Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Determination of the Elemental Composition of Air Particulate Matter ($PM_{2.5}$) by Instrumental Neutron Activation Analysis

Jong Hwa Moon,a Sun Ha Kim,a Jong Myoung Lim,a Jin Hee Chung,b Jin Hong Lee b
a Korea Atomic Energy Research Institute, 150-1 Deokjin-dong, Yuseong-gu,Daejeon, Korea, jhmoon1@kaeri.re.kr
b Chungnam National Univsersity, 220 Gung-Dong, Yuseong-gu, Daejeon, Korea

1. Introduction

Air quality in urban areas is one of the most important environmental issues and air particulate consisting of various elements from both artificial and natural origins is an indicator of an air quality. Especially, the mass concentration of $PM_{2.5}$ is recognized as being more serious than that of PM_{10} in consideration of the short and long term effects on human health[1]. Therefore, sampling and analysis of $PM_{2.5}$ in an urban area should be conducted regularly to monitor an air quality and the level of an air pollution. In this study, $PM_{2.5}$ samples were collected and the mass concentration of $PM_{2.5}$ was measured. In addition, the elemental concentrations in the $PM_{2.5}$ were determined by instrumental neutron activation analysis.

2. Experimental

2.1 Sampling

An annular denuder sampler(URG, 3000C model) which is able to load three different filter materials simultaneously and polycarbonate membrane filters(ϕ 47 mm, 0.4 μm pore size, Whatman) were employed to collect $PM_{2.5}$ samples. The sample collection was done at the roof-top of the third engineering building of Chungnam national university which is located in Yuseong, Daejeon city. The flow rate was adjusted to 18 L/min at the beginning of the sampling and collected for 24 hours. Sixty samples were collected from August 2005 to March 2006.

2.2. INAA

Samples for INAA using short lived nuclides were irradiated with thermal neutrons by using the Pneumatic Transfer System(PTS) that is connected to NAA#3 irradiation hole(Φ_{th} = 1.25 x 10^{14} n/cm^2·s, $R_{cd,Au} \fallingdotseq 10$) at the HANARO research reactor in the Korea Atomic Energy Research Institute[2]. Irradiation time was restricted to one minute because of a rapid temperature growth during a sample irradiation. Activation wires of 0.1% Au-Al(IRMM) were used for the neutron flux monitoring. For the INAA analysis using medium and long lived nuclides, samples were irradiated by using the IP irradiation hole at the HANARO research reactor which was inherently designed for a radio-isotope production. Small quartz vials were manufactured for safe irradiation of the samples of sixty samples for six hours at the same time. For a determination of the thermal neutron flux and the correction of irradiation geometry, Fe wires (Reactor Exp. Inc., R/X activation wire) were co-irradiated with the samples. The measured thermal neutron flux with respect to the irradiation position of the samples was in the range of 3.2 to 4.9 x 10^{13} n/cm^2·s. Gamma-ray measurement was carried out by using a high purity Ge detector of a 25% relative efficiency and 1.85keV resolution(FWHM) at 1332 keV of ^{60}Co and the peak to the Compton ratio was 45:1, coupled to a personal computer and 16k-multichannel analyzer (EG&G ORTEC, 919A MCB). Analytical conditions such as the decay and counting time were optimized after a preliminary experiment.

3. Results and Discussion

3.1 Quality Control

Standard reference material(NIST SRM 2711, Montana Soil) was used for an analytical quality control. The analytical results of NIST SRM 2711 are shown in Figure 1. Twenty five elements such as Al, As, Ba, Ce, Co, Cr, Cs, Dy, Eu, Fe, Hf, K, La, Mg, Mn, Na, Rb, Sb, Sc, Sm, Th, Ti, V, Yb and Zn from SRM 2711 were determined by INAA and the relative errors of most of the elements except for Mg are within 10%.

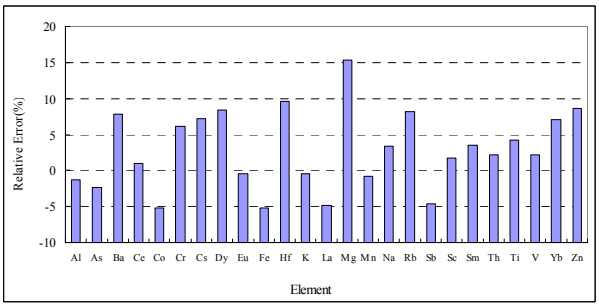

Figure 1. Analytical results of NIST SRM 2711-Montana Soil.

3.2 Mass concentrations of $PM_{2.5}$

The variation of the mass concentration of $PM_{2.5}$ according to the sampling dates is shown in Figure 2. The range of the mass concentration was 9.66 – 64.6 μg/m^3 and the average was 31.6 μg/m^3. In the summer, fall and winter seasons, the levels of the mean concentration are 20.6±2.6, 28.9±2.0 and 34.4±3.6 μg/m^3, respectively. Whereas, the spring season has the highest value, 42.9±3.7 μg/m^3 because of the yellow

dust from China. Figure 3 compares the seasonal average of the $PM_{2.5}$ mass concentrations.

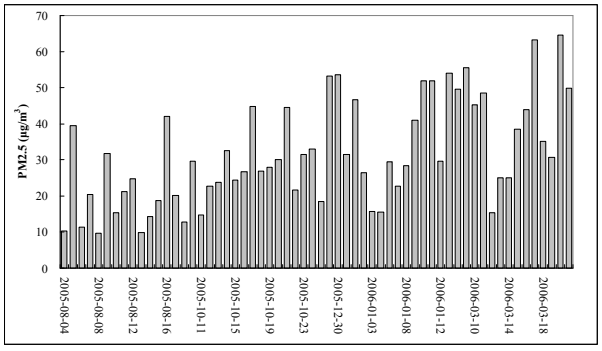

Figure 2. Variation of the mass concentration of $PM_{2.5}$ according to the sampling dates.

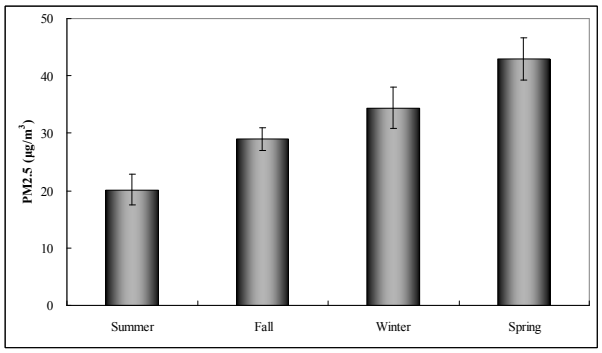

Figure 3. Comparison of seasonal average of the $PM_{2.5}$ mass concentration.

3.3 Elemental composition

Twenty eight elements of Al, As, Ba, Br, Ce, Cl, Co, Cr, Cs, Cu, Dy, Fe, Hf, I, In, K, La, Mg, Mn, Na, Sb, Sc, Se, Sm, Th, Ti, V and Zn were determined by INAA. The number of detections for Co, In and Th were 41, 49 and 43, respectively and the other elements were detected from more than fifty samples. The relative standard deviation (%) with respect to the mean values of the elemental concentrations was in the range of 35% ~ 133%. Especially, the relative standard deviation of Al, Cl, Sm and Th was higher than 100%. Figure 4 was drawn to identify and to compare the level of the elemental concentrations.

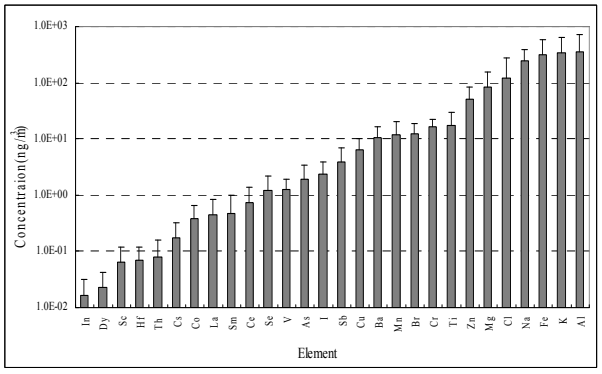

Figure 4. Elemental composition of PM2.5 in ascending order.

Elements such as Al, K, Fe and Na are placed in the highest level and Dy, Sc, Hf and Cs are in the lowest level. Therefore, the elemental components in $PM_{2.5}$ can be classified into three categories. The first category is crust elements such as Al, K, Fe, Na, Mg, Ti, and Mn and the second is rare earth elements like Ce, Dy, Sc, Hf, Th, Cs, Sm. The third could be trace elements like As, Ba, Br, Cl, Co, Cr, Cu, I, In, Sb, Se, V and Zn.

4. Conclusion

To monitor an air quality in Daejeon city by using an annular denuder sampler and instrumental neutron activation analysis, the mass concentration and the concentrations of twenty eight elements of $PM_{2.5}$ were determined. The analytical data by INAA will be used to apportion the emission sources by using PMF(Positive Matrix Factorization) program and furthermore, to identify the trajectory of a long range transport with $PM_{2.5}$.

REFERENCES

[1] M. Ebihara, Y. S. Chung, W. Chueinta, D. F. Ni, T. Otoshi, Y. Oura, F. L. Santos, F. Sasajima, A. Sutisna, A. K. B. H. Wood, Collaborative Monitoring Study of Airborne Particulate Matters among Seven Asian Countries, J. Radioanal. & Nucl. Chem., Vol. 269(2), p. 259, 2006.

[2] Y. S. Chung, H. M. Dung, J. H. Moon, K. W. Parl, H. R. Kim, Implementation of the k_0-NAA method in the NAA #3 irradiation hole of the HANARO research reactor, NIMA, Vol. 564, p. 702, 2006.