AEROSOL CONCENTRATION AND ELEMENTAL COMPOSITION OF PM2.5 IN A METROPOLITAN AREA WITH INTENSE HIGHWAY TRAFFIC AND INDUSTRIAL AIR POLLUTION SOURCES

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INTRODUCTION

Some adverse health effects, primarily respiratory problems, which are associated with the finer fractions of the PM2.5 aerosol and certain elements, have higher occurrence in populations living in large metropolitan areas with intense highway traffic and multiple industrial sources. To better understand the causes of these health effects, the monitoring data on PM2.5 and its elemental concentrations are needed.

EXPERIMENTAL METHODS

A one-year study of factors affecting the PM2.5 concentration levels and elemental composition of the ambient aerosol was performed in the Greater Cincinnati metropolitan area. This area has a heavy use of a concentric network of interstate highways forming major corridors for inter-coastal and north-south deliveries in the USA, an extensive public bus system, and a busy railway network. It is also impacted by several coal fired power plants and other industries. The study was conducted during four seasons and included 11 monitoring stations located at different distances from interstate highways and industrial air pollution sources. In each monitoring cycle, the ambient aerosol sampling was performed simultaneously at four sites during about two weeks. The measurements were conducted during working days only to assure that the traffic was approximately the same during the monitoring period. The samples were collected with Harvard impactors (Air Diagnostics and Engineering, Inc., Harrison, ME) operated at a sampling flow rate of 20 L/min for 24 hrs. The PM2.5 concentration was determined through the gravimetric analysis of the collection filters before and after the sampling. Teflon filters were utilized for the subsequent XRF elemental analysis, and quartz filters were used to analyze the elemental (EC) and organic (OC) carbon with the TOT technique. The spatial and temporal variation of the PM2.5 total mass concentration and the elemental concentrations were determined. Separate tests were performed with a MOUDI sampler (MSP Corp., Minneapolis, MN) continuously operated in parallel with Harvard impactors at a flow rate of 30 L/min for a period of up to 7 days to obtain the particle size distributions of the ambient aerosol. The data were analyzed and related to meteorological conditions, traffic density, configuration of interstate highways and state routes, and the industrial air pollution sources.

RESULTS

The data are presented in the Table 1. For each season, the lowest and the highest exposure levels was determined from the data obtained by various monitoring stations operated during that season. For each station (selected as either "lower" or "higher" exposure), the average and the standard deviation represent the variability of the data collected in this station during a two-week. The PM2.5 concentration ranges from 10.8±2.9 to 24.2±6.8 $\mu g/m^3$ and is evenly distributed through the city area along major highways

independently on the distance from the highways as well as industrial sources. This finding agrees well with our preliminary studies and with published data on the PM2.5 monitoring performed in Philadelphia (Burton et al., 1996) and New York (Kinney et al., 2000) although the average concentration levels in Cincinnati were found to be lower. The seasonal variation of the PM2.5 concentration ranged from 22 to 44 % in different locations. The weekly variation was not significant. Due to meteorological conditions and the variability in the intensity of industrial sources, the daily variability of the PM2.5 concentration ranged from 11 to 46 %. The mass concentrations of nine elements are shown in Table 1, including Al, Si, and Ca (crustal elements) and S, Mn, Fe, Ni, Zn, and Pb (anthropogenic elements). Sulfur had the highest concentration and demonstrated pronounced seasonal variation. The elevated sulfur concentration results from regional coal power plants. In contrast to PM2.5, elemental analysis showed that some elements, such as Mn, Fe, Ni, Zn, and Pb, were detected at elevated levels in the vicinity of interstate highways suggesting considerable contributions of the diesel and gasoline emission. The concentration of lead in particles was essentially lower than the USEPA NAAQS standard (annual average = 1.5 $\mu g/m^3$). Although the trace metal concentrations were somewhat elevated near highways, the traffic intensity did not significantly affect the data. It is anticipated that the meteorological parameters played a primary role influencing the measured PM2.5 and trace metal levels. The EC/OC ratio was about twice higher near highways compared to the rural areas. The particle-size-selective analysis of the ambient aerosol data collected in the vicinity of a highway showed that over 70% of PM2.5 mass is contributed by particles of low aerodynamic diameter (0.18–1 μm). The crustal elements showed the peak mass concentrations in the upper stages of MOUDI (>5.6 μm), while the trace metals had peak values in the sub-micron size range.

Category		Winter		Spring		Summer		Autumn	
		Lower exposure	Higher exposure	Lower exposure	Higher exposure	Lower exposure	Higher exposure	Lower exposure	Higher exposure
PM2.5, $\mu g/m^3$		10.8±2.9	16.3±3.8	11.7±3.7	16.4±4.5	20.8±6.4	24.2±6.8	NM	14.5±3.6
Crustal elements, ng/m^3	Al	44.4±19	42.4±8	25.8±25	43.6±23	27.2±8	38.9±10	NM	25.8±12
	Si	127±50	109±29	73.0±64	131±66	111±56	139±55	NM	91.0±36
	Ca	90.4±34	125±49	47.3±35	156±82	49.9±22	137±49	NM	107±60
Anthropogenic elements, ng/m^3	S	711±190	1080±39	1170±35	1220±36	2050±72	2340±60	NM	1202±30
	Mn	1.92±0.7	9.01±10	2.07±0.9	3.77±0.8	2.18±0.5	4.46±1.0	NM	2.46±1.5
	Fe	72.4±29	156±63	56.6±23	143±48	67.2±14	152±57	NM	125±80
	Ni	0.50±0.70	0.82±0.4	0.38±0.2	0.67±0.3	0.50±0.4	0.82±0.9	NM	0.63±0.3
	Zn	8.30±2.5	24.8±15	10.4±3.2	24.6±19	8.50±4.1	21.3±12	NM	24.8±13
	Pb	1.96±0.80	7.69±4.8	2.8±1.2	5.00±2.2	2.29±0.7	4.03±2.4	NM	4.28±1.8

NM = not measured

Table 1. PM2.5 concentrations and elemental concentrations measured during four seasons

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