2003)

Abstract : The purpose of this experimental study is to investigate seasonal deposition flux variations of the total dustfall and various inorganic elements in it. Total of 84 dustfall samples were collected from September, 1997 thru August, 1998 at 7 different sites in Kunsan. Each sample was analyzed by an AAS to determine the levels of 5 inorganic elements; Zn, Cd, Cr, Fe and Pb. Deposition fluxes, soluble/total fractions for each element were extensively investigated. Estimated deposition fluxes of dustfall and elements in Kunsan were in the range of 37.5~45.1 ton/km^2/yr for dustfall, 43.5~81.8 kg/km^2/yr for Zn, 6.6~11.0 kg/km^2/yr for Cd, 44.8~110.0 kg/km^2/yr for Cr, 223~323 kg/km^2/yr for Fe, 10.9~22.3 kg/km^2/yr for Pb, respectively. Thus, the estimated average total deposition fluxes of dustfall in Kunsan(376.35 km^2) per day were 43.3 ton and 58.6 kg for Zn, 8.9 kg for Cd, 80.6 kg for Cr, 293.8 kg for Fe and 14.1 kg for Pb, respectively.

Keywords : deposition flux, dustfall, inorganic element, soluble/total fraction, AAS

Introduction

The removal and the sink of particulate matter into the surface from atmosphere have two common mechanisms. First is the dry deposition that particulate matters move on the surface by gravity, sedimentation and diffusion process without rain, and second is the wet deposition that airborn pollutant fall on it by rain, fog and condensation.

We classify aerosol as suspended particulate matter and dustfall. Generally the size of suspended particulate matter is 0.001~500 μm, and the size of dustfall is over than 100 μm.

This dustfall depostion study can be anticipate and quantify about regional, seasonal flux, and use as basic information of many air pollution studies as well as effect of man and ecosystem. And also, using a trajectory model, it is possible for this study to be used as basic information of anticipating air pollutant of long range transport from surrounding countries such as China, Mongolia, Russia and Japan.

The purpose of this study is to examine fluxes of dustfall and metallic elements quantitatively and to understand air quality of this Kunsan region from investigating monthly and seasonal concentration variation trends in the air.

Material and Methods

In this study, dustfall sampling sites are 7 sites; that is, Doosan(A), Soryong campus of Kunsan National University(B), Kunsan elementary school (C), Moonhwa elementary school(D), Kyejung (E), Miryong campus of Kunsan National University(F) and Okku(G). And the sampling has being conducted from September, 1997 to update.

For this study, we made British deposit gauge and collected dustfall from air. The sampling sites were 7 monitoring sites in Kunsan and samples was collected during one year (from September, 1997 through August, 1988) were analyzed by AAS. This gauge was consisted of funnel (diameter = 36 cm) and PE container(6 liter) which is located under the funnel. The upper part of funnel is holded by stainless steel to prevent its movement, and $CuSO_4$(0.024 g) is used to defend occurrence of an algae during summer and fall. And the

†Corresponding author : School of Civil and Environmental Engineering, Kunsan National University
Tel. 82-63-469-4761, Fax. 82-63-469-1871
E-mail : ksc@kunsan.ac.kr

sampling collector was holded by stand which height is 1.8 m to avoid of turbulent. The collectors of all site was installed into air with considering of precipitation, and meteorological condition, temperature and those condition were checked by every day. During sampling period(September, 1997~August, 1998), total deposition(a month) are included rain and snow, and dry deposition (a week) doesn't included them. To collect total (bulk) dustfall, several samplers were used such as British Standard collector(BSI, 1969), British Standard direct collector(BSI, 1972), ISO dust collector(ISO, 1986), WSL gauge(1983), dry Fresbee gauge(Hall *et al.*, 1988) etc.

Results and Discussion

Elemental deposition of bulk sample by season

In this study, W is mixture of dry and wet deposition and it is possible to surmise W by using following general formula.

$$W = VC/TA$$

where, V = Collected precipitation(L)
C = Concentration of pollutant to collected precipitation(μg/*l*)
T = time(s)
A = Open area(cm^2)

The water insoluble dustfall flux by season showed that fall, 1997 and spring, 1988 were 8.2 ton and 4.8 ton respectively. The water insoluble dustfall flux was between 3.3 and 5.9 ton by sites, and C site has the highest value and G site also high with 5.7 ton despite of being expected as clean area.

And, the seasonal flux of the water soluble dustfall show that fall, 1997 and spring, 1988 were 10.3 and 7.0 ton respectively. The range of water soluble dustfall flux was between 5.7 and 8.2 ton in monitoring sites, and B site had a highest value as 8.2 ton and C(commercial site) and D(dwelling site) had a high value as 7.7 ton respectively.

The Table 1 is total flux which is sum of seasonal water insoluble flux and soluble flux. The seasonal flux of total dustfall from Table 1 shows that fall, 1997 was 18.5 ton, spring, 1988 was 10.1 ton and the average flux during sampling was 11.7 ton. The total average flux of Zn which is originated by antropogenic source was spring > summer > fall > winter, and the total annual average flux was 82.2 $kg/km^2/yr$. For Cd, it's flux was fall > summer > spring > winter and the total annual average flux was 8.8 $kg/km^2/yr$(Fig. 1). For Cr, it's flux was spring > summer > fall> winter, and the total annual average flux was 90.2 $kg/km^2/yr$(Fig. 1). The total average flux of Pb was summer > winter > fall > spring and the total annual average flux was 11.7 $kg/km^2/yr$(Fig. 1). And, the total average flux of Fe which is originated by natural source was spring > summer > winter > fall, and the total annual average flux was 686.6 $kg/km^2/yr$. As we mentioned above section, the flux of Zn and Cr which was originated by antropogenic source were spring> summer > winter > fall. And that of Pb, Fe and Cd

Table 1. Total elemental fluxes of total deposition collected from 7 monitoring sites

(kg/km^2/season)

Site	Season	Dustfall	Zn	Cd	Cr	Fe	Pb
A (Doosan)	97 fall	21908.3	14.40	4.32	9.72	47.23	1.40
	97,98 winter	9730.1	7.71	1.05	1.14	59.89	2.65
	98 spring	8832.4	32.07	2.45	72.18	478.84	0.83
	98 summer	8876.2	29.16	2.48	33.10	120.50	3.54
	avg	12336.7	20.84	2.58	29.79	276.62	2.11
B (Ocean College)	97 fall	15704.3	5.55	2.66	6.73	35.41	0.90
	97,98 winter	7949.1	5.51	1.19	1.10	45.22	3.20
	98 spring	10469.2	30.87	2.72	59.75	470.15	0.78
	98 summer	9114.7	11.31	2.73	35.22	170.86	15.03
	avg	10809.3	13.31	2.33	25.70	180.41	4.98

Table 1. Continued

Site	Season	Dustfall	Zn	Cd	Cr	Fe	Pb
C (Kunsan E.S)	97 fall	17308.9	8.29	3.67	9.87	48.87	2.16
	97,98 winter	10114.7	8.11	1.57	2.25	39.34	1.94
	98 spring	8164.0	25.94	2.55	75.44	490.87	0.57
	98 summer	10611.7	8.82	3.15	25.53	158.88	7.81
	avg	11549.8	12.79	2.73	28.27	184.49	3.12
D (Munwha E.S)	97 fall	15040.7	7.79	3.21	0.44	41.88	1.19
	97,98 winter	8718.2	11.29	1.13	4.27	40.00	4.52
	98 spring	9531.9	32.19	1.41	8.00	468.97	0.72
	98 summer	9388.8	20.53	2.11	25.62	152.80	5.68
	avg	10669.9	17.95	1.97	9.56	175.91	3.03
E (Kejung-dong)	97 fall	11849.3	10.85	3.37	2.52	28.40	1.08
	97,98 winter	10967.8	7.42	1.62	4.21	38.82	1.43
	98 spring	10741.1	26.16	0.49	60.06	434.25	0.62
	98 summer	7351.8	9.27	2.19	41.09	133.03	7.23
	avg	10227.5	13.43	1.92	26.97	158.63	2.59
F (Tech. college)	97 fall	13174.6	7.58	2.69	6.07	33.70	0.95
	97,98 winter	12129.3	6.65	1.24	2.94	31.29	1.73
	98 spring	8154.5	25.43	1.63	34.64	409.45	0.39
	98 summer	7411.7	9.04	2.56	19.27	194.87	7.18
	avg	10217.5	12.17	2.03	15.73	167.33	2.56
G (Okku)	97 fall	15130.4	8.47	2.73	6.38	33.84	4.65
	97,98 winter	7419.4	5.84	1.52	3.56	46.35	1.71
	98 spring	14659.8	24.24	1.01	45.44	444.31	0.48
	98 summer	9218.9	5.34	1.88	27.58	108.27	5.63
	avg	11607.1	10.97	1.78	20.74	158.19	3.12
Average	97 fall	18477.2	11.45	3.23	6.24	38.43	1.76
	97,98 winter	9575.5	7.31	1.33	3.17	43.81	1.90
	98 spring	10079.0	28.13	1.75	51.22	456.69	0.63
	98 summer	8853.4	13.35	2.44	29.63	148.46	7.44
	avg	11746.3	15.06	2.19	22.56	171.85	2.94

show the highest value at summer, spring and fall respectively.

The fraction range of the water soluble to the total element flux by season was from 0.45 to 0.65 at 7 monitering sites during sampling period. The fraction of Fe was 0.37, 0.35, 0.26, 0.24, 0.31, 0.44, and 0.43 at from A to G monitoring sites respectively and those average was 0.34, that was low value, but according to seasons, that was 0.63(spring, 1998), 0.46(summer, 1998), 0.14(fall, 1997), and 0.14(winter, 1997~1998). The range and the average of Zn were 0.56~0.65 and 0.62, and there was a little difference. The range and the average of Cd were 0.80~0.98 and 0.90 and the range and the average of Pb were 0.33~0.61 and 0.47. But Cr had a high value at Spring, 1988 as 0.90. It was different from Zn, Cd and Pb which are originated anthropogenic source, and the fraction of winter, fall and summer were 0.56, 0.54 and 0.48 respectively.

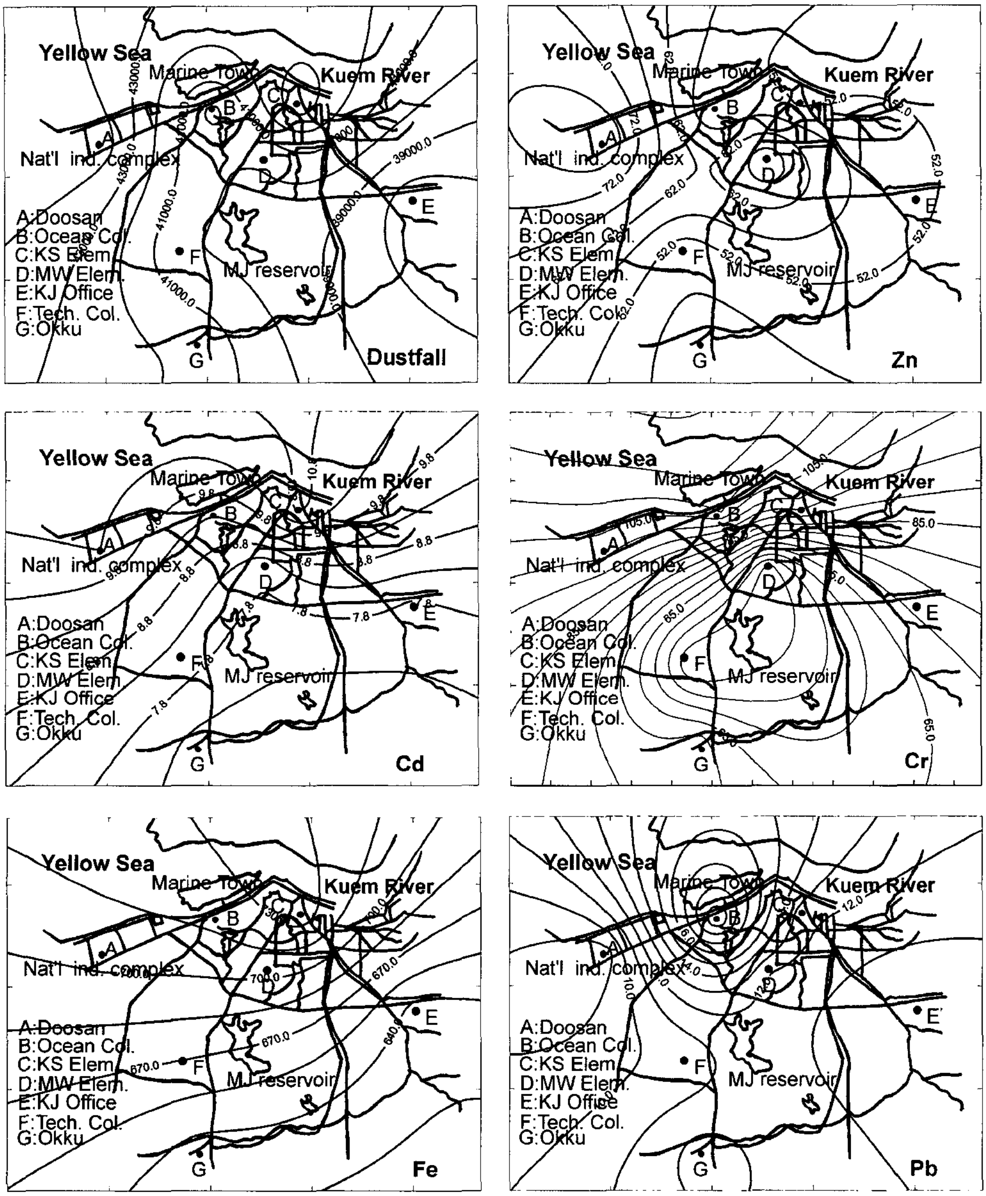

Fig. 1. Map of deposition flux of dustfall, Zn, Cd, Cr, Fe and Pb(kg/km^2/yr).

Total Dustfall Flux

From the Table 2, the average insoluble dustfall flux per 1 km^2 at Kunsan was 19.6 ton during sampling period and 53.6 kg a day. Therefore, total insoluble dustfall in Kunsan was 7,358.1 ton per year and 20.2 ton per day because area of kunsan are 376.35 km^2. And the water soluble dustfall in Kunsan was 24.3 ton per 1 km^2 a year, and 66.5 kg a day. Therefore, the total soluble dustfall per full aera of Kunsan was 9,134.4 ton and the water soluble dustfall was 25 ton a year. So, the total average dustfall per 1 km^2 in Kunsan was 48.8 ton a year and 0.1 ton a day. And, the total dustfall per full area of Kunsan was 16,492.5 ton a year and 45.2 ton a day.

Table 2. Mass of dustfall and elements by area and period in Kunsan

(kg)

Class	Element	yr.flux* 1 km^2	day.flux* 1 km^2	yr.flux* 376.35 km^2	day.flux* 376.35k m^2
Insoluble	Dustfall	19,551.2	53.6	7,358,108.9	20,159.2
	Zn	3.72	0.01	1,400.15	3.84
	Cd	0.08	0.00	30.76	0.08
	Cr	5.12	0.01	1,925.60	5.28
	Fe	167.15	0.46	62,906.23	172.35
	Pb	3.47	0.01	13,073.5	3.58
Soluble	Dustfall	24,271.0	66.5	9,134,378.3	2,5025.7
	Zn	55.90	0.15	21,037.42	57.64
	Cd	8.68	0.02	3,266.81	8.95
	Cr	85.11	0.23	32,029.77	87.75
	Fe	519.44	1.42	195,489.91	535.60
	Pb	8.27	0.02	3,111.06	8.52
Total	Dustfall	48,822.2	120.1	16,492,487.0	45,184.9
	Zn	59.62	0.16	22,437.57	61.47
	Cd	8.76	0.02	3,297.56	9.03
	Cr	90.22	0.25	33,955.36	93.03
	Fe	686.59	1.88	258,396.14	707.94
	Pb	11.74	0.03	4,418.41	12.11

Summary

In this study, we used the British deposit gauge to collect dustfall in air, and collected samples at 7 monitoring sites in Kunsan to obtain the measurement results during sampling period (September, 1997~August, 1998). And the conclusions were as follows;

1. The flux of total dustfall, Zn, Cd, Fe, and Pb had a little difference. but in G site as clean area, the fluxes of dustfall and Cr as well as Pb was very high, which were more than average. We think that those high flux was surmised due to long range transport of pollutant, therefore the regulation about marine source as well as land source will be needed.

2. The water soluble flux of dustfall, Zn, Cd, Cr, Fe and Pb were 1.4, 15.2, 106.2, 16.2, 3.1, and 2.4 times higher than the insoluble flux. The range of seasonal average flux of dustfall by monitoring sites was 8.8~18.5 ton, and A site had highest value as 12.3 ton, but there were a little difference at all site.

3. The seasonal fluxes of Zn and Cr which were originated anthropogenic source were spring > summer > fall > winter, and Pb, Fe and Cd had highest value at summer, spring and fall respectively.

4. In summer, 1998, Pb had high deposition flux at B site(15.0 kg/km^2/season) and C site(7.8 kg/km^2/season) which were near by coast, and those could be surmised by emission from ship oil, therefore the regulation about similiar source will be needed.

5. In case of the national industrial complex site (A), dustfall, Zn, Cr and Fe had high value, but B site which was near at industrial area and coastal area had higher value than A site, and C site which is commercial site and near by coastal area had high flux of Cd, so it must be considered that effect of meteorology.

6. The average water soluble flux ratio to seasonal elemental deposition flux by monitoring sites were 0.34(Fe), 0.62(Zn), 0.90(Cd), 0.47(Pb) and 0.62(Cr) respectively, so that was indicated

that Fe was included coarse particule mode, and Zn, Cd, and Cr was included fine particle mode.

7. The correlations of dustfall and other elements were low, but the correlation coefficient between Cd and Fe was 0.99($r = 0.99$), and Cr was 0.647 ($r = 0.47$).

Acknowledgements

I would like to thank the "Fisheries Science Institute" for their financial assistance to carry out this research.

References

1. Kim, S.C. and Kim, D.S. : Studies on estimating dry deposition velocities for atmospheric aerosol and metal elements in Korea, *Journal of Korea Air Pollution Research Association*, **12**(1), 101-112, 1996.
2. Park, K.C. : Fundamental Chemistry, Ilshin Co., pp.472-476, 1982.
3. BSI : Methods for the measurement of air pollution Part 1, Deposit Gauges, BS 1747. British Standards Institution, London, 1969.
4. BSI : Directional dust gauges, BS 1974: Part 5. British Standards Institution, London, 1972.
5. Hall, D.J. and Upton, S.L. : A wind tunnel study of the particle collection efficiency of an inverted Frisbee used as a dust deposition gauge, *Atmospheric Environment*, **22**, 1383-1394, 1988.
6. ISO : Measurement of particulate fallout by a horizontal deposit gauge, ISO/TC 146/ET 4 (Paris 75-2) 69E, International Organization for Standardization, Paris, 1986.
7. Jaffe, R.H., Cabrera, C.A. and Alvarado, J. : Organic compounds and heavy metals in the atmosphere of the City of Caracas, Venezuela I: Atmospheric Particles, II: Atmospheric Deposition. Water, Air, and Soil pollution, **71**, 293-313, 315-329, 1993.
8. Rojas, C.M., Injuk, J., Van Grieken, R.E. and Laane, R.W. : Dry and wet deposition fluxes of Cd, Cu, Pb, and Zn into the southern bight of the North sea, *Atmospheric Environment.*, **27A**, 251-259, 1993.
9. Ross, M. and MacGee, E.S. : Chemical and mineralogical effects of acid deposition on marble and Salem limestone test samples placed at four NAPAP weather-monitoring sites. *Am. Miner*, **74**, 367-383, 1989.
10. Standard Methods, for the examination of water and wastewater : 18th Ed., preliminary treatment of samples, 3030 E. Nitric acid digestion, 3-5, American Public Health Association, Washington, D.C., 1992.
11. Warren Spring Laboratory : Acid deposition in the United Kingdom, WSL, 104, 1983.