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## 1. INTRODUCTION

This paper presents findings from chemical analysis of  $PM_{2.5}$  conducted at Texas A&M University-Kingsville. This research project was conducted to provide a comprehensive study of the chemical and transport characteristics of  $PM_{2.5}$  in urban, sub-urban, and rural areas of central and southeastern Ohio. The objectives were also to study indoor and outdoor  $PM_{2.5}$  characteristics in these areas and to analyze the relationship of  $PM_{2.5}$  with various meteorological parameters. The research at Texas A&M University-Kingsville supports a larger study underway at Ohio University. The core focus of the Ohio study is to identify key  $PM_{2.5}$  components that may be harmful to the children in Ohio. This would also provide data for better understanding of health effects on the general population. This study is first of its kind in elementary schools in Ohio.  $PM_{2.5}$  aerosol samples were collected from an outdoor monitor and an indoor sampler at three elementary schools in central and southeastern Ohio between February 1, 1999 and August 31, 2000. The field experiment, which began in February of 1999, consists of three longitudinal studies involving a rural elementary school location, Athens, Ohio (East elementary school), and two urban school settings, both within Columbus, Ohio (Koebel and New Albany). The three sites representing urban, suburban and rural locations in Ohio are shown in figure 1. The average  $PM_{2.5}$  concentrations considered in this paper are the arithmetic averages of the filter mass collected at each site during the entire period of study. Organic matter and elemental carbon were not analyzed as a part of this study.

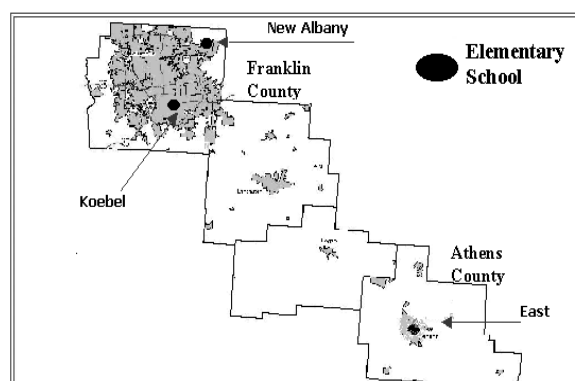


Figure 1:  $PM_{2.5}$  monitoring locations in Ohio

## 2. METHODOLOGY

Filter-based ambient  $PM_{2.5}$  measurements were made with an Automatic Cartridge Collection Unit (ACCU) System, which was connected, to the TEOMs. The 24 hour averaged filter samples were collected daily during weekdays. Measurements of indoor  $PM_{2.5}$  concentrations were carried out using 2.5  $\mu m$  cyclones (URG-2000-30EH). Indoor monitors were timed to run from 8:00 a.m. to 3:00 p.m. weekdays throughout the school year. The indoor and outdoor samples were collected on 37 mm and 47 mm Whatman Teflon filters (2- $\mu m$  pores size), respectively.

After the sampling, the filters were placed in Petri dishes, double bagged and kept at 4°C until analysis. Samples were then sent to the Department of Environmental Engineering at Texas A & M University - Kingsville to perform chemical speciation and analysis. Elemental analysis was conducted on the indoor and outdoor filter samples using a Kevex 771-EDX Spectrometer (Energy Dispersive x-ray Fluorescence) instrument. The  $PM_{2.5}$  mass was analyzed for Si, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd and Sn. The filters were subsequently extracted with deionized water by ultrasonic treatment, and the anions ( $F^-$ ,  $Cl^-$ ,  $NO_3^-$ ,  $SO_4^{2-}$ ,  $PO_4^{3-}$ ) and cations ( $Li^+$ ,  $Na^+$ ,  $NH_4^+$ ,  $K^+$ ,  $Mg^{+2}$ ,  $Ca^{+2}$ ) present were determined using

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the Dionex DX-500 IC (ion chromatography) system.

### 3. RESULTS & DISCUSSION

On an average, 65% of the total particulate (PM<sub>2.5</sub>) mass was successfully analyzed at the indoor and outdoor sites. Total carbon could form major part of the unidentified species. The components determined by the chemical analysis included: F<sup>-</sup>, Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>-2</sup>, PO<sub>4</sub><sup>-3</sup>, Li<sup>+</sup>, Na<sup>+</sup>, NH<sub>4</sub><sup>+</sup>, K<sup>+</sup>, Mg<sup>+2</sup>, Ca<sup>+2</sup>, Si, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd and Sn. Sulfate comprised the largest fraction (~20-25%) of the total PM<sub>2.5</sub> mass. Sulfate concentrations were found to be highest at the East rural site, which is located near the Ohio River valley, a huge source of sulfur dioxide emissions. The multiplier (1.37) was used to calculate sulfate values based on the assumption that all elemental sulfur is from sulfate and all sulfate is from ammonium sulfate. Other abundant components included phosphate, nitrate, ammonium and chloride ion and sodium, calcium, iron and silicon. The anion and cation average concentrations followed the pattern SO<sub>4</sub><sup>-2</sup> > NO<sub>3</sub> > Cl<sup>-</sup> and NH<sub>4</sub><sup>+</sup> > Ca<sup>+2</sup> > Na<sup>+</sup> > K<sup>+</sup> > Mg<sup>+2</sup>. Significant levels of sodium, chloride and potassium were found in the rural samples when compared with the urban samples. Heavy metals such as titanium, vanadium, manganese, iron, copper, and zinc were found in all the samples. Iron was the most abundant metal found on the filter samples.

In general, indoor PM<sub>2.5</sub> concentrations were higher than outdoor levels. Human activities in the indoor settings affected the monitored levels. Activities such as cooking, vacuuming, and most importantly movement of people (mainly children at these locations) must have increased the levels to varying degrees. Soil concentration at the indoor sites were found to be significantly higher compared to the outdoor site soil concentrations. The soil percentage ranged from 36% to 56% at the New Albany and the East indoor site respectively. Major categories of average PM<sub>2.5</sub> at six sites are depicted in Figure 2. East, New Albany, Koebel outdoor and indoor sites have been represented by EO, NO, KO, EI, NI and KI respectively.

An analysis of the ambient mass concentration distribution revealed slightly higher PM<sub>2.5</sub> concentrations at the urban site as compared to the suburban and rural sites. There were also significant seasonal variations in the concentrations of PM<sub>2.5</sub> observed. In the

outdoor atmosphere sulfate ion concentration showed strong seasonal variations with maximum concentrations observed during the summer months.

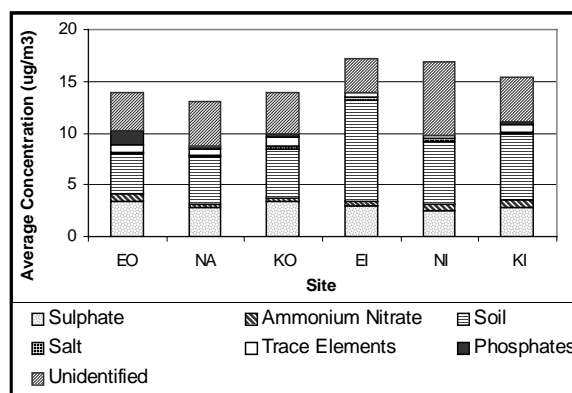


Figure 2: Average PM<sub>2.5</sub> mass and chemical composition at the three locations in Ohio

Correlation analysis between PM<sub>2.5</sub> and weather components showed that the PM<sub>2.5</sub> concentrations tended to increase with rising temperatures, dropped significantly during precipitation events and decreased with increasing wind speeds. Correlating wind direction with PM<sub>2.5</sub> at the New Albany site indicated that the PM<sub>2.5</sub> concentration was highest when the winds were blowing from the southeast, despite the low frequency of occurrence of this particular wind direction. A similar pattern was observed at the Koebel site in Columbus. The East Athens site, however, showed a slightly different pattern in the sense that the PM<sub>2.5</sub> concentration was highest when the winds were blowing from the south and the southeast direction. This analysis suggests that when the PM levels are elevated, the Ohio River valley appears to be one of the main source regions of PM precursors in Ohio.

### 3. REFERENCES

Malm, W. C., Pitchford, M. L., Scruggs, M., Sisler, J. F., Ames, R., Copeland, S., Gebhart, K. A., Day, D. E., May 2000: *Spatial and Seasonal patterns and temporal variability of haze and its constituents in United States: Report III (IMPROVE)*, ISSN 0787-5352-47

Tropp, R. J., Kohl S. D., Chow J. C., Frazier C. A., Dec 1998: *Final report for the Texas PM<sub>2.5</sub> Sampling and Analysis study*, DRI Document No. 6570-685-7770. 1F