Particulate Matter Concentrations

"Particulate matter" (PM) is the general term used for a mixture of solid particles and liquid droplets found in the air. Airborne PM comes from many different sources. "Primary" particles are released directly into the atmosphere from sources such as cars, trucks, heavy equipment, forest fires, and burning waste. Primary particles also consist of crustal material from sources such as unpaved roads, stone crushing, construction sites, and metallurgical operations. "Secondary" particles are formed in the air from reactions involving precursor chemicals such as sulfates (which are formed from sulfur dioxide emissions from power plants and industrial facilities), nitrates (which are formed from nitrogen dioxide emissions from cars, trucks, and power plants), and carbon-containing reactive organic gas emissions from cars, trucks, industrial facilities, forest fires, and biogenic sources such as trees.

Ambient air monitoring stations throughout the country measure air concentrations of two size ranges of particles: $PM_{2.5}$ and PM_{10}. $PM_{2.5}$ consists of "fine particles" with aerodynamic diameters less than or equal to 2.5 microns (μm). PM_{10} includes both fine particles ($PM_{2.5}$) and "coarse particles," which is the subset of PM_{10} that is larger than 2.5 μm and smaller than 10 μm. The chemical makeup of particles varies across the U.S. For example, fine particles in the eastern half of the U.S. contain more sulfates than those in the West, while fine particles in southern California contain more nitrates than those in other areas of the U.S. Carbon is a substantial component of fine particles everywhere (U.S. EPA, 2004, 2010).

Fine particles also have seasonal patterns. $PM_{2.5}$ values in the eastern half of the U.S. are typically higher in the third calendar quarter (July-September), when sulfates are more commonly formed from sulfur dioxide emissions from power plants in that part of the country. Fine particle concentrations tend to be higher in the fourth calendar quarter (October-December) in many areas of the West, in part because fine particle nitrates are more readily formed in cooler weather, and wood stove and fireplace use produces more carbon.

Many recent epidemiologic studies show statistically significant associations of various ambient PM indicators (e.g., coarse or fine particulate, short-term or long-term concentrations) with a variety of cardiovascular and respiratory health endpoints, including mortality, hospital admissions, emergency department visits, other medical visits, respiratory illness and symptoms, and physiologic changes in pulmonary function (U.S. EPA, 2009). Sensitive groups that appear to be at greatest risk to such PM effects include older adults, individuals with cardiopulmonary disease such as asthma or congestive heart disease, and children (U.S. EPA, 2009). Unlike other criteria pollutants, PM is not a single specific chemical entity, but rather a mixture of particles from different sources with different sizes and chemical compositions. Toxicological studies suggest that some airborne particles are more toxic than others, due to differences in their chemical composition—a topic that is thoroughly reviewed in other publications (e.g., U.S. EPA, 2009).

PM also can cause adverse impacts to the environment. Fine particles are the major cause of reduced visibility in parts of the U.S., including many National Parks and Wilderness Areas (the Regional Haze indicator). PM deposition affects vegetation and ecosystems by altering nutrient and chemical cycles in soils and surface water. For example, deposition of particles containing nitrogen and sulfur may change the nutrient balance and acidity of aquatic environments so that species composition and buffering capacity change (the Lake and Stream Acidity indicator). Some particles that deposit onto plant leaves can corrode leaf surfaces or interfere with plant metabolism. PM also causes soiling and erosion damage to materials, including monuments, statues, and other objects of cultural

importance (U.S. EPA, 2009).

This indicator presents trends in PM_{10} and $PM_{2.5}$ concentrations, using averaging times consistent with the pollutants' corresponding National Ambient Air Quality Standards (NAAQS). For PM_{10}, trend data from 1988 to 2011 are presented for the second highest 24-hour concentrations measured at the trend sites during each calendar year. For $PM_{2.5}$, trend data from 1999 to 2011 are presented both for seasonally weighted annual average concentrations and for the 98^{th} percentiles of 24-hour average concentrations measured at the trend sites over three consecutive calendar years. Trend data are based on measurements from the State and Local Air Monitoring Stations network and from other special purpose monitors. This indicator presents PM_{10} trends for 197 monitoring sites in 131 counties nationwide and $PM_{2.5}$ trends for 583 monitoring sites in 414 counties nationwide. For both PM_{10} and $PM_{2.5}$, the indicator displays trends for the entire nation and for the ten EPA Regions.

The indicator's exhibits display the pollutants' NAAQS as points of reference. However, the fact that the national values or those shown for EPA Regions fall below the standards does not mean that all monitoring sites nationally or in any particular EPA Region also are below the standards. The indicator displays trends in the number of PM_{10} monitoring sites and $PM_{2.5}$ monitoring sites nationwide that recorded ambient air concentrations above the level of the standards, but these statistics are not displayed for each EPA Region.

What the Data Show

PM_{10} Concentration Trends

In 2011, the national 24-hour PM_{10} concentration (based on the second highest 24-hour concentration at each site) was 41 percent lower than the average 1988 level (Exhibit 1). Additionally, of the 197 sites used to determine this trend (out of 765 total monitoring sites that were operating in 2011), the number reporting PM_{10} concentrations above the level of the 24-hour standard declined 77 percent between 1988 and 2011 (Exhibit 2). All EPA Regions, except Region 6, experienced a steady decrease in 24-hour PM_{10} levels over this period (Exhibit 3). EPA Region 10 showed the greatest relative decrease (84 percent) since 1988.

Also shown in Exhibit 1 are the 90^{th} and 10^{th} percentiles based on the distribution of annual statistics at the monitoring sites. This provides additional graphical representation of the distribution of measured concentrations across the monitoring sites for a given year. Thus, the graphic displays the concentration range where 80 percent of measured values occurred for that year. (Note that this presentation style also applies to Exhibits 4 and 7, discussed below.)

$PM_{2.5}$ Concentration Trends

The seasonally weighted annual average $PM_{2.5}$ concentrations decreased 28 percent between the 1999-2001 averaging period and the 2009-2011 averaging period (Exhibit 4). This trend is based on measurements collected at 583 monitoring stations that have sufficient data to assess trends over that period. The number of monitoring sites in this trend (583 out of 764 total sites that were operating in 2011) reporting ambient air concentrations above the level of the annual average $PM_{2.5}$ standard decreased by 83 percent over this period (Exhibit 5). Regional declines were greatest in EPA Region 9, where seasonally weighted average $PM_{2.5}$ levels over the 2009-2011 averaging period were all 34 percent lower than those in the 1999-2001 averaging period (Exhibit 6).

In 2009-2011, the average of 98^{th} percentiles of 24-hour $PM_{2.5}$ concentrations at the 583 monitoring sites used for the trend was 30 percent lower than the 1999-2001 level (Exhibit 7). The number of monitoring sites in this trend (583 out of a total of 778 sites that were operating in 2011) reporting ambient air concentrations above the level of the 24-hour $PM_{2.5}$ standard declined 88

percent over this period (Exhibit 8). All ten EPA Regions experienced decreasing 24-hour $PM_{2.5}$ levels between the 1999-2001 averaging period and the 2009-2011 averaging period, with Region 9 showing the largest decline (40 percent) (Exhibit 9).

Limitations

- Because there are far more PM_{10} and $PM_{2.5}$ monitors in urban areas than in rural areas, the trends might not accurately reflect conditions outside the immediate urban monitoring areas.
- PM_{10} and $PM_{2.5}$ measurement data are based on monitoring methods that are consistent with those used to establish EPA's health-related standards. These "indicator" measurements provide mass concentrations that may be different than the concentrations of particulate matter (PM_{10} and $PM_{2.5}$) in the ambient air. These potential differences are due to losses from volatilization of nitrates and other semi-volatile materials and retention of particle-bound water associated with hygroscopic species. A study of six locations in the Eastern U.S. showed that the net difference was less than 10 percent (Frank, 2006).
- Due to the relatively small number of monitoring sites in some EPA Regions, the regional trends are subject to greater uncertainty than the national trends. Some EPA Regions with low average concentrations may include areas with high local concentrations, and vice versa. In addition, the trend sites in this indicator are not dispersed uniformly across all states in the EPA Regions. For instance, the 197 PM_{10} trend sites are located in 36 states. In the remaining 14 states, there currently are insufficient long-term data from the existing PM_{10} monitoring sites to include in this indicator. In contrast, the 583 $PM_{2.5}$ trend sites are located in all 50 states.
- To ensure that long-term trends are based on a consistent set of monitoring sites, selection criteria were applied to identify the subset of PM monitoring sites with sufficient data to assess trends over the time frames covered by this indicator. Monitoring sites without sufficient data are not included in the trend analysis. Some excluded monitoring sites reported PM concentrations above the level of the PM standard during the years covered by this indicator. In 2011, for example, 67 monitoring sites nationwide recorded 24-hour PM_{10} concentrations above the level of the NAAQS: this includes the five sites shown in Exhibit 2, and 62 sites that did not have sufficient long-term data to be included in this indicator.

Data Sources

Summary data in this indicator were provided by EPA's Office of Air Quality Planning and Standards, based on PM ambient air monitoring data in EPA's Air Quality System (U.S. EPA, 2012) (http://www.epa.gov/ttn/airs/airsaqs/). National and regional trends in this indicator are based on the subset of PM monitoring stations that have sufficient data to assess trends over the period of record (i.e., since 1988 for PM_{10} and since 1999 for $PM_{2.5}$).

References

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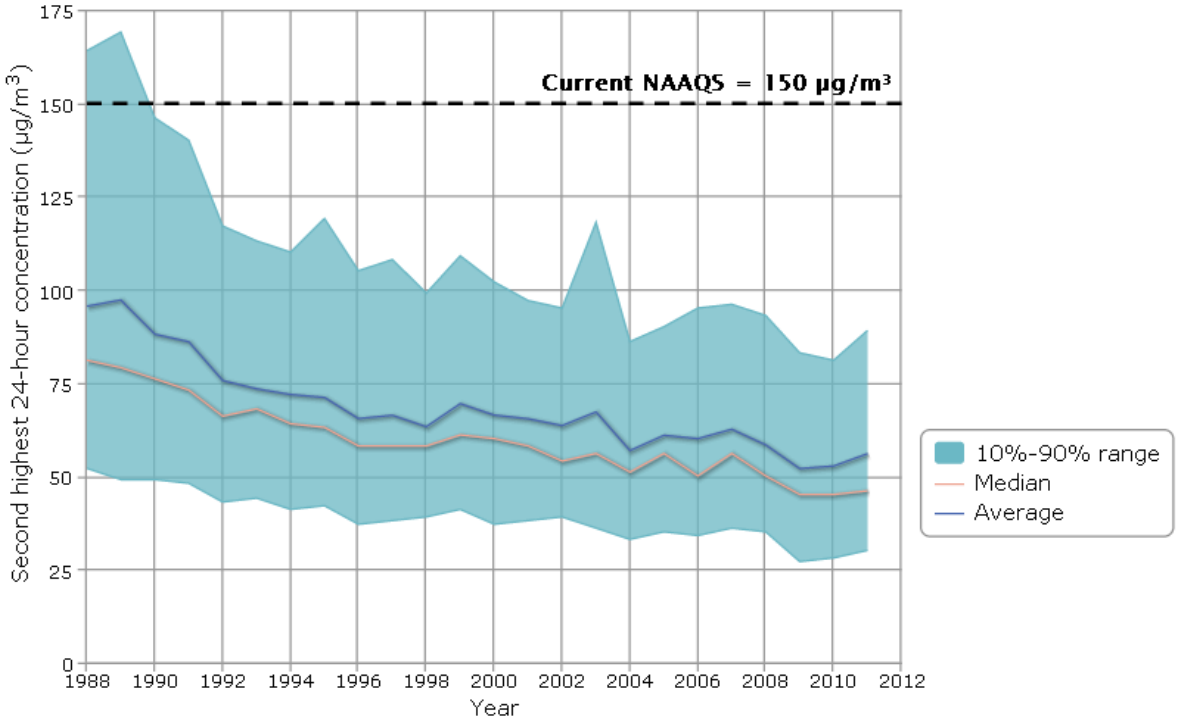
Exhibit 1. Ambient 24-hour PM_{10} concentrations in the U.S., 1988-2011



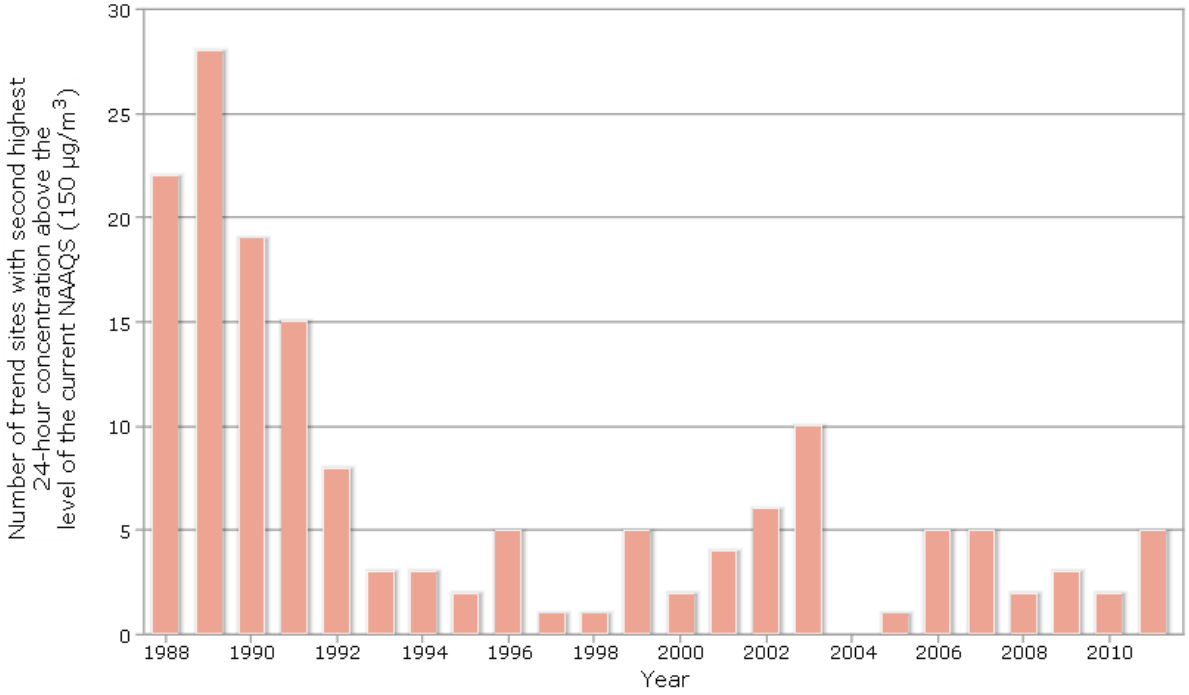
The current 24-hour NAAQS was established in 1987 and has not been revised since (U.S. EPA, 2014).

Coverage: 197 monitoring sites in 131 counties nationwide (out of a total of 765 sites measuring PM_{10} in 2011) that have sufficient data to assess PM_{10} trends since 1988.

Information on the statistical significance of the trend in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2012

Exhibit 2. Ambient 24-hour PM_{10} concentrations above the level of the current NAAQS in the U.S., 1988-2011



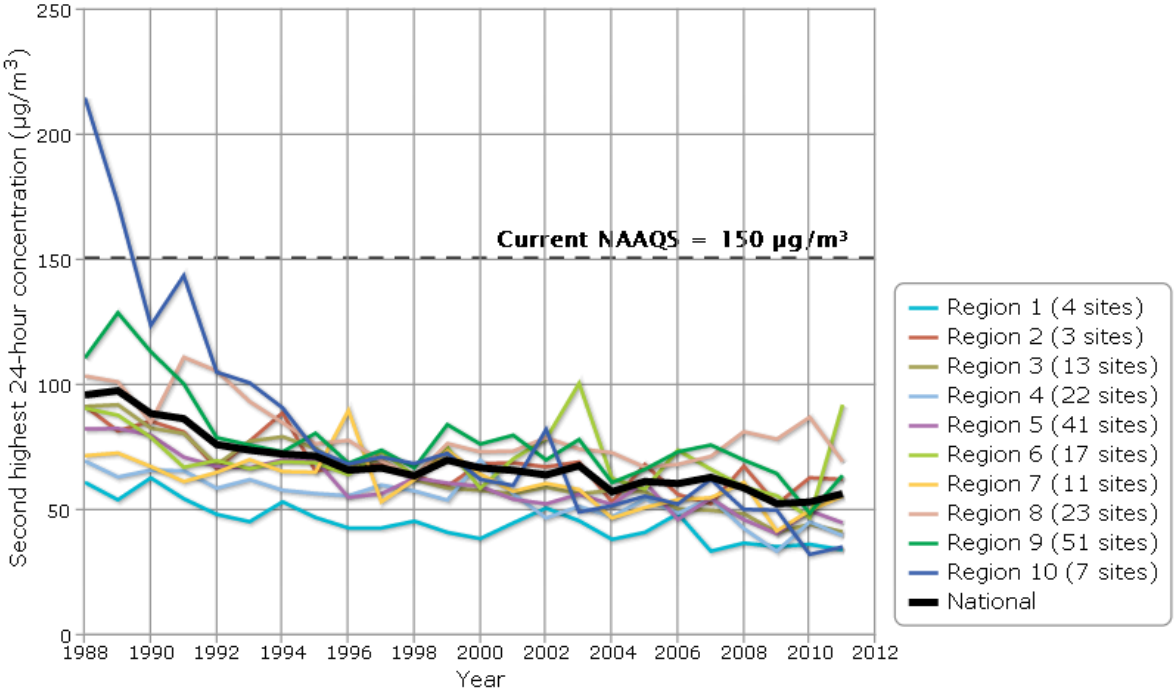
The current 24-hour NAAQS was established in 1987 and has not been revised since (U.S. EPA, 2014).

Coverage: 197 monitoring sites in 131 counties nationwide (out of a total of 765 sites measuring PM_{10} in 2011) that have sufficient data to assess PM_{10} trends since 1988.

Information on the statistical significance of the trend in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2012

Exhibit 3. Ambient 24-hour PM_{10} concentrations in the contiguous U.S. by EPA Region, 1988-2011



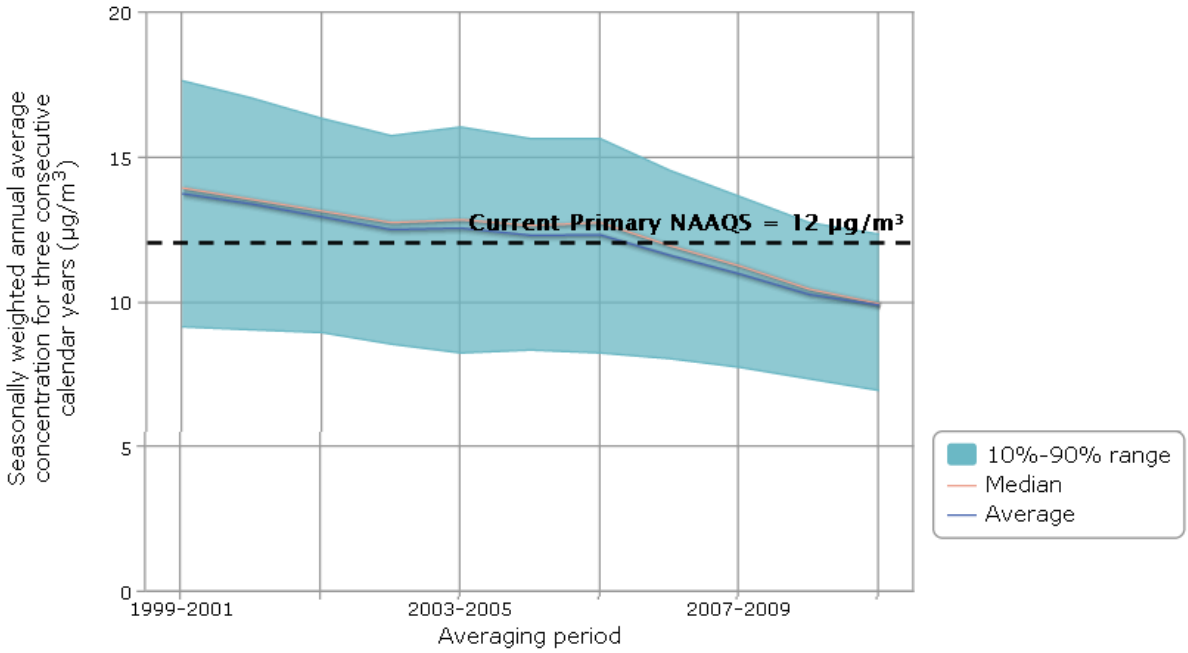
The current 24-hour NAAQS was established in 1987 and has not been revised since (U.S. EPA, 2014).

Coverage: 192 monitoring sites in the EPA Regions (out of a total of 765 sites measuring PM_{10} in 2011) that have sufficient data to assess PM_{10} trends since 1988.

Information on the statistical significance of the trends in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2012

Exhibit 4. Ambient annual $PM_{2.5}$ concentrations in the U.S., 1999-2011



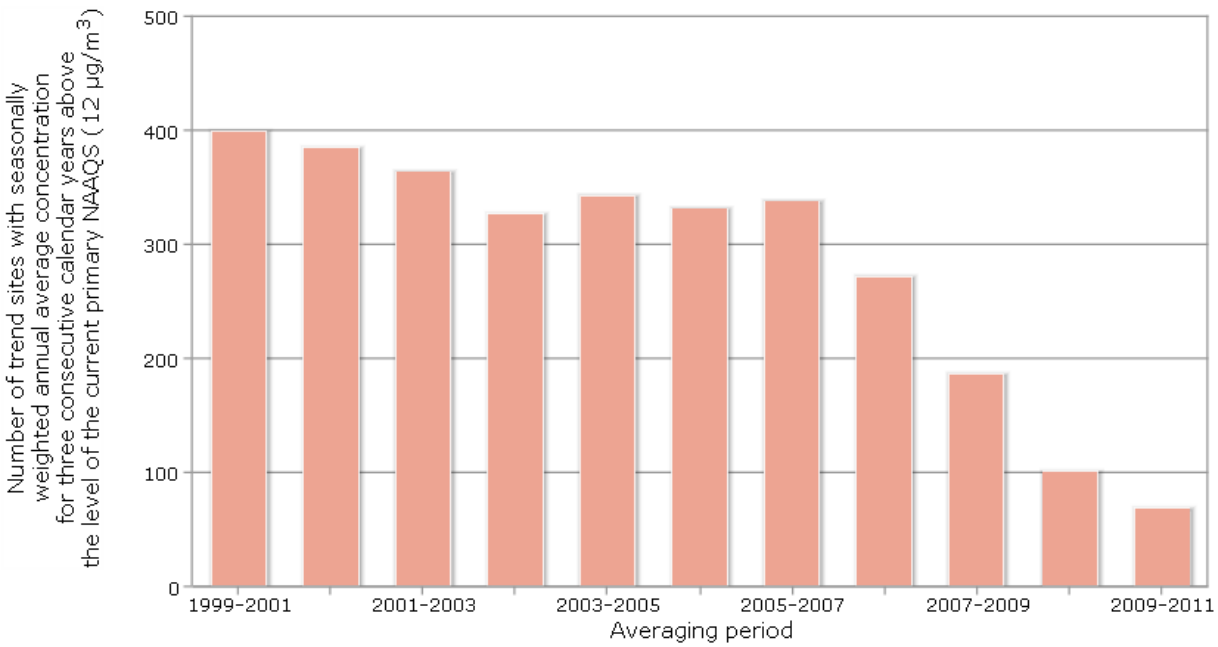
The current NAAQS was established in 2012 and is shown to provide context for the magnitude of pollutant concentrations. It is more stringent than all previous NAAQS (e.g., the concentration levels for the previous NAAQS are higher) (U.S. EPA, 2014).

Coverage: 583 monitoring sites in 414 counties nationwide (out of a total of 764 sites measuring $PM_{2.5}$ in 2011) that have sufficient data to assess $PM_{2.5}$ trends since 1999.

Information on the statistical significance of the trend in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2012

Exhibit 5. Ambient annual $PM_{2.5}$ concentrations above the level of the current primary NAAQS in the U.S., 1999-2011



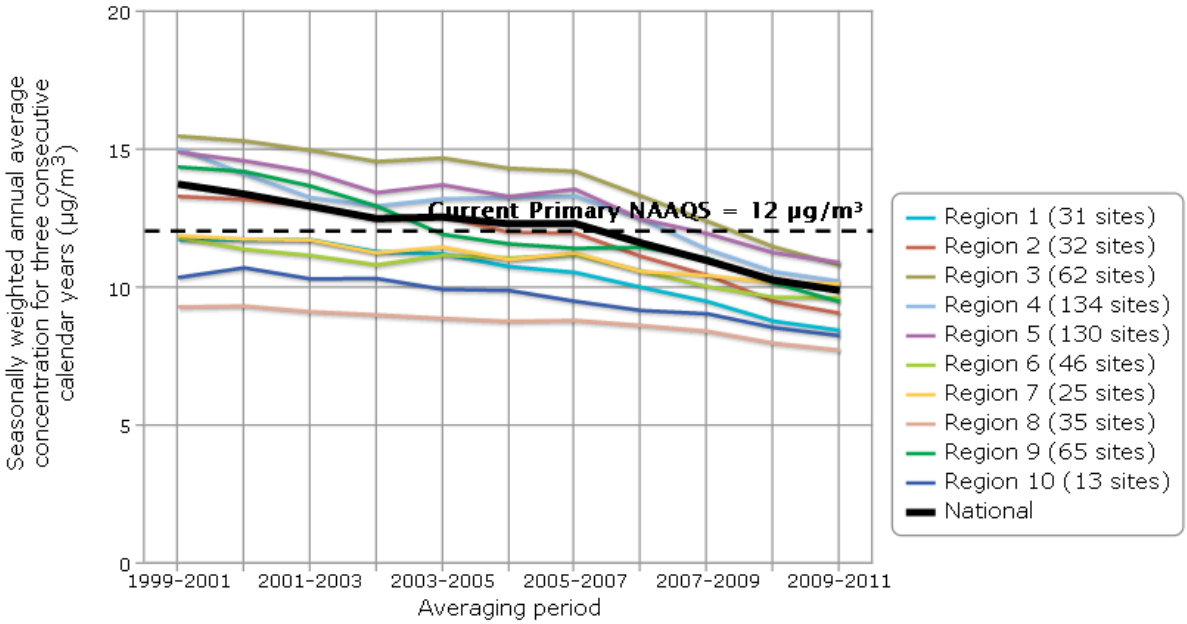
The current primary NAAQS was established in 2012 and is shown to provide context for the magnitude of pollutant concentrations. It is more stringent than all previous NAAQS (e.g., the concentration levels for the previous NAAQS are higher) (U.S. EPA, 2014).

Coverage: 583 monitoring sites in 414 counties nationwide (out of a total of 764 sites measuring $PM_{2.5}$ in 2011) that have sufficient data to assess $PM_{2.5}$ trends since 1999.

Information on the statistical significance of the trend in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2012

Exhibit 6. Ambient annual $PM_{2.5}$ concentrations in the contiguous U.S. by EPA Region, 1999-2011



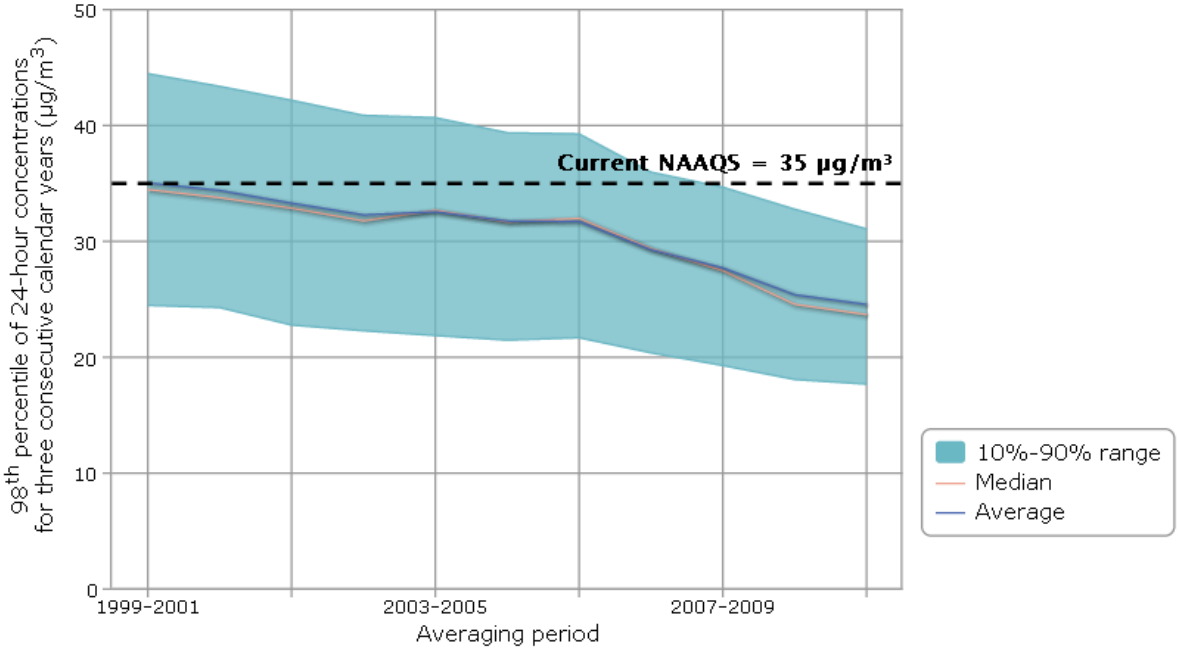
The current NAAQS was established in 2012 and is shown to provide context for the magnitude of pollutant concentrations. It is more stringent than all previous NAAQS (e.g., the concentration levels for the previous NAAQS are higher) (U.S. EPA, 2014).

Coverage:573 monitoring sites in EPA Regions (out of a total of 764 sites measuring $PM_{2.5}$ in 2011) that have sufficient data to assess $PM_{2.5}$ trends since 1999.

Information on the statistical significance of the trends in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2012

Exhibit 7. Ambient 24-hour $PM_{2.5}$ concentrations in the U.S., 1999-2011



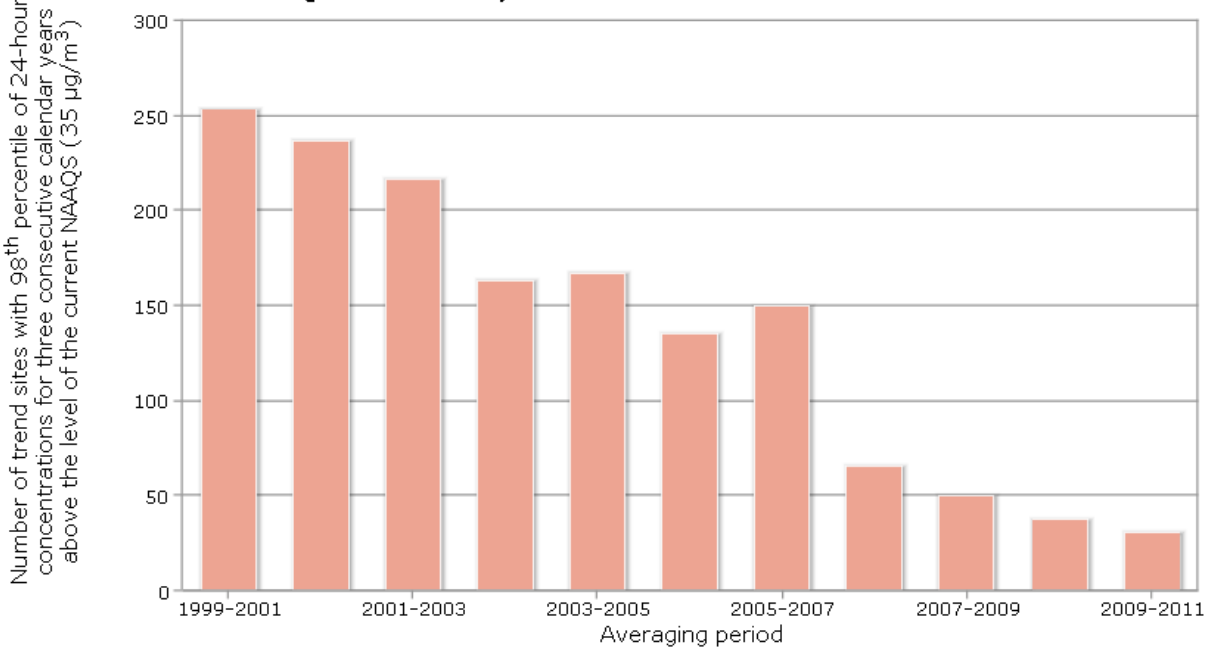
The current NAAQS was established in 2006 and is shown to provide context for the magnitude of pollutant concentrations. It is more stringent than all previous NAAQS (e.g., the concentration levels for the previous NAAQS are higher) (U.S. EPA, 2014).

Coverage: 583 monitoring sites in 414 counties nationwide (out of a total of 778 sites measuring $PM_{2.5}$ in 2011) that have sufficient data to assess $PM_{2.5}$ trends since 1999.

Information on the statistical significance of the trend in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2012

Exhibit 8. Ambient 24-hour $PM_{2.5}$ concentrations above the level of the current NAAQS in the U.S., 1999-2011



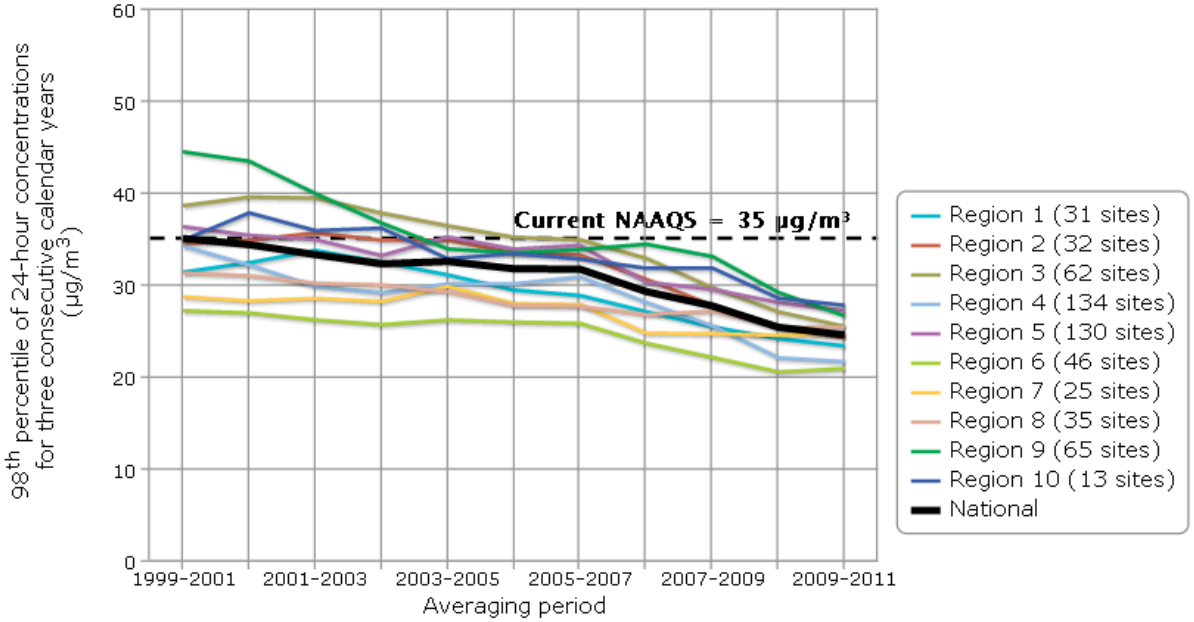
The current NAAQS was established in 2006 and is shown to provide context for the magnitude of pollutant concentrations. It is more stringent than all previous NAAQS (e.g., the concentration levels for the previous NAAQS are higher) (U.S. EPA, 2014).

Coverage: 583 monitoring sites in 414 counties nationwide (out of a total of 778 sites measuring $PM_{2.5}$ in 2011) that have sufficient data to assess $PM_{2.5}$ trends since 1999.

Information on the statistical significance of the trend in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2012

Exhibit 9. Ambient 24-hour $PM_{2.5}$ concentrations in the contiguous U.S. by EPA Region, 1999-2011



The current NAAQS was established in 2006 and is shown to provide context for the magnitude of pollutant concentrations. It is more stringent than all previous NAAQS (e.g., the concentration levels for the previous NAAQS are higher) (U.S. EPA, 2014).

Coverage: 573 monitoring sites in the EPA Regions (out of a total of 778 sites measuring $PM_{2.5}$ in 2011) that have sufficient data to assess $PM_{2.5}$ trends since 1999.

Information on the statistical significance of the trends in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2012