4.1 IMPACT OF METEOROLOGY ON THE FINE PARTICULATE MATTER DISTRIBUTION IN CENTRAL AND SOUTHEASTERN OHIO

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1. INTRODUCTION

Air quality problem related to fine particulate matter ($PM_{2.5}$) in Ohio is associated with both local emission sources and pollutants transported here from great distances. Favorable meteorological situations contribute to the formation and transport of $PM_{2.5}$ within Ohio. A detailed understanding of the sources of pollutants and meteorological conditions affecting air quality is therefore required for any meaningful air quality planning in Ohio. In this study, the characteristics of fine particulate matter distribution are evaluated for selected monitoring sites in Ohio.

Trajectory and cluster analyses were employed to study the movement of air parcels carrying pollutants from sources situated long distances. Recent studies have used cluster analysis for various purposes. Dorling et al. (1992) applied cluster analysis to find out the relationships between large-scale surface pressure patterns and the pollution climatology of a site. Also, they used cluster analysis as a tool for examining the influence of synoptic weather patterns on air and precipitation chemistry. Brankov et al. (1999) examined the relationship between synoptic-scale atmospheric transport patterns and concentration levels of several toxic trace elements with cluster analysis. Another study by Rao et al. (1998) addressed the influence of a finite number of synoptic patterns associated with pollutant transport from a different source region.

2. STUDY AREA, DATA & METHOD OF ANALYSIS

2.1 *Air Monitoring Sites*

PM data was obtained from air monitoring sites located in schools in Ohio and are operated by Ohio university. The School of Health Sciences at Ohio university operates several monitoring sites around the central and southeastern portion of the state. Each site measured particulate matter and local meteorological conditions. Table 1 shows a list of the air monitoring sites used in this study and the pertinent geographic details for each of them.

TABLE 1

City	Site Name	Latitude, N	Longitude, W
Athens	East Athens	39°31′94″	82°81′11″
Columbus	Koebel	39°96′40″	82°95′75″
Columbus	New Albany	40°08′50″	82°81′60″

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2.2 *Air Quality Data*

For the statistical analysis of particulate matter, data obtained from the three monitoring sites were used. Hourly averaged values of particulate matter were obtained from these sites for 1999-2000. Meteorological data such as temperature, resultant wind speed, and resultant wind direction for 1999 were obtained from the Ohio Environmental Protection Agency (Ohio EPA).

2.3 *Time Series and Correlation Analysis*

Time series analysis was adopted to study monthly and hourly distribution of the $PM_{2.5}$ concentrations for the three sites in Ohio using monitored dataset in 1999-2000. Also, correlation analysis was applied to evaluate the effect of weather components.

2.4 *Back Trajectory Analysis*

Draxler (1996) used trajectories to aid in complex decisions regarding atmospheric transport pathways. The hybrid single-particle lagrangian integrated trajectory (HYSPLIT4) model described by Draxler et al. (1997) was applied to estimate backward trajectories for the study period from 1999 through 2000. Twenty four-hour back trajectories at 500 meter for high PM days (when the maximum $PM_{2.5}$ concentration exceeded 30 $\mu g/m^3$) were calculated using the HYSPLIT4 model. A start time of 16 UTC, corresponding to high PM values each day, was adopted in this study.

2.5 *Cluster Analysis*

Cluster analysis, which consists of splitting a data set into several dominant groups, is frequently applied in air pollution research to find out pollutant source region. The clustering approach proposed by Dorling et al. (1992) was chosen and modified in this study. For each 24-hour back trajectory, 6 four-hourly x-y coordinates were used as input variables for the clustering algorithm. Each trajectory was assigned to several clusters in terms of directions of original source regions that are x-y coordinates of starting points of 24-hour back trajectory. The transport path was calculated by averaging trajectories assigned to each cluster. Main clusters in this study were divided into eight directional components and one additional category called Close describing near-proximity trajectories.

3. RESULTS AND DISCUSSION

During the study period, there were exceedances of the $PM_{2.5}$ 24-hour standard of 65 µg/m^3 at the Koebel urban site. In the monthly percentile distribution, the mean PM concentrations were high during the summer months and low during the winter months. It was found that the hourly $PM_{2.5}$ median values at the three school sites showed peak levels between 7:00 and 9:00 a.m., the main rush hour in a day, and a secondary peak during the late afternoon hours.

High $PM_{2.5}$ concentrations levels were generally observed when wind speeds were below 8 mph and temperatures were typically above 70°F. The $PM_{2.5}$ concentrations were observed to be high at all locations when the winds were blowing from the south and southeast. No significant relation was found between $PM_{2.5}$ and relative humidity. A correlation between two neighboring monitors in close proximity with each other showed a spatial homogeneity in the distribution of $PM_{2.5}$. All sites showed a high correlation in the temporal patterns revealing homogeneity in the spatial concentrations across the central and southeastern Ohio during high $PM_{2.5}$ days.

Cluster analysis is an advanced method, which shows the path of the air parcel, as it segregates and merges each trajectories into distinct groups based on their directions and/or similarities. It is a useful method to trace original pollutant source regions. Percentage and frequency of each cluster and the average $PM_{2.5}$ concentrations associated with these individual clusters for the Koebel site are presented in Figure 1. The highest $PM_{2.5}$ concentrations were associated with trajectories from the North, Northwest, and Southeast directions, while the dominant wind was from the Southwest. Most clusters' source regions corresponded with major industrial and urban areas in the neighboring states and with major cities in Ohio.

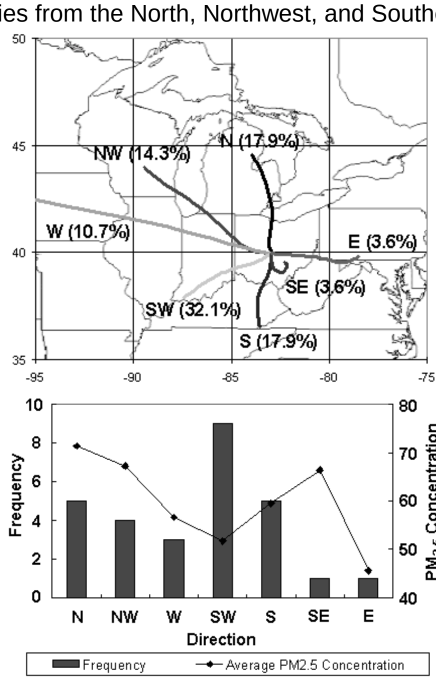

Figure 1 Cluster plot (above) and frequencies and average $PM_{2.5}$ concentrations by cluster (below) at Koebel, Columbus, Ohio, 1999-2000

4. CONCLUSION AND RECOMMENDATIONS

This study provides a detailed analysis of the air quality issues affecting the urban, suburban, and rural areas in Ohio and evaluates the atmospheric transport patterns associated with PM episodes and potential source regions affecting the PM levels in Ohio.

The time series analysis showed exceedances of the $PM_{2.5}$ 24-hour standard of 65 µg/m^3 at the one urban site. Hourly $PM_{2.5}$ distributions showed possibility of mobile source influence on the $PM_{2.5}$ levels. Additional temporal and chemical analysis is needed to identify mobile source linkage to $PM_{2.5}$ levels.

Temperature, wind speed, and wind direction had significant influences on $PM_{2.5}$ concentrations. High $PM_{2.5}$ concentrations levels were generally observed when wind speeds were below 8 mph, temperatures were typically above 70 °F, and the winds were blowing from the south and southeast.

Trajectory and cluster analysis showed that most high PM days occurred along the Southwest cluster, but the highest average PM concentrations appeared along the North, Northwest, and Southeast clusters. Main source regions correspond with major cities in neighboring states and with major cities in Ohio. For better understanding of the meteorological influence among these major cities and source regions, longer-term analysis and additional trajectory analysis for non-high PM days need to be studied.

5. REFERENCES

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