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The Main Composition of $PM_{2.5}$ in Three Middle American Cities

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Abstract:To better understand the characteristic and speciation of $PM_{2.5}$ pollution in US, three American cities (including Taft; St. Bernard; Chase) were selected for monitoring in Cincinnati, Southwest Ohio from 2003 to 2013. Chase has similar levels of $PM_{2.5}$ and speciation as Taft. St. Bernard both had higher levels of $PM_{2.5}$, OM and EC. Taft site, which has most detailed data showed that $PM_{2.5}$ mass concentrations are lower in spring and fall than in winter and summer. Reductions about 21 percent in $PM_{2.5}$ mass were also be observed from 2003 (13.41 $\mu g/m^3$) to 2013 (10.55 $\mu g/m^3$). In Strong seasonal trends are also observed in sulfate and nitrate. Nitrate levels are higher in winter and sulfate is higher in summer. Sulfate was the most abundant material (33.43%) in Taft (2009 to 2013), followed by OM and nitrate (2nd and 3rd; 31.71% and 17.71%). Elemental carbon (2.84%) and crustal (3.61%), on the other hand, took much smaller portions.

Introduction.

Fine particulate matter ($PM_{2.5}$),which particulate matter of aerodynamic diameter less than 2.5μm, has strong impacts to our environment with visibility reduction and also have detrimental effects on human health, such as pulmonary and chronic carcinogenic diseases for it can penetrate directly in to the lung [1-3]. Previous research has indicated that 31,000 restaurants in Los Angeles emit 11.6 tons of PM pollutants from meat cooking everyday [4]. Characteristics of $PM_{2.5}$ that may be relevant to toxicity include metals, organic compounds absorbed onto particles or forming particles themselves, biologic components, sulfate, nitrate, acidity and surface-absorbed reactive gases such as ozone [5, 6].

Cincinnati, which located in the southwest Ohio and beside the Ohio River, is Ohio's second-largest city and used to be the most dynamic city in the United States. Cincinnati is very important City in USA not only because its advanced industrial and famous railway systems, but also its diversified economic. The goal of this work is using the EPA Air Quality System (AQS) database to characterize the chemical composition of $PM_{2.5}$ in Cincinnati, including getting an overview of the air quality in this area, the seasonal trends of the major species. The air pollutant concentrations are not only an environmental issue within the cities themselves, but also have regional and global environmental effects [7, 8].Comprehensive information on the chemical composition of airborne $PM_{2.5}$ in Cincinnati is useful to improve climate models, to propose emission abatement strategies and to estimate public health impacts.

Experimental methods

Data Collected. All the data analyzed in this study is collected from the AQS website, which is completely open to the public. It also includes information on how to request AQS data on the website.

Sampling sites. The sampling sites chose in this study were including Taft; St. Bernard; and Chase. A site (Taft) is located off of exit 3 on I-71(No.71 Freeway) on Taft road, which is close to the University of Cincinnati, several major hospitals, three miles south of a coal power plant, one mile southeast of a natural gas power plant and is located in a residential neighborhood. B site (The St. Bernard) is on the north of Cincinnati.Chase is on the other side of the Ohio River in Kentucky, but the location of the site is very close to Southwest Ohio and is located upwind of Cincinnati.

For these sites, some of them are temporarily used for research or they are no longer actively collecting data, so they have the data for only specific situations or the data are incomplete. For instance, Chase has data from 2001 to 2010, however, St. Bernard and Lower Price Hill both has only two years data, 2007 to2008 data 2002 to 2003 respectively (Table 1). Taft is the only sampling site that has the most complete $PM_{2.5}$ speciation data among all the sites near Cincinnati (there are a total of 12 months of 'OC' and 'EC' data missing from 2007 and 2008; the data for $PM_{2.5}$ speciation before 2003 is dated and incomplete, so in this study data from 2003 to 2013 will be analyzed in Taft). Taft is also near downtown Cincinnati, so there is a mix of traffic, stationary and area PM sources. The pollution pattern is representative for an urban site.

Sampling Instrument. The Spiral Ambient Speciation Sampler (SASS, Met One Instrument, USA) is used to collect $PM_{2.5}$ speciation samples for all the sampling sites in this paper. The SASS has five separate channels, which are each operated through a common controller and pump. Every channel has its own function and contains a spiral impactor, which can give a 2.5 micron cut point (50% collection efficiency) with a slope and cut point. The flow rate through each channel is nominally 6.7 L/min and is controlled by a critical orifice.The flow rate in this instrument is monitored using calibrated mass flow meters. A quartz filter collects $PM_{2.5}$, which is used to analyze total organic, elemental carbon, while the Teflon filter is for total mass and trace elements, and the Nylon filter is used to analyze sulfate, nitrate, Ammonium, Sodium and Potassium in this paper. Crustal trace elements, such as different kinds of metals, are analyzed by X-ray fluorescence method; Thermal-optical Reflectance method is used for determining OC and EC. Sulfate, nitrate and ammonium are first collected on Teflon filters, then use ion chromatography to qualitative and quantify.

Results and discussion

Ambient Concentrations Ambient concentrations of $PM_{2.5}$ and their chemical components in four sampling sites are presented in Table 1. As shows in Table 1, the most abundant speciation in Chase has similar levels of $PM_{2.5}$ and speciation as Taft. St. Bernard both had higher levels of $PM_{2.5}$, OM and Sulfate. The descending order is St. Bernard">" Chase">" Taft". This is not surprised, for St. Bernard site was set near the railroad, and therefore will register higher overall $PM_{2.5}$ and black carbon levels. While Taft is located off of exit 3 on I-71 on Taft road, which is close to the University of Cincinnati, several major hospitals, three miles south of a coal power plant, one mile southeast of a natural gas power plant and is located in a residential neighborhood. It is also near downtown Cincinnati, so there is a mix of traffic, stationary and area $PM_{2.5}$ sources. However, the annual $PM_{2.5}$ average is decreasing (Taft; 2003 to 2013) and in the past five years, ambient $PM_{2.5}$ levels decreased about 20 percent, while there are just one year data available on B and C site, so the comparison result might not be so accurate. As a result, the following data are focus on the Taft site, where is more closed to downtown Cincinnati, more complete data and therefore more representative.

Table 1 $PM_{2.5}$ speciation values detail, from 2002 to 2013 in four sampling sites (μg/m^3).

Compounds	Taft (Jan.2003-Dec.2013)		St. Bernard (Aug.2007-Jul.2008)		Chase (Jan.2003-Dec.2010)	
	Mean	Range	Mean	Range	Mean	Range
$PM_{2.5}$	13.1	10.6-17.3	15.2	12.5-17.6	13.7	11.4-15.3
Sulfate	4.95	2.21-6.43	6.45	4.78-7.67	6.74	3.25-10.7
Nitrate	2.23	0.98-3.32	2.40	1.14-4.46	2.36	1.12-4.28
OM	4.67	2.66-5.59	7.96	3.32-11.87	5.96	3.67-8.85
EC	0.46	0.23-0.56	1.13	0.56-2.33	0.66	0.41-0.87
Crustal	0.46	0.31-0.63	0.80	0.42-2.19	0.51	0.31-0.77
Other	0.44	-0.45-1.18	-3.38	-4.45-2.21	-2.19	-3.31-1.46

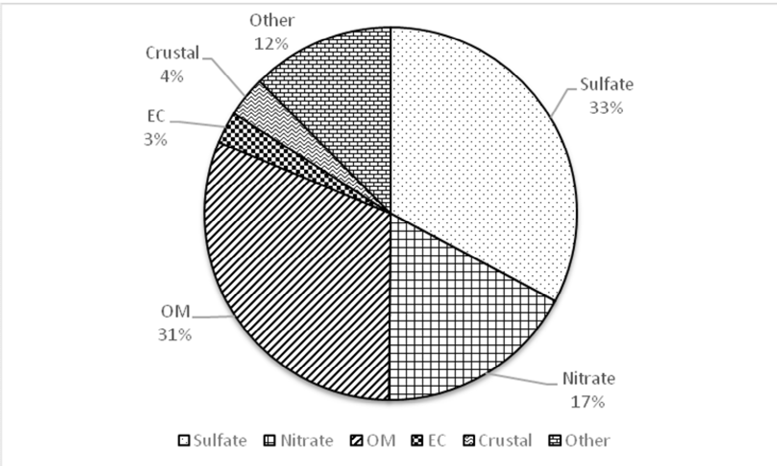

Fig.1. Overall $PM_{2.5}$ composition, Taft 2009 to 2013

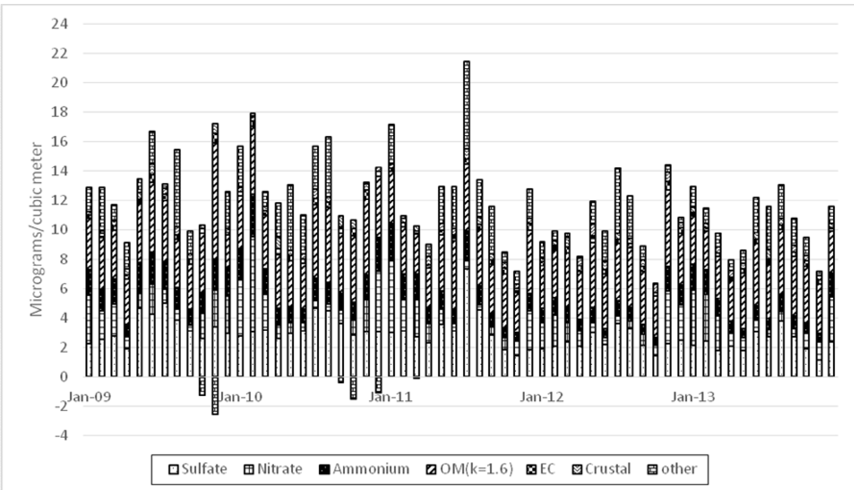

Fig.2. $PM_{2.5}$ speciation monthly data, Taft 2009 to 2013 (μg/m^3)(ammonium including)

Fig. 1 and Fig.2 shows the overall $PM_{2.5}$ data from 2009 to 2013 at Taft. In the Taft data, the largest $PM_{2.5}$ concentration happened in July 2011, when the monthly average concentration was up to 21.463 μg/m^3 – about twice as high as the average $PM_{2.5}$ concentration (11.88 μg/m^3). The lowest

$PM_{2.5}$ value is found in October 2012; the monthly average value at that time is only 6.35 μg/m^3. Referencing the past five years, PM value is decreased by about 15 to 20 percent in 2013 and 2012, compared to in 2009, 2010 and 2011. For the $PM_{2.5}$ chemical speciation, the sulfate is the most dominant content, taking up to 33.43% while the following is organic mass (31.71%) and nitrate (17.71%).(In the atmosphere, sulfate, nitrate and ammonium are combined with each other, so Bill Malm's reconstruction formula is used to put ammonium with sulfate and nitrate together.) If the amount of sulfate and nitrate are added together, they make up about half (49.19%) of the $PM_{2.5}$ in total. These three components make up 80.9 % of the whole $PM_{2.5}$. As for the yearly average, sulfate and organic matter levels are decreasing steadily. For the rest of them, nitrate stays at a constant value about 1.5 μg/m^3, while in 2010 the value jumps to 2.03 μg/m^3 and in 2012, it drops to 1.32 μg/m^3. EC values fluctuate around 0.35μg/m^3, while it drops to 0.287 μg/m^3 in 2013. Crustal materials do not change much except for in 2010, when they increased to 0.492 μg/m^3.

Conclusion

This study has analyzed the characteristic and compositions of the $PM_{2.5}$ in Cincinnati using the data from Air Quality System (AQS). In Cincinnati, the mean $PM_{2.5}$ decreased (Taft; 2003 to 2013) and in the past five years, ambient $PM_{2.5}$ levels decreased about 21 percent. The $PM_{2.5}$ in Cincinnati is composed of sulfate (3.97 μg/m^3), nitrate (2.10μg/m^3), OM (3.77 μg/m^3), EC (0.34 μg/m^3) and crustal material (0.43 μg/m^3). The most dominant component is sulfate. This might be explained by the heavily rely on the railway transport in Cincinnati. Because of the greater amount of energy consumption during summer and winter, $PM_{2.5}$ at Cincinnati also presents a seasonal trend, with higher values in summer and winter, while turning out to be lower in spring and fall. For the sulfate, the concentration is always higher in summer and lower in winter. In contrast, nitrate is lower in summer and higher in winter. High correlation between sulfate, ammonium, OC and $PM_{2.5}$ implied that sulfate, ammonium, OC in Cincinnati might come from the same source and when $PM_{2.5}$ concentration increases, those components contribute a lot to the increase.

Acknowledgments

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