PM$_{10}$ Metal Distribution in an Industrialized City

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The dense population in Taiwan leads to high level of suspended particulate pollution, which represents serious problem. This problem is particularly acute in the highly industrialized and densely populated cities of Kaohsiung in southern Taiwan. In this area, the percentage of days with PSI (Pollutant standards index) over 100 was highest in Taiwan. Anthropogenic contribution became more evidence as the dominant source of many pollutants including most metal species (Nriagu, 1989). The results of Michellozzi et al. (1998) have indicated that the mass concentrations of some particulate pollutants vary according to seasons. However, the spatial and temporal distribution of metal elements adsorbed in aerosols is still incomplete in Taiwan. According to Antonio et al. (2001), metal-loaded particles pose a latent risk to public health. In this study, 110 samples taken in 2002/2003 at five sampling sites (A, B, C, D and E) in Kaohsiung county, were divided into summer, autumn, winter and spring samples and analyzed for metal elements.

MATERIALS AND METHODS

Five sites (A, B, C, D, and E) located in Kaohsiung county of southern Taiwan were selected in this study. The sampling sites were in proximity to the air quality monitoring stations of the environmental protection agency of Taiwan (EPA). The samples were taken simultaneously by PEM-PM$_{10}$ (MSP) and Harvard samplers (Air Diagnostics and Engineering). Each sample was collected continuously on three consecutive days for 24 hours from September 2002 to August 2003. The filters were digested following the procedure of NIEA A301.11C, which is the EPA reference method in Taiwan, and metal elements were quantified by ICP-MS (Agilent 7500). Additionally, nonparametric correlations and the median test analysis for all 110 samples were analyzed using SPSS 13.0 software.

RESULTS AND DISCUSSION

The average metal element mass concentrations in ambient air at the five sampling sites over the entire measurement period are shown in Fig 1 for

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Figure 1. The average mass concentration (mean ± standard deviation) of metal elements in ambient air and measured on PM$_{10}$ particles (n=110) at the five sampling sites over the periods September 2002 to August 2003.

Particulate smaller than 10μm (PM$_{10}$). The metal elements were classified into anthropogenic (As, Ba, Cd, Cr, Cu, Mn, Ni, Pb, Sb, Se, Sr, Ti, V and Zn) and crust (Al, Ca, Fe, K and Mg) groups according to Wang, et al. (2003). The highest concentrations were found in crust elements such as: Fe, Ca, K, Al and Mg (1108, 897, 700, 609 and 275 ng.m$^{-3}$), respectively, and three anthropogenic elements, Zn, Pb and Ba (418, 156 and 127 ng.m$^{-3}$). Fe, Ca, K, Al, Mg, Zn, Pb and Ba account for 24.5%, 19.8%, 15.5%, 13.4%, 6.07%, 9.22%, 3.43% and 2.80% of total metal elements mass concentrations, respectively. Arsenic was found to have the lowest of the 20 investigated metal element mass concentrations with a mean value of 3.54 ng.m$^{-3}$. The mass concentration of Pb of 156 ng.m$^{-3}$ is similar to the result of Vasconcelos and Tavares (1998) (145–505 ng.m$^{-3}$, sampling site near an old incinerator and a busy street) and Kim, et al. (2003) (120 ng.m$^{-3}$ for non-Asian Dust period in a moderately developed urban area), however, it is higher than the results of Becceiro-Gonzalez, et al. (1997) and Bilos, et al. (2001) (27 and 10 ng.m$^{-3}$, in a moderately polluted to unpolluted area).

Aluminum, iron and calcium are the most common metal elements formed in earth’s crust (Taylor, 1964). The pattern for enrichment factor (EF) is a reference value of contamination status (Kim, et al.2002). The EF will provide information to judge either the enrichment (or depletion) of a given element relative to the reference element (Al, in this study). The EF was defined as follows: EF = $\{X/Al\}_{sample}/\{X/Al\}_{crust}$ (X denotes a metal of interest). The EF values were grouped into three categories: (1) <10, Al, Ca, Fe, K, Mg, Mn, Sr, Ti and V, (2) 10–1000, As, Ba, Cr, Cu, Ni, and Zn,