EXECUTIVE SUMMARY

The Air Pollution and Pediatric Health Impact Assessment project is a comprehensive health-based study evaluating the impact of air pollution on children and the general population in Ohio. Air quality data was obtained from the state and local air agency monitoring sites and monitoring sites at elementary schools in Columbus, New Albany, and Athens. Health information data was obtained from the Ohio Hospital Association, local Hospitals (emergency room admissions), and non-invasive medical monitoring at the elementary schools.

The project was a collaborative effort of researchers from Ohio University and Texas A&M University-Kingsville. The three components of the project includes a prospective analysis of air quality and the corresponding impact on respiratory health, a retrospective analysis of air quality across the state and the corresponding impact on respiratory health, and an analysis of ambient, indoor, and personal air toxic concentrations.

PROSPECTIVE ANALYSIS

The prospective analysis was designed to measure air pollution levels and exposures of children at three study locations in central and southeastern Ohio. Three components comprise the prospective analysis: particulate matter measurements, chemical characterization of particulate matter, and a health status evaluation of students involved in the study.

**Particulate Matter Measurements**

Personal, indoor, and outdoor PM$_{2.5}$ mass concentrations were monitored at three elementary schools in central and southeastern Ohio. A rural site was represented by East Elementary School and located in Athens, which is in Southeastern Ohio. Koebel Elementary School located in South Central side of
Columbus represented the urban testing center. A suburban site was located in New Albany and was represented by New Albany elementary school.

This report focuses on the temporal and spatial variations of ambient PM$_{2.5}$, and the relationships between personal, indoor, and outdoor PM$_{2.5}$ concentrations. The PM$_{2.5}$ measurements were conducted from January 1999 through August 2000. At each monitoring location, personal, indoor, and ambient PM$_{2.5}$ measurements were obtained. Three groups of 4th and 5th grade students, approximately 30 students at each site, participated in the project.

Ambient PM$_{2.5}$ displays an apparent seasonal trend and homogeneous spatial distribution. No clear seasonal or spatial patterns exist for indoor and personal PM$_{2.5}$ concentrations. However, high variations of personal and indoor concentrations occurred during school days at all three sites. Indoor PM$_{2.5}$, generated by human activities (such as walking) was an important determinant of personal PM$_{2.5}$ exposures. As a result of indoor sources, personal exposures and indoor PM$_{2.5}$ concentrations tend to be higher than corresponding outdoor concentrations at all sites. When students were not in the buildings, indoor and outdoor PM$_{2.5}$ concentration (I/O) ratios and sulfate (SO$_{4}^{2-}$) I/O ratios decreased.

Indoor PM$_{2.5}$ also influences the relationship between personal and outdoor PM$_{2.5}$ concentrations. Personal PM$_{2.5}$ concentrations were more aligned with indoor levels than with outdoor levels. Moderate personal-outdoor correlations occurred at Koebel (R= 0.32, P<0.0001) and Athens (R=0.27, P=0.0001). No significant personal-outdoor correlation was found at New Albany. On the other hand, personal and indoor PM$_{2.5}$ concentrations are highly correlated at all three sites with the R-values ranging from 0.30 to 0.68 (P<0.0001). Moderate indoor-outdoor correlations were found at Koebel (R =0.26) and New Albany (R= 0.30). At Athens, although there was a weak correlation between indoor and outdoor concentrations of PM$_{2.5}$ (R= 0.13), it was not statistically significant.

The analysis of correlations between personal, indoor, and outdoor PM$_{2.5}$ are crucial in understanding the health effects in epidemiological studies. The central assumption of epidemiological studies is that ambient PM concentration, monitored by a fixed site, is a sufficient surrogate for personal exposure. In this study, ambient PM$_{2.5}$ distributed homogeneously throughout the study area. This indicates that ambient PM$_{2.5}$ concentrations monitored from a fixed site can represent the average ambient PM$_{2.5}$ level over a large area. However, high variations occurring with indoor and personal concentrations indicates that the ambient PM$_{2.5}$ may not be a strong indicator for indoor concentrations or total personal exposures.
Characterization of Particulate Matter

Chemical characterization analysis of fine particulate matter (PM$_{2.5}$) was measured at the elementary schools for the outdoor and indoor monitors. The collected filter samples were analyzed at Texas A&M University–Kingsville. using an ion chromatography unit and an X-ray fluorescence spectrophotometer. Concentrations of Cl$^-$, NO$_3^-$, SO$_4^{2-}$, PO$_4^{3-}$, Li$^+$, Na$^+$, NH$_4^+$, K$^+$, Mg$^{2+}$, Ca$^{2+}$, Si, P, S, Cl, K, Ca, Ti, Co, Ni, V, Mn, Fe, Cu, and Zn were determined for each site and compared. Sulfate comprised the largest fraction (~20-25%) of the total PM$_{2.5}$ mass.

High sulfate concentrations were found at the East (rural) site, which is located near the Ohio River valley, a significant source of sulfur dioxide emissions. Other abundant components included nitrate and ammonium ions and silicon. The anion and cation average concentrations followed the pattern SO$_4^{2-} >$NO$_3^->Cl^-$ and NH$_4^+ >$ Ca$^{2+} >$ Na$^+ >$ K$^+ >$ Mg$^{2+}$. Significantly higher levels of sodium, chloride, and potassium were found in the rural 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 the outdoor environment, sulfate ion concentration showed strong seasonal variation with maximum concentrations observed during the summer months. In the indoor environment, the percentage of soil in the samples was higher than the outdoor samples.

Additional data analysis included a comparison of PM$_{2.5}$ with meteorological parameters such as temperature, relative humidity, wind direction, and wind speed. It was noted that PM$_{2.5}$ concentrations tend to increase with rising temperatures, and decrease with increasing wind speeds. Correlating wind direction with PM$_{2.5}$ at the New Albany site indicated that the PM$_{2.5}$ 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 site, however, showed a slightly different pattern; the PM$_{2.5}$ 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 sources.

Health Status Evaluation

Longitudinal studies were conducted at all three elementary schools providing an opportunity to assess different patterns of exposures to air pollutants. All students enrolled in 4th and 5th grades were considered eligible
for the study. Components of the prospective health status evaluation included: 1) emergency room visits, 2) daily monitoring of pulmonary function, 3) daily school and class absenteeism, and 4) a cross-sectional health survey.

There were few consistent relationships between respiratory measures and air quality measures, after controlling for seasonality and weather. At two of the three sites (Koebel and New Albany), indoor filter weights were negatively related to attendance of students who had a prior history of respiratory illness. At New Albany, outdoor filter weights were negatively related to mean standardized peak flow, but this relationship was statistically significant for all students in 2000, not just those students with a history of respiratory illness. However, in 1999, outdoor filter weights were negatively related to mean standardized peak flow only for students with a history of respiratory illness. Although negative correlations between peak flow and outdoor filter weights were observed at the other two sites in 2000, none were statistically significant.

RETROSPECTIVE ANALYSIS

The retrospective analysis was comprised of two major activities: analysis of historical air quality trends in Ohio and analysis of hospital admissions data.

Air Quality Data

Air quality and meteorological data from monitoring sites located in Cincinnati, Dayton, Toledo, Columbus, Chesapeake, Cleveland, Akron, Marietta, and Steubenville for the period of 1992-2000 were obtained from the Ohio EPA and Ohio University. Time series analysis, statistical analysis and meteorological analysis were applied to achieve the objectives of this study which were: 1) to analyze time series and long-term trends of the air pollutants; 2) to characterize meteorological parameters that impact air pollutant levels in Ohio; and 3) to identify atmospheric patterns associated with the transport of air pollutants to and from Ohio.

Long-term trends of ozone, PM$_{10}$, CO, SO$_2$, and NO$_2$ concentrations in the major urban centers were analyzed using an advanced technique called the Kolmogorov-Zurbenko (KZ) filter. Long-term trends analysis for ozone at several of the sites shows an increase trend in ozone levels. For PM$_{10}$ the trend line remained fairly constant at all sites. All the sites showed visible decreasing trends in CO and SO$_2$, while NO$_2$ concentrations slightly increased.

Most high ozone episodes in the state last for several consecutive days. High ozone values during these episodes occur on the same day for most of the sites, a tendency that is prominent in the 8-hour ozone distribution rather than the 1-hour ozone distribution. This suggest that the new 8-hour NAAQS for ozone could result in the spatial expansion of the ozone problem in Ohio. Many urban areas in attainment of the current 1-hour ozone NAAQS will
become a non-attainment area under the new standard. Evaluation of back trajectories revealed that high ozone days occurred more frequently when winds were out of the southwest but the highest average ozone concentrations appeared with the south and the southeast wind direction.

Temperature, wind speed, and wind direction were significantly correlated with PM$_{10}$ concentrations. High PM$_{10}$ concentration levels were generally observed when the wind speed was lower than 8 mph and temperature was higher than 70°F or 80°F. Concentrations were also high when the winds were blowing from the south and east direction.

Cluster analysis was used to trace PM source regions and the pollutant’s impact on the receptor sites. The results of this analysis showed that most high PM days occurred along the southwest cluster, but the highest average PM concentrations appeared along the southeast or north clusters.

Monthly distributions indicated that the mean CO and SO$_2$ concentrations are high during the winter months and low during the summer months, implying that CO and SO$_2$ concentrations are affected by seasonal impact. Weekdays are relatively higher than weekends in weekly distribution of CO, SO$_2$ and NO$_2$. The daily peak concentrations of CO were measured at 7 am and at 8am for SO$_2$ and NO$_2$.

**Hospital Admissions Data**

An examination of the zero-order correlations between respiratory health and air pollution reveals a significant amount of consistency across the eight sites included in the study. At every site, O$_3$ is significantly negatively correlated with hospital admissions for all respiratory illnesses and for asthma in children. Ozone is also significantly negatively correlated with hospital admissions for COPD in the elderly at two sites and with total respiratory deaths at five sites. This analysis suggests that high levels of ozone are not related to hospital admissions for respiratory illness in children or the elderly, a result that was unexpected, but explainable.

The negative zero order correlations can be related to a couple of factors. First, respiratory illness peaks during the winter months and drops steadily through July while ozone shows an inverse temporal pattern typically peaking in July and is relatively low during the cooler months. Second, the zero order correlations do not account for lags, the time between the hospital admission and the preceding high ozone event, that may trigger respiratory conditions. These differences in seasonal patterns highlight the importance of accounting for the confounding effects of seasonality and meteorology when statistically evaluating the relationships between air quality and respiratory illness.
The other pollutants that were also negatively correlated with respiratory health were NO₂ and PM₁₀. Surprisingly, the correlation between respiratory health and PM₁₀ varied substantially from one site to another. For example, the correlation between total respiratory illness and PM₁₀ was positive at Akron, negative at Cincinnati, Cleveland, and Columbus, and non-significant at Steubenville and Youngstown.

Not unexpectedly, CO and SO₂ were generally positively correlated with respiratory illness. The results from the eight sites were far from unanimous however, as many of the correlations were not statistically significant, suggesting that CO and SO₂ were either uncorrelated or weakly correlated with respiratory health at many of the sites.

After partitioning out the effects of seasonality and weather, there was little evidence of a consistent relationship between any of the air pollutants and any of the measures of respiratory health across the eight sites. No general pattern for a given pollutant across the state was identified.

Even after controlling for seasonality and weather, respiratory health and air pollution remained correlated with one another, although to a far lesser extent than what would have been expected after an examination of the correlations between the air pollutants and the respiratory health measures. This suggests that a sizeable amount of the relationship between air pollution and respiratory health can be attributed to other factors.

AIR TOXICS MONITORING

Air toxics monitoring was conducted for VOCs identified by the EPA to have the greatest potential effect on the public and the environment. Environmental measurements of VOC levels were made during the school year from September 1999 to May 28, 2000. Indoor, outdoor, and personal concentrations of 45 volatile organic compounds were simultaneously assessed at the three elementary schools participating in this study. Samples were collected with passive dosimeters analyzed by gas chromatography and mass spectrometry. VOC measurements included benzene, 1,3-butadiene, carbon tetrachloride, chloroform, methylene chloride, 1,1,2,2-tetrachloroethane, and trichloroethylene.

In general, very low total VOCs were found in this study. Like several other studies examining background, or baseline, concentrations of VOCs in nonproblematic settings, levels found in this study were in the low ug/m³ range. The significance of exposures to VOC mixtures at low levels is unclear. Although specific VOC concentrations were not distinctly affected by weekly temperature or relative humidity, this study shows a significant seasonality to VOC prevalence. Higher levels of most chemical species occurred in spring months as compared to either winter or summer.
Indoor concentrations typically exceeded outdoor levels, and personal exposures were generally the highest of the three levels analyzed. Of the three locations studied, the rural setting had the highest TVOC levels. This was unexpected and contradicts the intuitive expectation that the inner city site, with ostensibly greater local emissions, would contain the highest levels of TVOCs. This finding indicates that location may not always determine the concentration of VOCs present at a site, and that local variability may play a greater role in contaminant levels present. This study further confirms earlier work showing that indoor and personal sample VOC concentrations are higher than outdoor concentrations.

Many studies have examined VOC concentrations, but this study is one of a very few to examine ambient and personal VOC concentrations in elementary schools. This work is also notable in that it employed a passive dosimeter for the assessment of these low-level organic contaminants. Despite difficulties with elevated background concentrations of benzene on some dosimeters, passive dosimeters show promise for ambient air monitoring.