CHAPTER 2 - Air Quality Trends and Comparisons

Particulate Sampling

Total Suspended Particulate Matter

With the monitoring for $PM_{2.5}$ particulate matter being labor intensive, DEP reduced the number of sites monitoring for total particulate matter in 1999 since no air quality standard exists. The TSP monitoring sites that remain were chosen for other needs, such as lead monitoring.

Total suspended particulates (TSP) are the solid or liquid matter in air. Particles vary in size and may remain suspended in the air from a few seconds to several months. Sources of particulate emissions include coal-burning power plants, industrial processes, mining operations, municipal waste incinerators and fuel combustion. They also are produced by natural sources such as forest fires and volcanoes. The smaller particles are breathed deeply into the lungs, where they can aggravate or cause respiratory ailments. These smaller particles can also carry other pollutants into the lungs.

The federal ambient air quality standard for particulate matter was revised to reflect the adverse health effects of smaller particulate matter less than 10 microns in size (PM_{10}). There is no federal or state air quality standard for TSP.

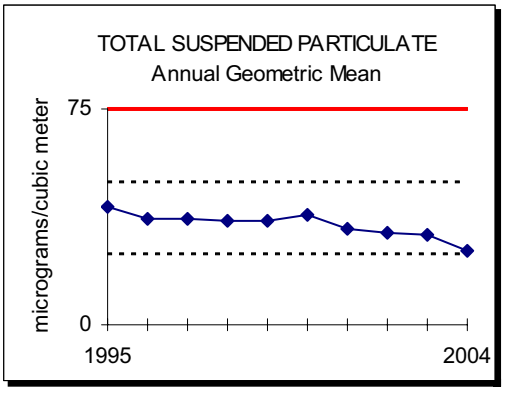


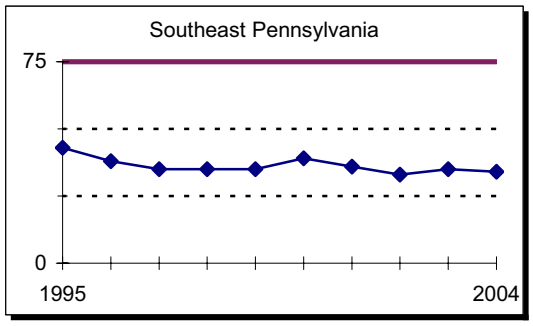
Figure 2-1. Trend in annual geometric mean TSP concentrations, 1995-2004.

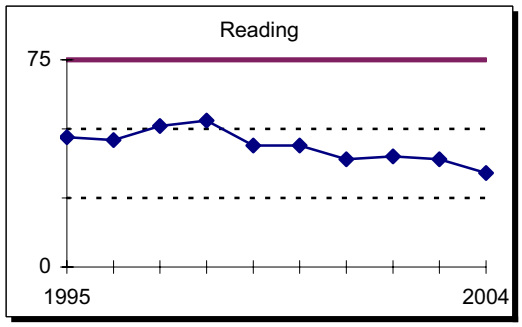
Figure 2-1 shows a decrease in annual geometric mean TSP concentrations. In 1995, the statewide average concentration was 41 micrograms per cubic meter ($\mu g/m^3$) and in 2004 the statewide average concentration was 26 micrograms per cubic meter ($\mu g/m^3$), representing a statewide decrease of 37% for this period. The solid line represents the former annual primary air quality standard of 75 micrograms per cubic meter ($\mu g/m^3$).

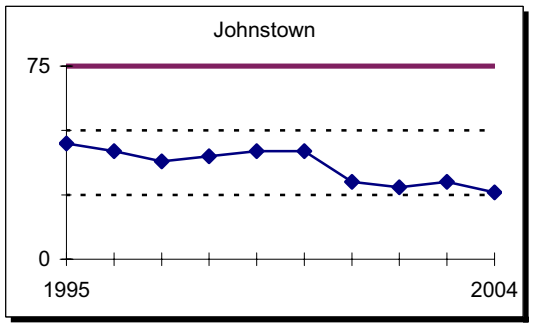
The 2004 calendar year TSP summary is contained in Appendix A, Table A-1. There were no sites in the Commonwealth that exceeded the former annual or 24-hour primary air quality standards in 2004. For comparison to the PM_{10} annual air quality standard, the TSP annual arithmetic mean was calculated by averaging the four quarterly arithmetic means.

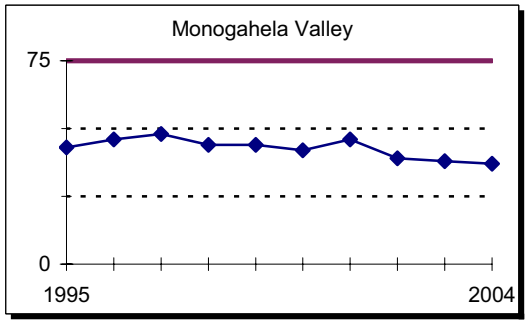
Figure 2-2, located on the following page, shows the TSP trends over the last 10 years in various areas of the Commonwealth where monitoring remains. The graphs of the air basin's annual geometric means consist of all stations that were operated during that year and which had at least 30 samples taken. Thus, stations that were moved or discontinued in the past are still included in the 10-year trend. The solid line represents the former annual primary air quality standard of 75 $\mu g/m^3$. The historical data illustrated in Figure 2-2 are contained in Appendix A, Table A-2. This table lists the annual geometric means over the last 10 years for each site monitored in 2004. The annual mean is shown if at least 30 samples were collected that year.

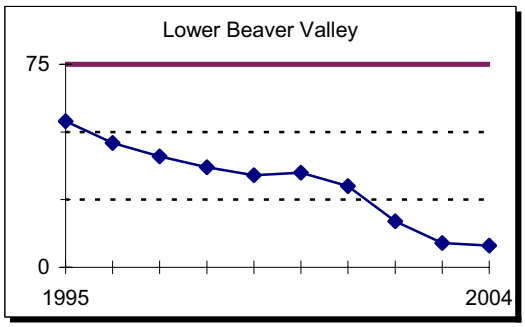
Figure 2-2. TSP Trends in Pennsylvania 1995 to 2004
Annual Geometric Means (micrograms per cubic meter)











Former Annual TSP National Ambient Air Quality Standard was 75 micrograms per cubic meter

Sulfate and Nitrate Particulate Matter

With the monitoring for $PM_{2.5}$ particulate matter being labor intensive, DEP reduced the number of sites monitoring for total particulate matter in 1999 since no air quality standard exists. As a result, the number of sites with filter analysis for sulfates and nitrates was also reduced.

Sulfate particulate matter in the atmosphere is composed of two types: primary and secondary. Primary sulfates are emitted directly into the atmosphere from industrial processes. Secondary sulfates are formed in the atmosphere from other sulfur-containing compounds under mechanisms that involve photochemical processes.

Studies have shown a significant correlation between high sulfate levels and increased absences from work and school because of illness. Sulfates are also of interest due to their effects of reducing visibility and contributing to acid rain.

Pennsylvania's ambient air quality sulfate standard was repealed since it was more stringent than federal regulations. There are no short- or long-term air quality standards for sulfates. However, elevated sulfate values, consistent with previous years, continue to be recorded statewide.

The 2004 sulfate summary is contained in Appendix A, Table A-3. The large number of high sulfate levels during the summer is caused by the relationship between sulfate formation and photochemical processes. The maximum values will occur at the majority of sites from May to September.

Nitrates are particulate compounds that are usually formed in the atmosphere from the oxidation of oxides of nitrogen gases. They are of interest since they represent a significant portion of the finer particulates which can be inhaled into the lungs and which have a great impact on visibility. Nitrates are also being studied to determine their impact on acid precipitation.

Appendix A, Table A-4 summarizes nitrate data collected during 2004. As seen from the annual means, the levels of nitrates in the Commonwealth are relatively constant from area to area.

There are no long-term or short-term air quality standards for nitrates.

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Lead

Lead is a highly toxic metal when ingested or inhaled. It is a suspected carcinogen of the lungs and kidneys and has adverse effects on the cardiovascular, nervous, and renal systems. Lead is emitted to the atmosphere by vehicles burning leaded fuel and from certain industrial processes, primarily battery manufacturers and lead smelters. As a result of the reduction in lead in gasoline, metal processing is the major source of lead emissions.

Lead concentrations for 1995 to 2004 are represented in Figure 2-3 by the maximum quarterly mean during the year for all DEP monitors across the state. After dramatic reductions seen in the late 1970s to early 1980s due to the implementation of lead-free gasoline, lead concentrations have leveled off. Figure 2-3 indicates that the maximum quarterly lead concentrations have remained fairly constant and well below the air quality standard over the past 10 years even though source-oriented sites dominate the data. The solid line represents the quarterly mean air quality standard of 1.5 micrograms per cubic meter ($\mu g/m^3$).

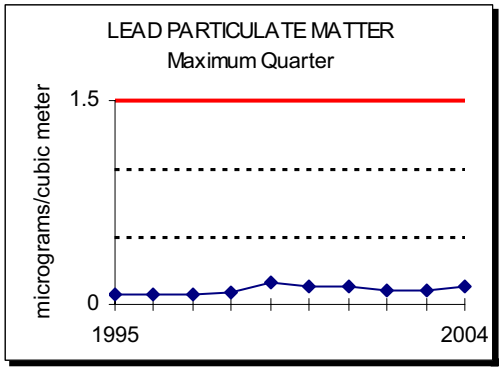


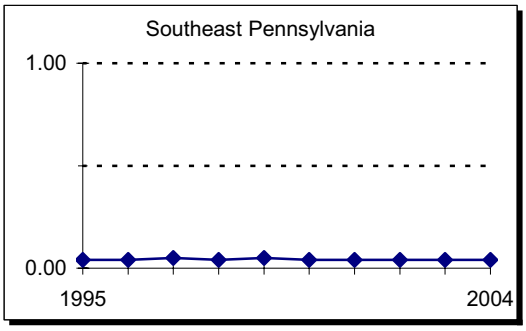
Figure 2-3. Trend in maximum quarterly average lead concentrations (including source-oriented sites), 1995-2004.

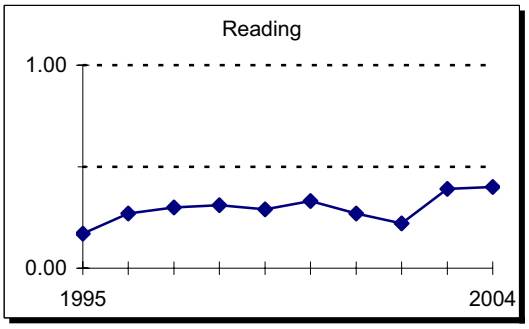
Lead trends for the individual areas in the state are shown in Figure 2-4, located on the following page, for 1995 to 2004.

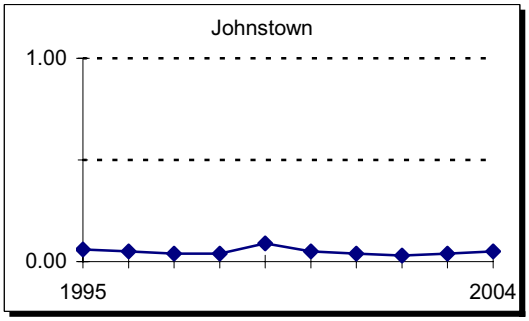
The particulate lead standard was not exceeded at any monitoring site in 2004, including source-oriented sites. Quarterly averages for all stations that monitored lead in 2004 are shown in Appendix A, Table A-5, along with the number of samples taken in each quarter, the annual arithmetic mean, and the total number of samples for the year.

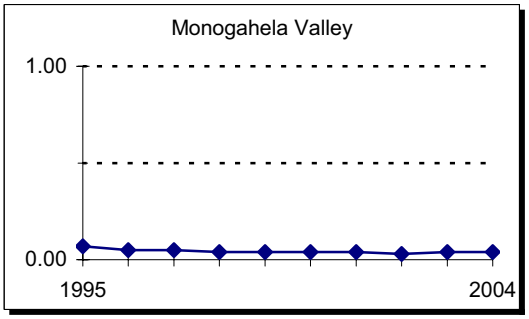
Lead historical trend data is presented in Appendix A, Table A-6 for 1995 to 2004. The table contains the maximum quarterly mean for each year. Trend data is shown for all sites that operated in 2004. The quarterly mean is shown if at least 30 samples were collected during the year. No current monitoring site has exceeded the air quality standard for at least the last 10 years. Higher lead levels recorded at sites located in Laureldale (Reading Air basin) and Lyons are due to the influence of lead point sources close to the monitoring sites, although these sites are well below the air quality standard.

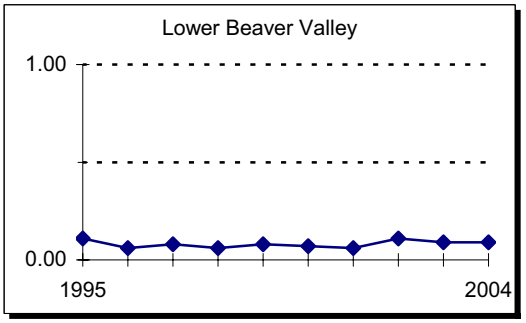
Figure 2-4. Lead Particulate Trends in Pennsylvania 1995 to 2004
Maximum Quarterly Means (micrograms per cubic meter)

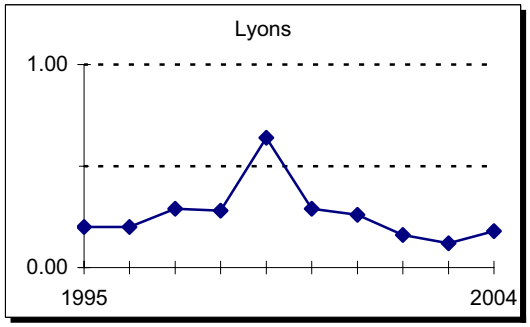


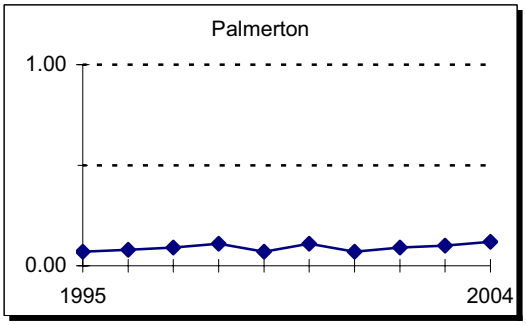












Lead National Ambient Air Quality Standard is a quarterly average of 1.5 micrograms per cubic meter

PM_{10} Suspended Particulate Matter

Particulate matter (PM) is solid matter or liquid droplets from smoke, dust, fly ash, or condensing vapors that can be suspended in the air for long periods of time. Particulate matter in air with aerodynamic diameters less than 10 micrometers is PM_{10}. PM_{10} has replaced the total suspended particulate (TSP) standards because many of the larger particles included in the TSP measurement (up to 45 micrometers) do not penetrate into the lungs and have very little effect on health. Consequently, the PM_{10} measurement is believed to be a better indicator of actual health risks.

PM_{10} appears to represent essentially all of the particulate emissions from transportation sources and most of the emissions in the other traditional categories (coal-burning power plants, steel mills, mining operations, etc). The standard for PM_{10} was adopted in July 1987. On July 18, 1997, EPA revised the particulate matter standards by adding new standards for $PM_{2.5}$ (particles less than or equal to 2.5 micrometers).

The PM_{10} concentrations are measured using both discrete (single sample) monitors that collect particulate matter on a filter for 24 hours and continuous real-time instruments. The continuous TEOM monitor is a gravimetric instrument that draws ambient air through a filter, constantly weighing the filter and calculating real-time PM_{10} concentrations. The analyzer reports 1-hour data, which are then used to calculate daily 24-hour averages (midnight to midnight), for comparison to the ambient air quality standard.

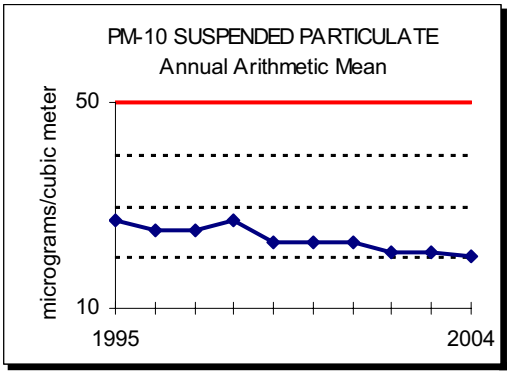


Figure 2-5. Trend in annual mean PM_{10} concentration, 1995-2004.

Figure 2-5 is a graph of the historical statewide PM_{10} trend from 1995 to 2004. Because of an EPA policy change, data prior to 1988-99 is reported in units corrected to standard conditions while data since 1998-99 is corrected to local conditions. In 1995, the statewide average concentration was 27 micrograms per cubic meter ($\mu g/m^3$) and in 2004 the statewide average concentration was 20 micrograms per cubic meter ($\mu g/m^3$), representing a statewide decrease of 26% for this period.

The map in Figure 2-6 shows the range of PM_{10} annual mean levels in the different counties across the Commonwealth where monitoring is performed. When there are multiple sites in the county, the annual mean is the highest reading of these sites. Only sites that have monitored 50 percent of the time during 2004 are included in this figure. All counties monitored by DEP are in attainment of the annual PM_{10} NAAQS. The map in Figure 2-7 displays the highest second maximum 24-hour PM_{10} by county in 2004. All counties monitored by DEP are in attainment of the 24-hour PM_{10} standard.

PM_{10} trends for the individual areas of the state are shown in Figure 2-8 for 1995 to 2004. The air basin or area averages consist of all stations that were operated during that year and had at least 30 discrete samples or 50 percent valid continuous data. PM_{10} levels have remained fairly constant over this period with an average 7 percent decrease in levels over the last five years. The apparent dramatic improvement shown in the Scranton-Wilkes Barre air basin for 1999 may be due to the lack of sampling data and should not be viewed as representative of the particulate levels. The solid line represents the annual air quality standard of 50 micrograms per cubic meter ($\mu g/m^3$).

The 2004 PM_{10} data summary appears in Appendix A, Table A-7. Historical trend data for each site monitored in 2004 is shown in Appendix A, Table A-8. This table lists the annual arithmetic means and second maximum 24-hour mean over the last 10 years for each site that monitored in 2004 with at least 50 percent data completeness.

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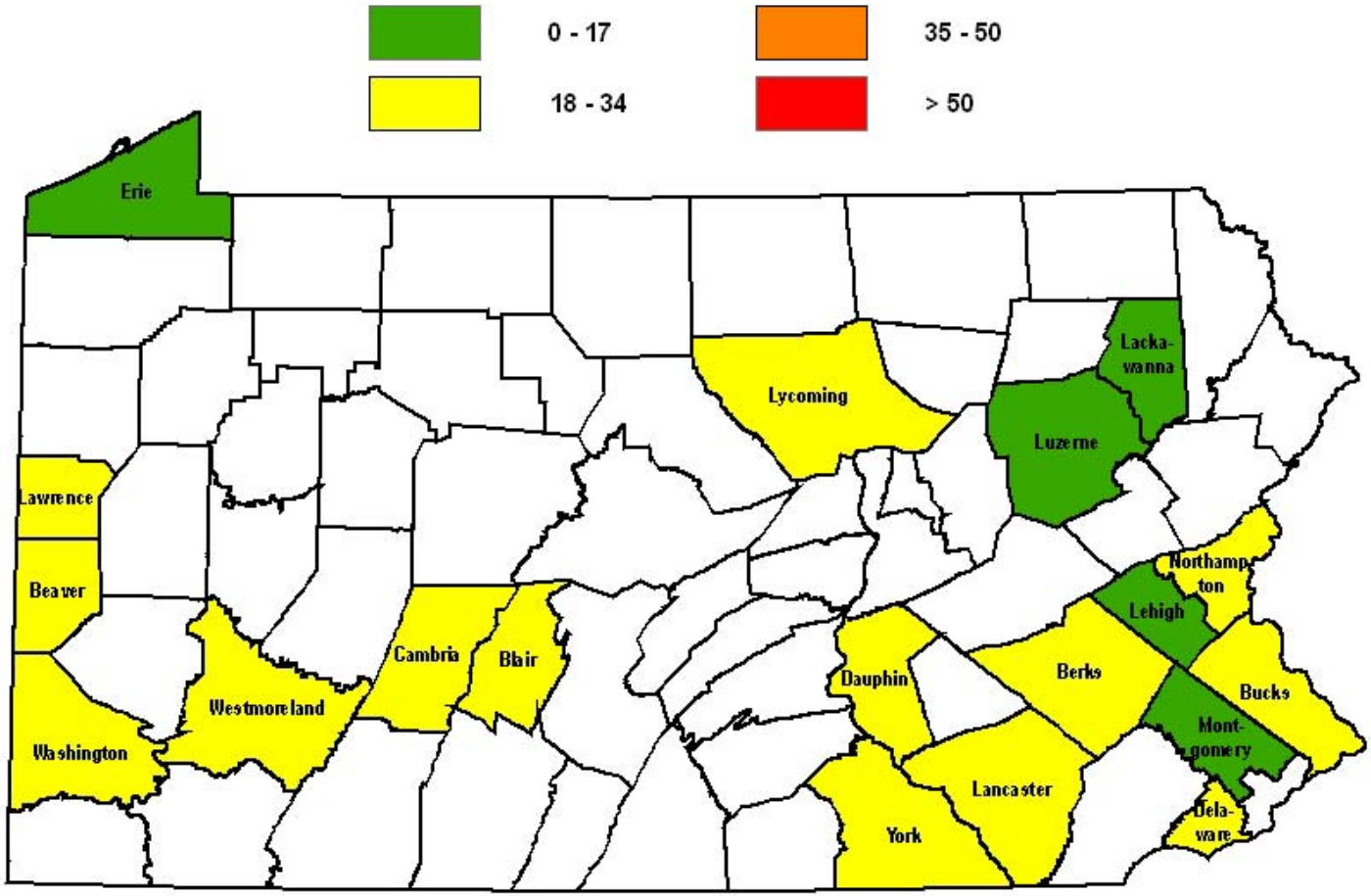
Figure 2-6. PM-10 Concentrations

Annual Means (Average by County, for 2004)

(Micrograms per Cubic Meter)



Primary and Secondary National Ambient Air Quality Standard for PM-10
Annual Mean = 50 micrograms per cubic meter
(Data are displayed for single calendar year, but the standard is based on a 3-year average)

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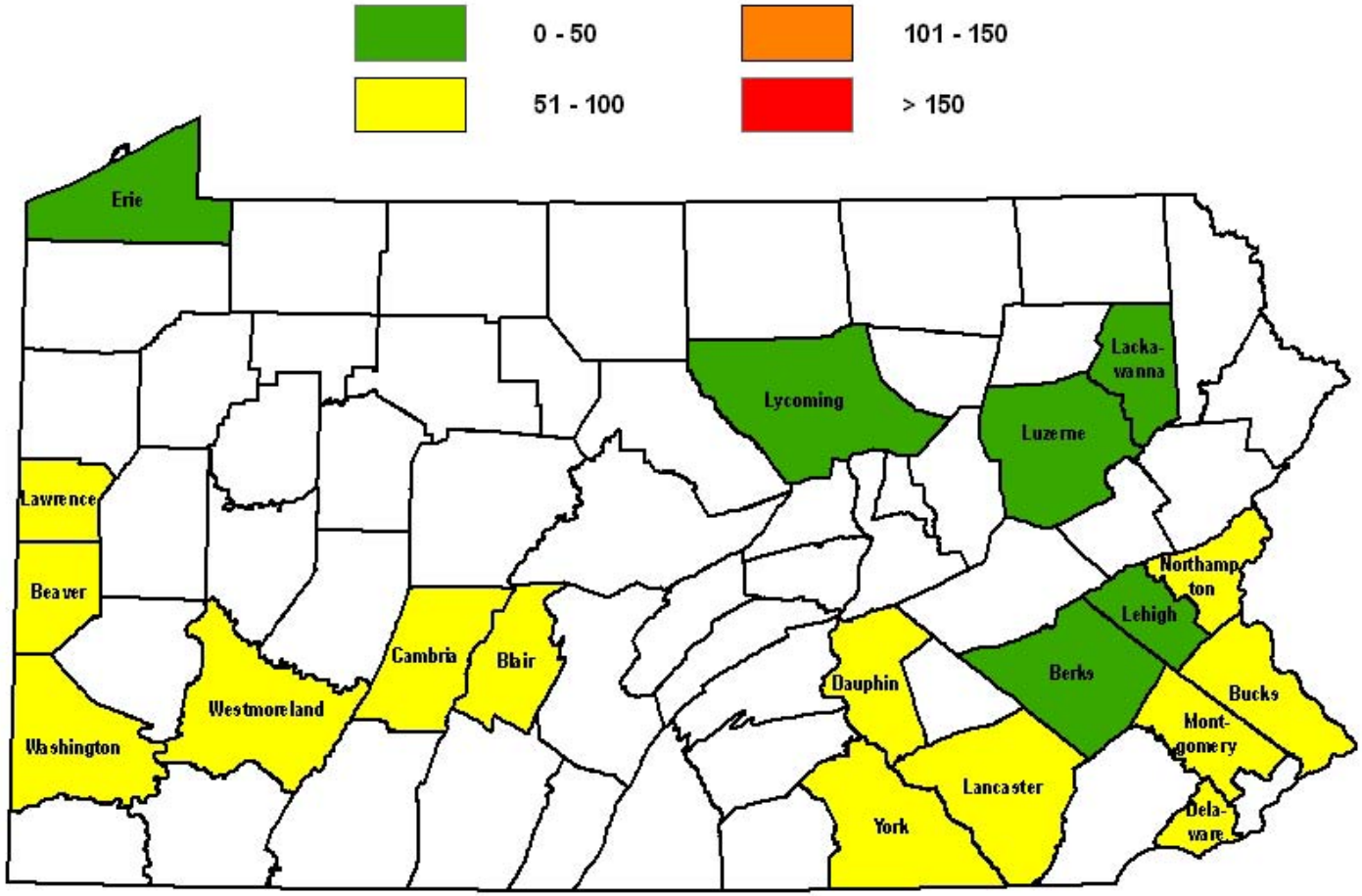
Figure 2-7. PM-10 Concentrations

Highest Second Maximum 24-Hour Mean (by County, for 2004)

(Micrograms per Cubic Meter)



Primary and Secondary National Ambient Air Quality Standard for PM-10
24-Hour Mean = 150 micrograms per cubic meter (not to be exceeded more than once per year)

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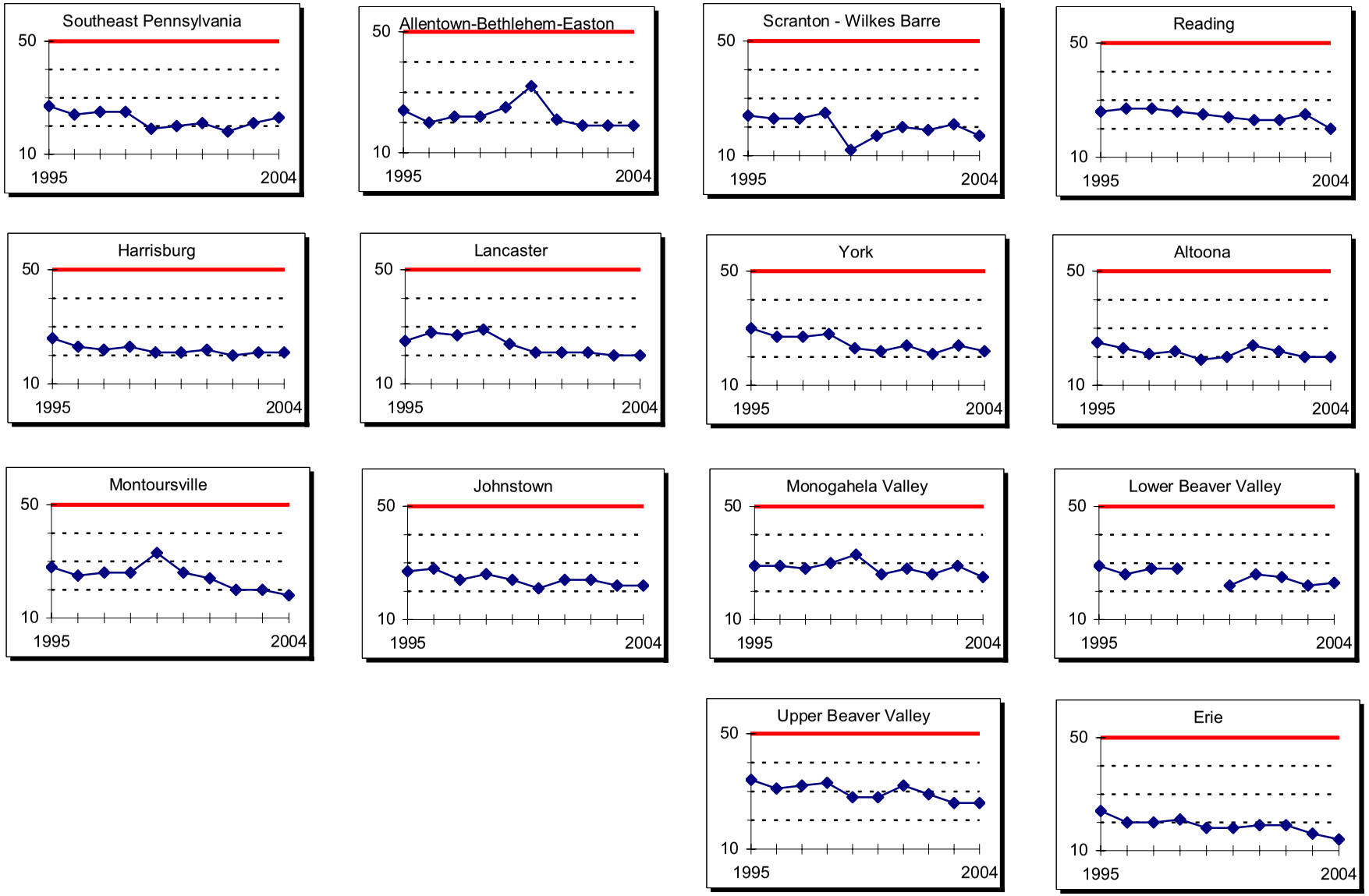
Figure 2-8. PM-10 Trends in Pennsylvania 1995 to 2004
Annual Arithmetic Means (micrograms per cubic meter)



PM-10 Annual National Ambient Air Quality Standard is 50 micrograms per cubic meter

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$PM_{2.5}$ Suspended Particulate Matter

Particulate matter (PM) is the general term used for a mixture of solid particles and liquid droplets found in the air. These particles, which come in a wide range of sizes, may be emitted directly by a source or formed in the atmosphere. Fine particles are those that are less than 2.5 micrometers in diameter ($PM_{2.5}$). Fine particles can accumulate in the respiratory system and are associated with numerous adverse health effects including decreased lung function and increased respiratory symptoms and disease. Sensitive groups that appear to be at greatest risk include the elderly, individuals with cardiopulmonary disease such as asthma, and children. Particulate matter also can cause adverse impacts to the environment. $PM_{2.5}$ is the major cause of reduced visibility in parts of the United States. Other environmental impacts occur when particles deposit onto soil, plants, water, or man-made materials such as monuments or statues.

The $PM_{2.5}$ concentrations are measured using both discrete (single sample) monitors and continuous real-time instruments. The discrete monitors collect particulate matter on a filter for 24 hours. The filter is then collected and shipped to the lab to be weighed.

The continuous Tapered Element Oscillating Microbalance (TEOM) monitor is a gravimetric instrument that draws ambient air through a filter, constantly weighing the filter and calculating real-time $PM_{2.5}$ concentrations. The analyzer reports 1-hour data, which are then used to calculate daily 24-hour averages (midnight to midnight), for comparison to the ambient air quality standard.

The continuous Beta-Attenuation Mass (BAM) sampler draws ambient air through a section of filter tape. The filter tape passes between a beta ray source and a beta ray detector. As the particulate mass on the filter increases, the number of beta ray particles transmitted through the filter decreases. So the detector measures the number of beta particles transmitted through the exposed filter tape, and then the instrument calculates the particulate mass using a correlation equation. The analyzer reports 1-hour data, which are then used to calculate daily 24-hour averages (midnight to midnight), for comparison to the ambient air quality standard.

Nine of the DEP monitoring sites have both discrete manual and continuous samplers, but only the discrete $PM_{2.5}$ sampler is approved by EPA as a Federal Reference Method (FRM) for compliance purposes.

The map in Figure 2-9 shows the range of $PM_{2.5}$ annual mean levels in the different counties across the Commonwealth where monitoring is performed. When there are multiple samplers in a county, the highest FRM monitor reading is used. Only sites that have monitored 50 percent of the time during 2004 are included in this figure. In 2004, six counties monitored by DEP exceeded the annual $PM_{2.5}$ standard.

The map in Figure 2-10 displays the highest 98th percentile 24-hour PM2.5 mean by county. When there are multiple samplers in a county, the highest FRM monitor reading is used. In 2004,no counties monitored by DEP exceeded the 24-hour $PM_{2.5}$ standard.

With only six complete years of data collected, no graphical trend analysis is available. Data collected in 2004 is summarized in Appendix A, Table A-9 for all FRM monitors and continuous monitors. Historical trend data for each site that was monitored in 2004 is shown in Appendix A, Table A-10. Six of the FRM monitoring sites exceeded the annual air quality standard, and none of the FRM sites exceeded the 24-hour air quality standard in 2004.

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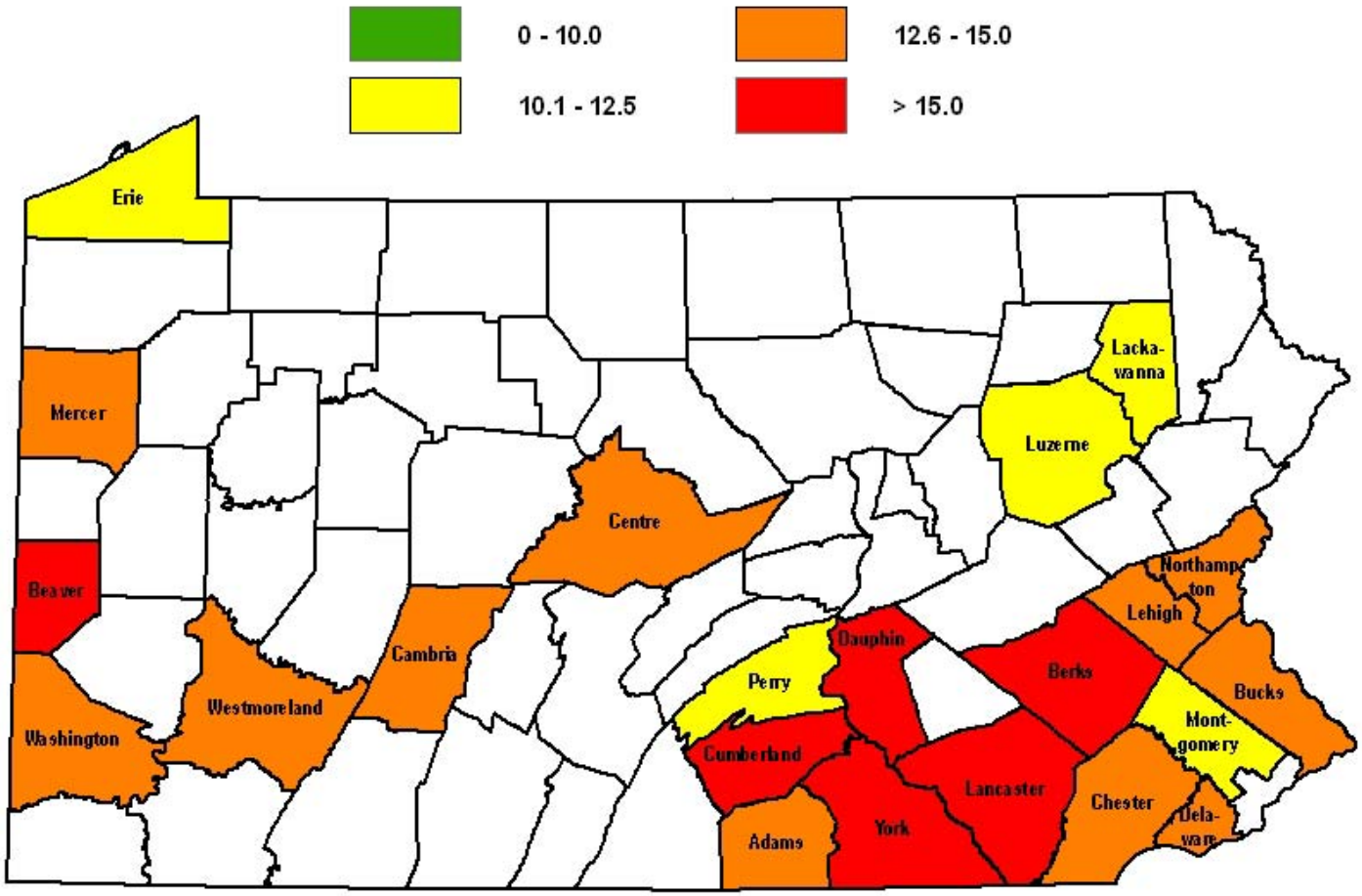
Figure 2-9. PM-2.5 Concentrations

Annual Mean (Average by County, for 2004)

(Micrograms per Cubic Meter)



Primary and Secondary National Ambient Air Quality Standard for PM-2.5
Annual Mean = 15 micrograms per cubic meter
(Data are displayed for single calendar year, but standard is based on a 3-year average)

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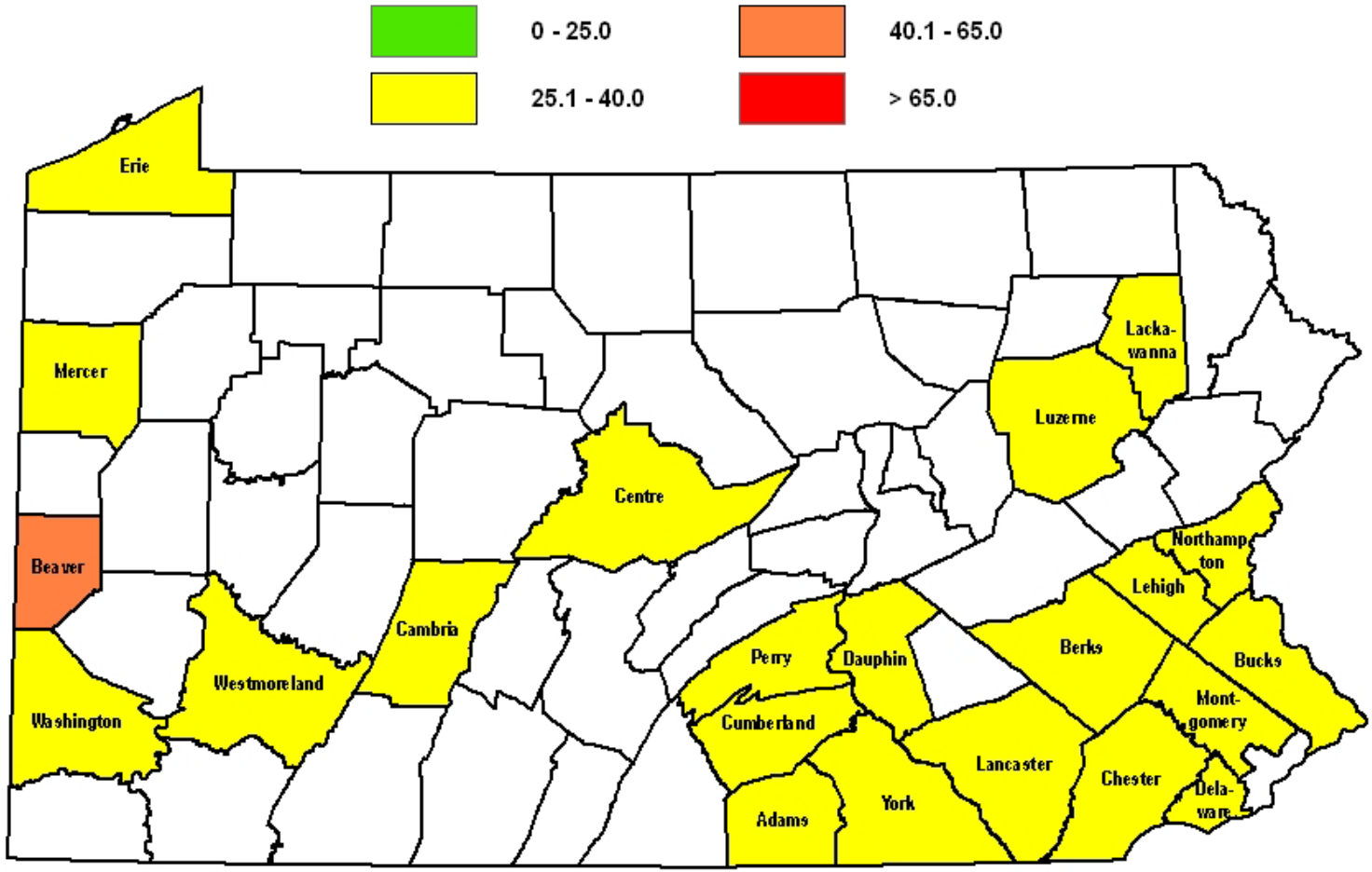
Figure 2-10. PM-2.5 Concentrations

98th Percentile 24-Hour Daily Mean (by County, for 2004)

(Micrograms per Cubic Meter)



Primary and Secondary National Ambient Air Quality Standard for PM-2.5
98th Percentile 24-Hour Mean = 65 micrograms per cubic meter.
(Data are displayed for a single calendar year, but standard is based on a 3-year average)

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Chemical Speciation of $PM_{2.5}$ Suspended Particulate Matter

Particulate matter (PM) is a general term used for a mixture of solid particles and liquid droplets (also known as aerosols) found in the air. $PM_{2.5}$ refers to particulate matter that is 2.5 micrometers or smaller in size. For reference, 2.5 micrometers is approximately 1/30 the size of a human hair. Speciation is a physical or chemical analysis of the captured particles that provide a first order characterization of the metals, ions, and carbon constituents of $PM_{2.5}$.

Physical and chemical speciation data can be used to support several areas of study as:

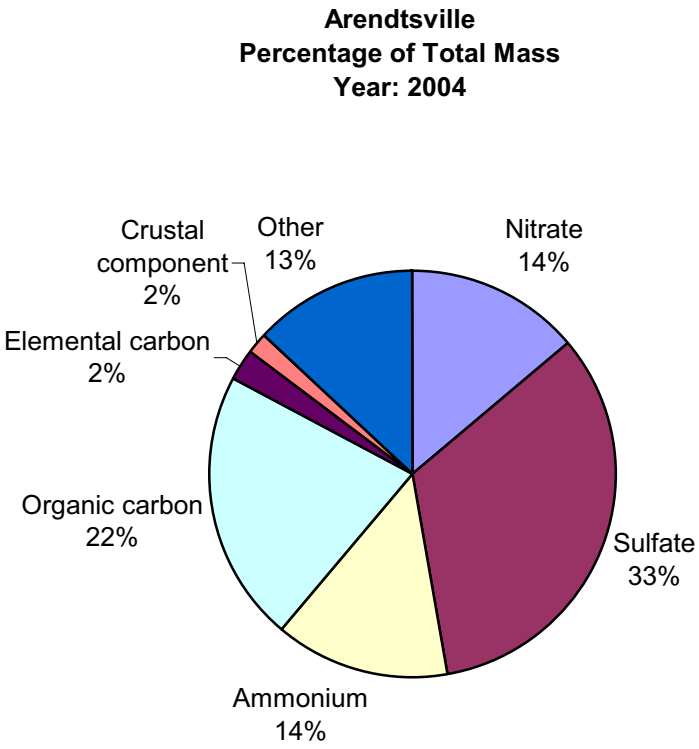
- Inputs to air quality modeling analyses used to implement the $PM_{2.5}$ standard;
- Indicators to track the progress of air pollution controls;
- Aids to interpret studies linking health effects to $PM_{2.5}$ constituents;
- Aids to understand the effects of atmospheric constituents on visibility impairment; and
- Aids in designing and siting monitoring networks.

PM2.5 is composed of a mixture of primary and secondary particles, both having long lifetimes in the atmosphere (days to weeks), traveling long distances (hundreds to thousands of kilometers) and hence, not easily traced back to their individual sources. Primary particles include soil-related particles such as road dust, construction and agriculture and combustion-related particles. Combustion-related particles come from a variety of sources such as diesel and gasoline vehicles, open burning operations, and utility and commercial boilers. The principle types of secondary aerosols are organics, sulfates and nitrates. Sulfur dioxide, nitrogen oxides and ammonia (ammonium sulfate, ammonium bisulfate, ammonium nitrate) are important precursors to secondary particles.

Knowing the chemical composition of the $PM_{2.5}$ mix is also important for determining sources of pollution. By developing seasonal and annual chemical characterizations of ambient particulates across the nation, this speciation data will be used to perform source attribution analyses, evaluate emission inventories and air quality models, and support health related research studies and regional haze assessments.

Pennsylvania began operating a $PM_{2.5}$ speciation network, consisting of 13 sampling sites, in April 2002. The pie charts on the following pages, Figures 2-11 to 2-17 show the major constituents, consisting of nitrates, sulfates, ammonium, organic carbon, elemental carbon and other trace elements.

Figure 2-11. $PM_{2.5}$ Speciation Pie Charts for Arendtsville and Chester



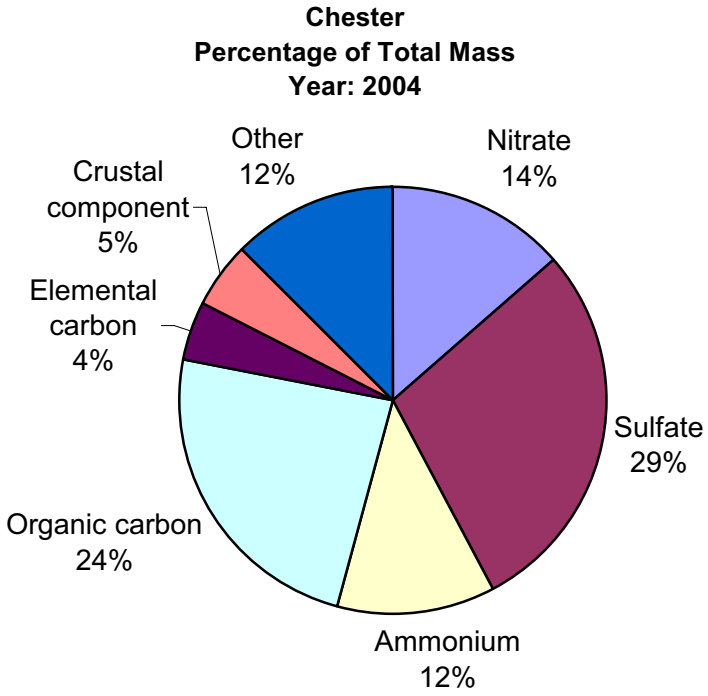
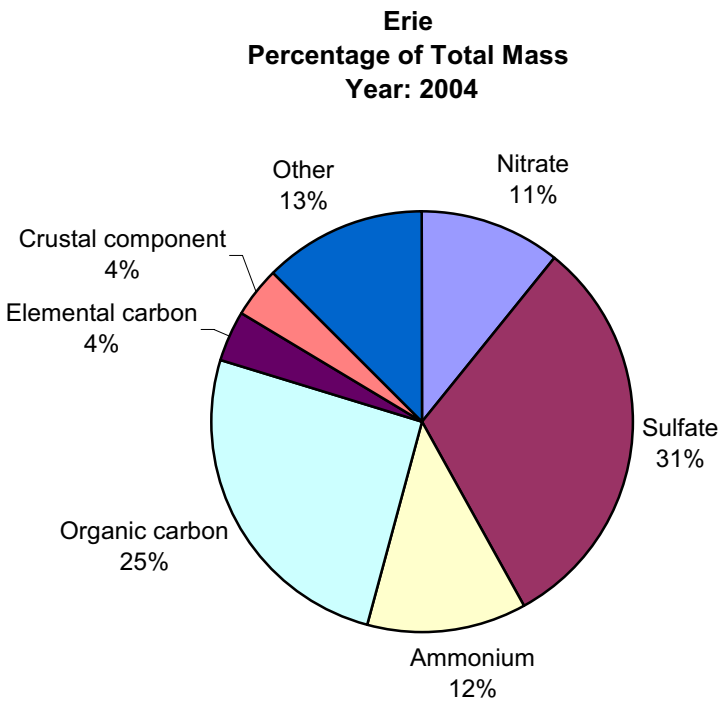


Figure 2-12. $PM_{2.5}$ Speciation Pie Charts for Erie and Florence



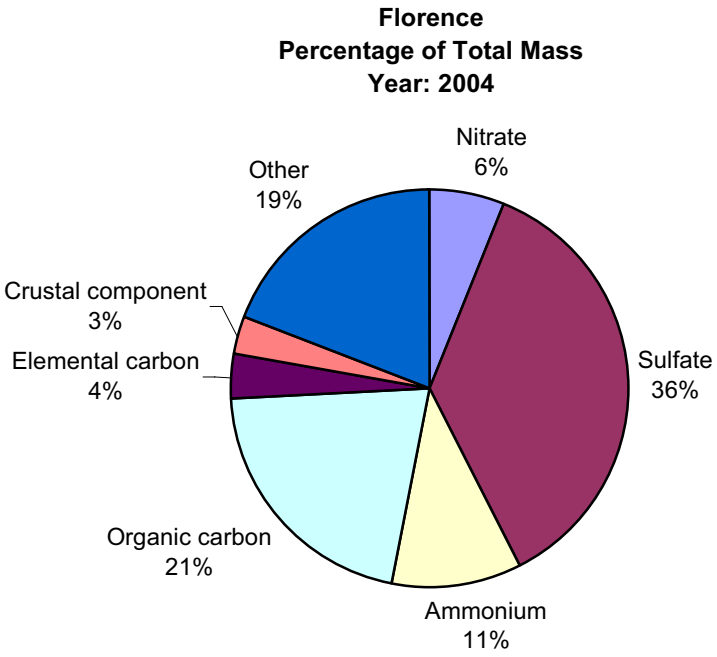
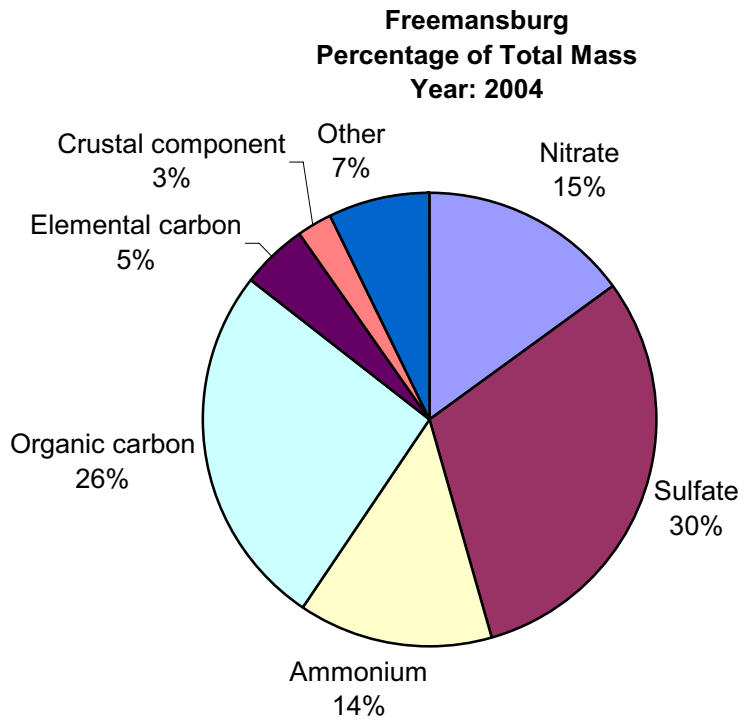


Figure 2-13. $PM_{2.5}$ Speciation Pie Charts for Freemansburg and Greensburg



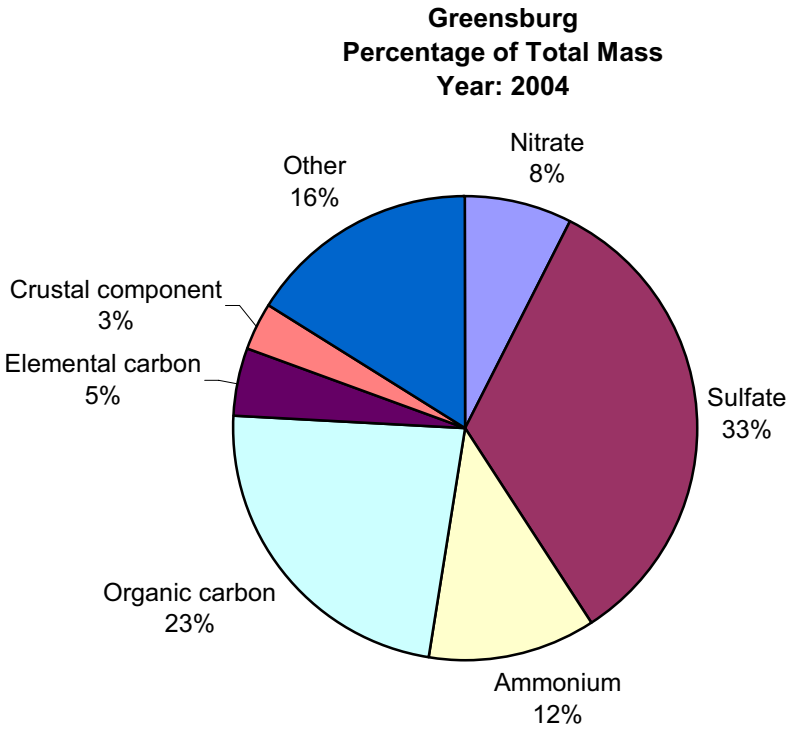
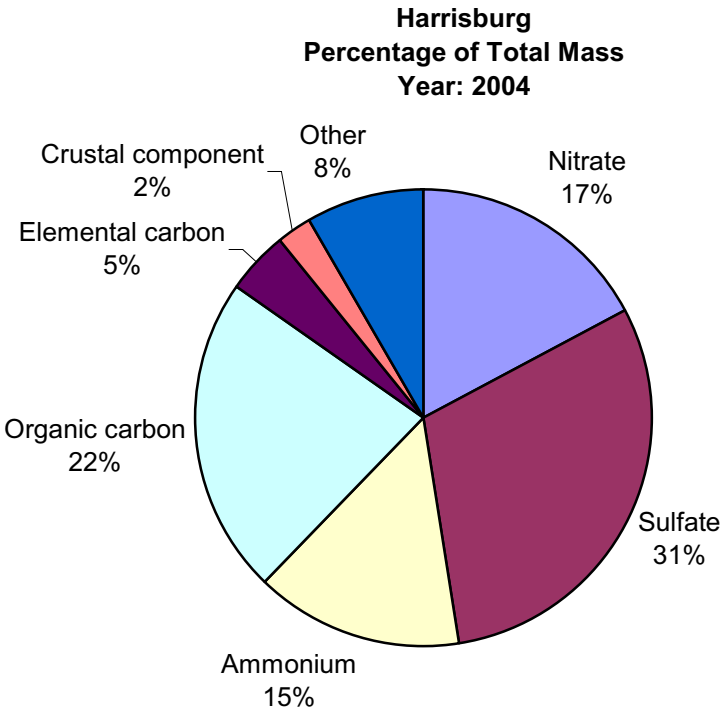


Figure 2-14. $PM_{2.5}$ Speciation Pie Charts for Harrisburg and Lancaster



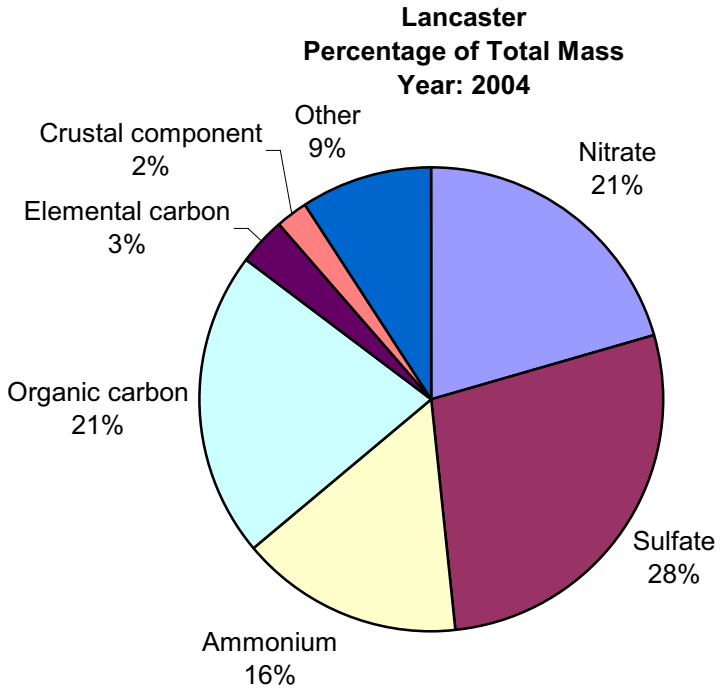
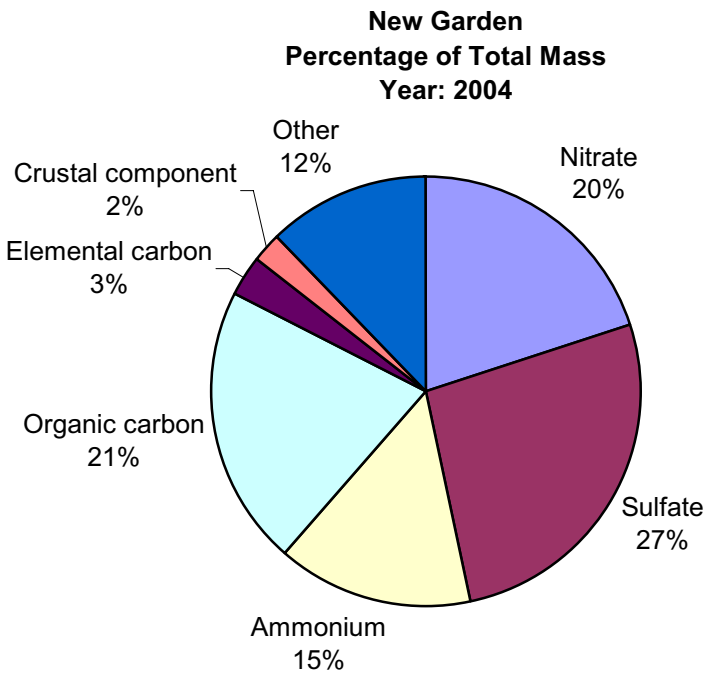


Figure 2-15. $PM_{2.5}$ Speciation Pie Charts for New Garden and Perry County



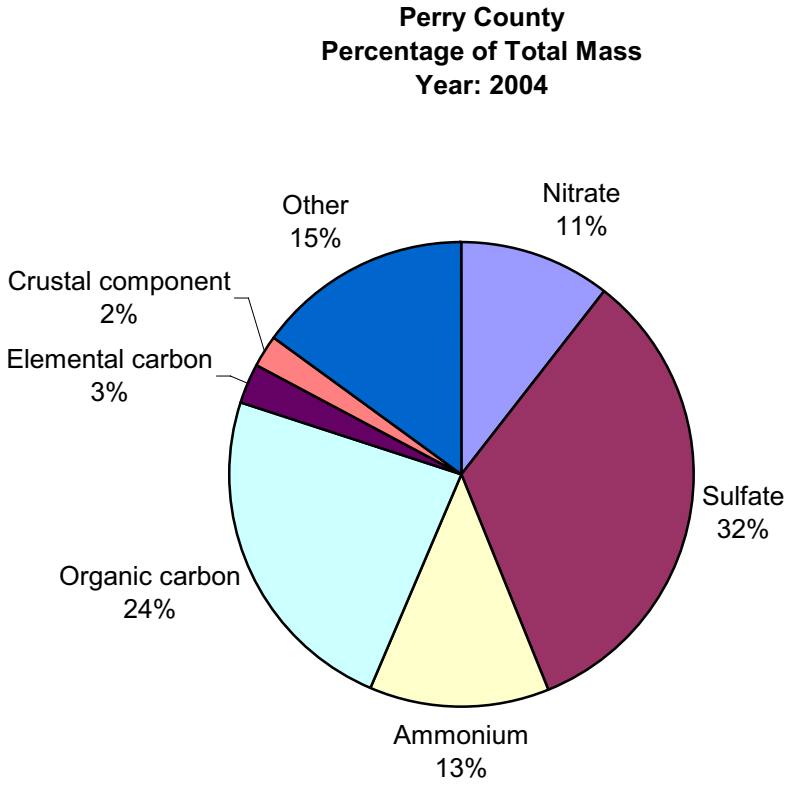
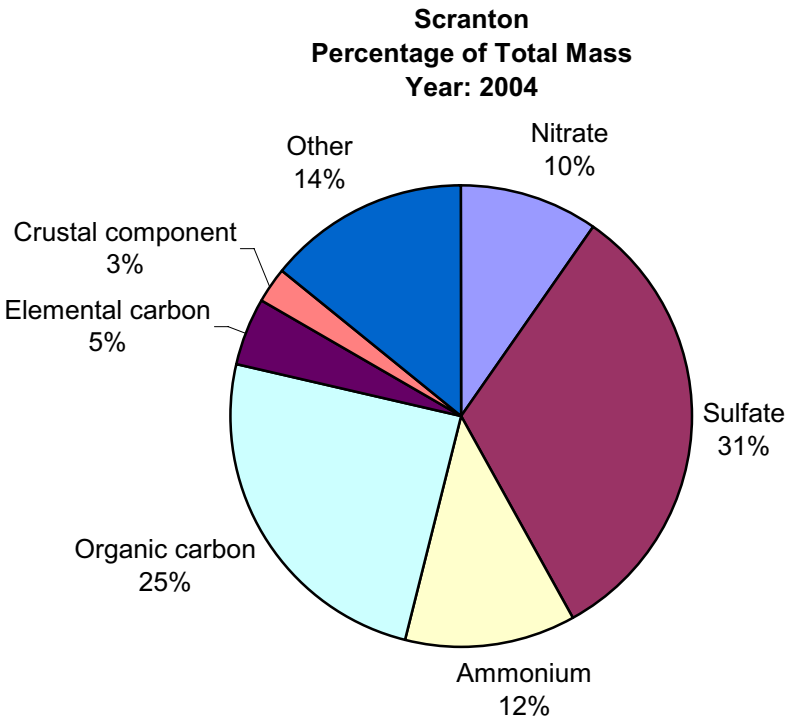


Figure 2-16. $PM_{2.5}$ Speciation Pie Charts for Scranton and State College



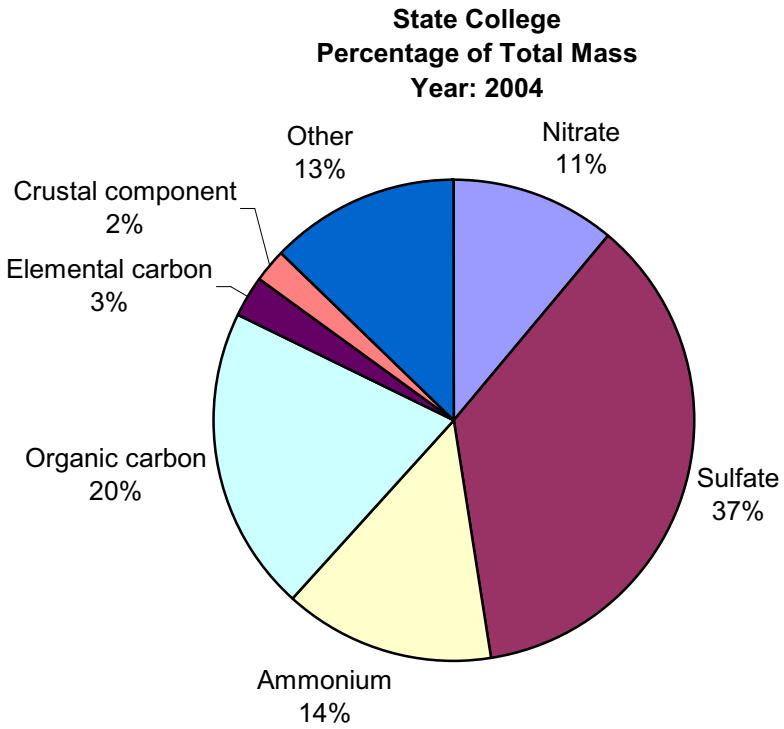


Figure 2-17. $PM_{2.5}$ Speciation Pie Chart for York