Fine Particles (PM2.5)

Background

Particulate matter (PM) consists of both solid particles and liquid droplets, and is generally categorized according to the size of the particles. Particles that are approximately 10 micrometers (µm) or larger in diameter usually are trapped along a person's respiratory tract before reaching the lungs. Particles less than 10 µm (PM10) can reach the lungs. Of greatest concern are particulate matter less than 2.5 µm in diameter – referred to as fine particles or PM2.5 – which can go deep inside the lungs.

Particles are either directly emitted into the air or formed by reactions of chemicals such as sulfur dioxide (SO_2) and oxides of nitrogen (NO_x) in the atmosphere. Human-made sources of PM2.5 include emissions from wood burning, commercial cooking, fuel combustion such as from motor vehicles, construction equipment and for heating, and from road traffic dust from automobile tire and brake wear. Fine particles can also be produced naturally from gases released by plants and other organisms.

A number of studies have shown an association between concentrations of PM in the air and increased respiratory and cardiovascular health problems and mortality.[1] Persons that appear to be at the greatest risk from exposure to PM include children, the elderly, and individuals with heart and lung diseases, such as asthma.[2] Particles in diesel exhaust, often referred to as diesel "soot", are toxic and are a target of the New Jersey Department of Environmental Protection (NJDEP) risk reduction program.[3] Diesel soot contains many toxics and can be inhaled into the deepest parts of the lungs where it is able to enter the bloodstream. USEPA classifies diesel exhaust as likely to be carcinogenic to humans by inhalation, and the International Agency for Research on Cancer (IARC) classifies it as carcinogenic to humans.[4] In addition to health effects, PM is a major cause of reduced visibility in many parts of the United States. It can also adversely affect vegetation and aquatic ecosystems and can damage buildings and materials.

Pursuant to the Clean Air Act, the United States Environmental Protection Agency (USEPA) established National Ambient Air Quality Standards (NAAQS) for PM2.5. The current PM2.5 standards are expressed as an annual standard of 12 micrograms per cubic meter (µg/m^3) and a 24-hour standard of 35 µg/m^3. New Jersey is currently monitoring compliance with both the annual and 24-hour standards for fine particles. On December 18, 2014, the USEPA issued final area designations for the 2012 annual standard of 12 µg/m^3.[5] USEPA has designated New Jersey as "unclassifiable/ attainment" indicating that no area within New Jersey violates the 2012 standard or contributes to a nearby violation of the standard.

In addition to regulating fine particulate matter emissions to reduce health impacts, the State is working to lower airborne particle levels to improve visibility. Without the effects of pollution, the visual range in the Eastern United States under good weather conditions would be about 90 miles; but, due to the presence of fine particles, the current range is typically 14-24 miles.[6] The Clean Air Act and the 1999 federal Regional Haze rule require states to reach natural levels of visibility by 2064 in 156 national parks and wilderness areas (like the Grand Canyon), including the Brigantine Wilderness area of the Edwin B. Forsythe National Wildlife Refuge in southern New Jersey.

Status and Trends

Monitoring

NJDEP monitors PM2.5 at 21 sites statewide with filter-based samplers that periodically collect 24-hour samples. At 9 sites, concentrations are also measured every minute using continuous PM2.5 instruments and made available at the NJDEP's public website.[7] NJDEP monitors smoke shade at 3 sites. Smoke shade is an old indicator of PM levels based on optical properties and is an indirect measure of particle concentrations.

"Design values" or 3-year averages are the metrics that are compared to the NAAQS levels to determine compliance. Figures 1 and 2 show annual and daily design value trends from 1999-2014 for New Jersey. The existing data show a decreasing trend in PM2.5 concentrations for the annual and 24-hour standards. In 2014, the annual average PM2.5 design values ranged from 7.2 µg/m^3 to 10.6 µg/m^3. The 24-hour design values (98th percentile) ranged from 17 µg/m^3 to 27 µg/m^3.

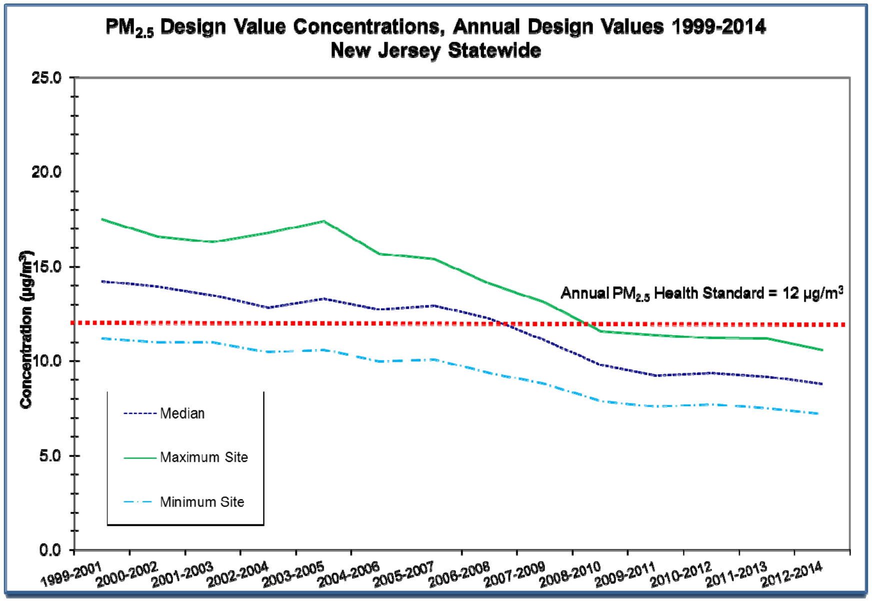

Figure 1

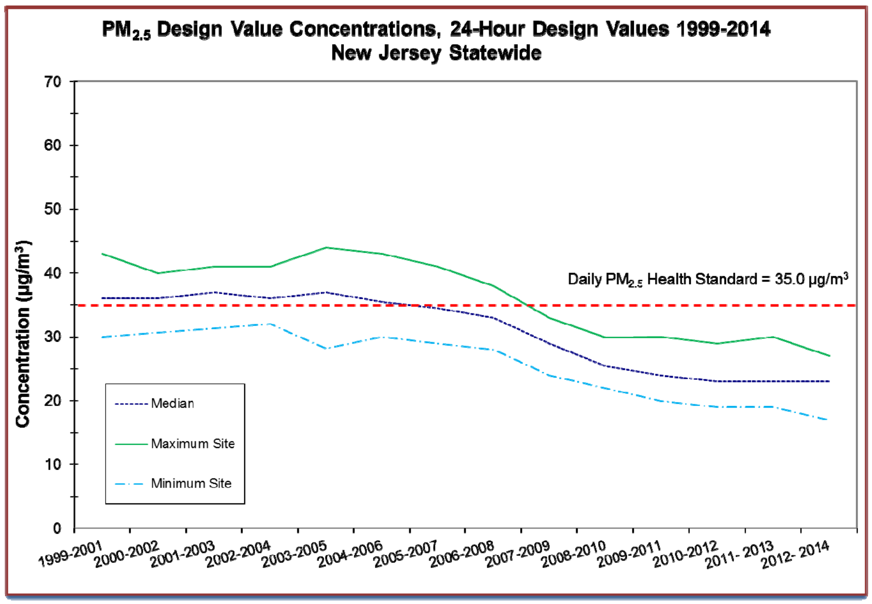

Figure 2

Although the monitoring of smoke shade is an indirect measure of particle concentrations, the monitoring of smoke shade since 1970 provides long term evidence of a consistent decline in particle concentrations in the State (Figure 3). In the early 1970s, the State's average smoke shade concentration was in the range of 1.2 coefficient of haze (COH), a measurement that is based on how much light transmits through the air. Since the mid-1990s, it has consistently remained below 0.4 COH. Concentrations above 2.0 COH are considered unhealthy for sensitive groups according to NJDEP's Web-based Air Quality Index.[8]

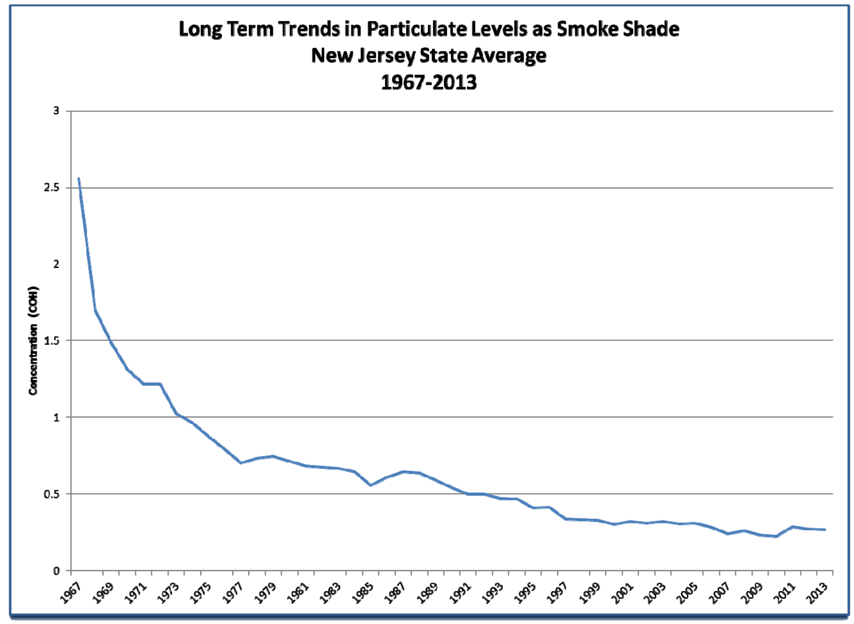

Figure 3

The NJDEP also measures the chemical composition of fine particles at four sites: Elizabeth Lab Site, Newark Firehouse Site, New Brunswick Site, and Chester Site. The Elizabeth Lab and Chester sites are representative of urban and rural areas of the State, respectively. Of the 39 measured analytes, organic carbon, sulfate, nitrate, sulfur, and elemental carbon are the most prevalent species. Combined, they create the majority of the total mass of particles.[9]

As shown in Figures 4 and 5, higher concentrations of carbon (elemental carbon (EC) and organic carbon (OC)) are observed at New Jersey's Elizabeth Lab site compared to the Chester site, due to its proximity to a major roadway and motor vehicle traffic.

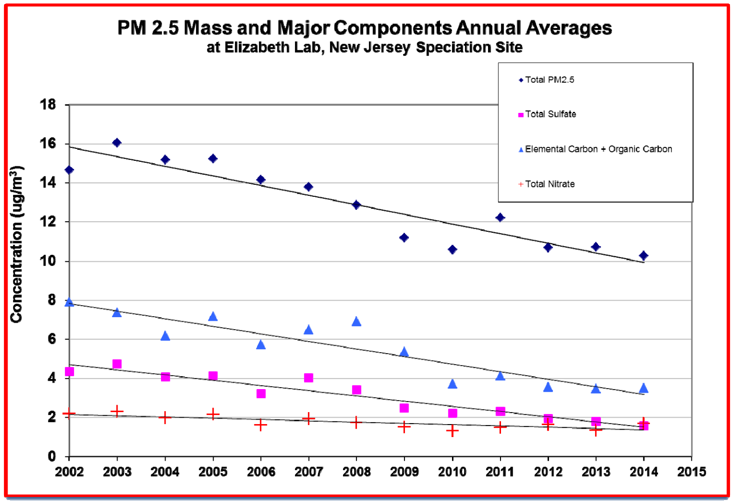

Figure 4: Annual Average PM2.5 Components at Elizabeth.
(The solid lines show the statistically significant trends ($p<0.05$) with time as determined using the Kendall Tau Correlation Test.)

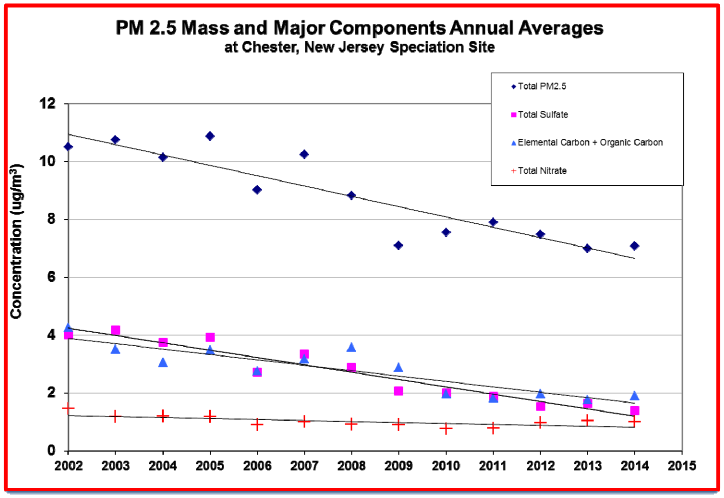

Figure 5: Annual Average PM2.5 Components at Chester.
(The solid lines show the statistically significant trends ($p<0.05$) with time as determined using the Kendall Tau Correlation Test.)

Visibility - IMPROVE Program Monitoring at Brigantine

The Interagency Monitoring of Protected Visual Environments (IMPROVE) program, the cooperative measurement effort managed by representatives from federal and regional-state organizations that was established in 1985, has been working on implementing the Regional Haze rule. A long-term record of PM2.5 data has been collected at the federal IMPROVE monitoring site at the Brigantine Wilderness Area, where NJDEP is working with federal and regional partners to improve visibility. Figure 6 shows the total PM2.5 long term trends measured at the site, as well as the chemical composition of the fine particles. The data in Figure 6 also shows a decreasing trend in PM2.5 concentrations.

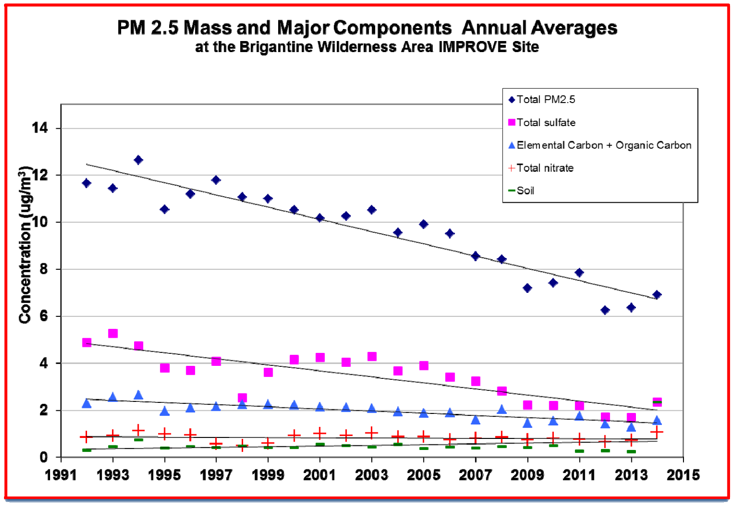

Figure 6: Annual Average PM2.5 Components at Brigantine
(The solid lines show the statistically significant trends ($p<0.05$) with time as determined using the Kendall Tau Correlation Test.)

A comparison of median values of the 1992 through 2003 period with the median values of the 2004 through 2014 period is shown in Table 1. The data in Table 1 also show significant decreases in $PM_{2.5}$ concentrations and its components. This comparison reveals lower median values of total $PM_{2.5}$, elemental carbon, organic carbon, total sulfate and total nitrates in the more recent period. It also indicates that as the carbons and sulfates decrease, the percent nitrate component of the PM2.5 mass increases. A statistical test indicates a statistically significant lower median concentration of the carbons and sulfates in the more recent period, with a p-value of < 0.01.[10] Differences of total nitrates and soil particles in the two periods were not significant.

The data for annual arithmetic means in elemental carbon (EC) and organic carbon (OC) concentration are shown separately in Figure 7, below. Elemental carbon shows an improving linear trend that is statistically significant.

Table 1: Comparison of Median Values, 1992 – 2003 vs. 2004 – 2014 at the Brigantine Wilderness Area IMPROVE Site

Particle type	Median, 1992 through 2002 $\mu g/m^3$	Median, 2003 through 2013 $\mu g/m^3$
Total PM2.5	9.23	6.69
Elemental Carbon	0.47	0.29
Organic Carbon	1.46	1.15
Total Sulfates	3.10	2.05
Total Nitrates	0.59	0.49

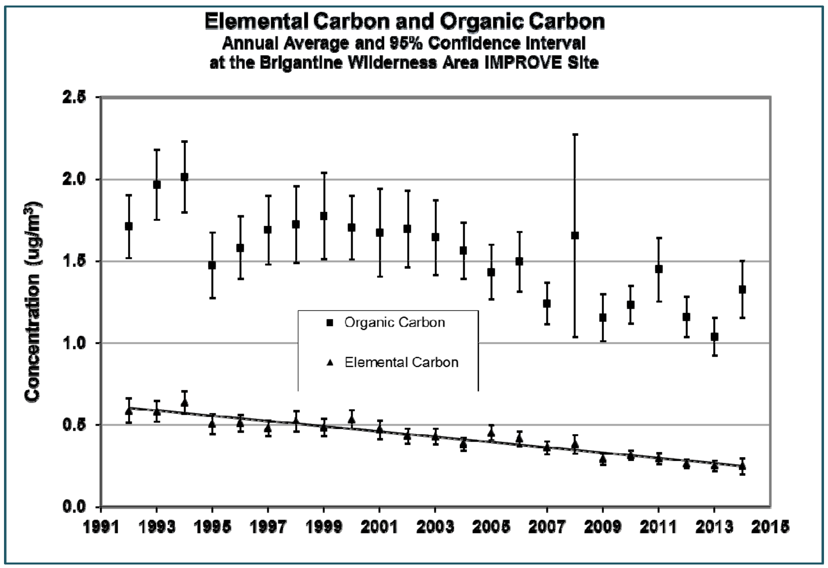

Photo credits: Bruce Ruppel, NJDEP, Division of Science, Research and Environmental Health

Figure 7: Annual Average Elemental and Organic Carbon at Brigantine.
(The solid line shows the statistically significant trend ($p<0.05$) with time as determined using the Kendall Tau Correlation Test.)

Outlook & Implications

The existing data show a decreasing trend in PM2.5 concentrations due to existing State and federal controls, especially for sulfates from SO_2 emission reductions.[11] NJDEP expects additional emission reductions of PM2.5 and its precursors (SO_2 and NO_x) in the future due to State and federal controls that have been adopted that will be implemented in the future, such as new vehicle and off-road equipment engine standards (fleet turnover of new vehicles and equipment), the federal Mercury and Air Toxics Standards (MATS) and New Jersey's low sulfur fuel rule for heating oil. Hence, NJDEP expects the decreasing trend in ambient PM2.5 concentrations to continue.

More Information

For more information, visit http://www.njaqinow.net/ (Accessed 4/21/2015) http://www.epa.gov/pm/actions.html or www.hazecam.net. Information on the IMPROVE program is available at http://vista.cira.colostate.edu/improve/.

References

[1]*PM – How Particulate Matter Affects the Way We Live and Breathe,* USEPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC November 2000, URL: http://www.epa.gov/oar/particlepollution/ (Accessed 4/21/2015)

[2]*Environmental Health Threats to Children*, USEPA, Office of the Administrator, EPA-176/F-96-001, September 1996.

[3]NJDEP Bureau of Mobile Sources: http://www.state.nj.us/dep/stopthesoot/ (Accessed 4/21/2015)

[4]USEPA Health Assessment Document for Diesel Engine Exhaust, Final 2002: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=29060 (Accessed 4/21/2015)

[5]U.S. EPA Area Designations for the 2012 Annual Fine Particle ($PM_{2.5}$) Standard: http://www.epa.gov/airquality/particlepollution/designations/2012standards/regs.htm (Accessed

(Accessed 4/21/2015)

[7]NJDEP Air Monitoring Website: http://www.njaqinow.net/ (Accessed 4/21/2015)

[8]NJDEP Air Monitoring Website: http://www.njaqinow.net/ (Accessed 4/21/2015)

[9]NJDEP Air Monitoring Website: http://www.njaqinow.net/ (Accessed 4/21/2015)

[10]As determined by the statistical program R, using the non-parametric Wilcoxon two-sample test.

[11]New Jersey State Implementation Plan Revision for the Attainment and Maintenance of the Fine Particulate Matter (PM2.5) National Ambient Air Quality Standards, Final Redesignation Request and Maintenance Plan, Annual 15 µg/m3 and Daily 35 µg/m3 PM2.5 National Ambient Air Quality Standards, December 2012 . http://www.state.nj.us/dep/baqp/pmrequest.html (Accessed 4/21/2015)