Fine Particles ($PM_{2.5}$)

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 (PM_{10}) can reach the lungs. Of greatest concern are particulate matter less than 2.5 µm in diameter – referred to as fine particles or $PM_{2.5}$ – 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. To a lesser extent, volatile organic compounds and ammonia are also considered precursors to fine particulates. Human-made sources of $PM_{2.5}$ include emissions from burning wood (residential, commercial and industrial), prescribed forest burning, commercial cooking, fuel combustion such as from motor vehicles, from construction equipment, for heating, from power plants and refineries 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. Wildfires can also be a large, unpredictable source of fine particulates.

A number of studies have shown an association between concentrations of PM in the air and increased respiratory and cardiovascular health problems and mortality. 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. Particles in diesel exhaust, often referred to as diesel "soot", are toxic and are a target of the New Jersey Department of Environmental Protection (DEP) risk reduction program. Diesel soot contains many toxics and can be inhaled into the deepest parts of the lungs where it is able to enter the bloodstream. The United States Environmental Protection Agency (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. 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 USEPA established National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$. The current $PM_{2.5}$ 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 January 15, 2015, the USEPA issued final area designations for the 2012 annual standard of 12 µg/m^3. The 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. 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 (like the Grand Canyon) and wilderness areas, including the Brigantine Wilderness area of the Edwin B. Forsythe National Wildlife Refuge in southern New Jersey.

View of Atlantic City from Brigantine marsh (Getty Images, 2021)

Status and Trends

Monitoring

DEP monitors $PM_{2.5}$ at 14 sites statewide with filter-based samplers that periodically collect 24-hour samples. At 13 sites, concentrations are also measured every hour using continuous $PM_{2.5}$ instruments. Hourly data are made available at the DEP's public website.

"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 1999-2019 for New Jersey, where each data point represents a 3-year rolling average. The existing data show a decreasing trend in $PM_{2.5}$ concentrations for the annual and 24-hour standards.

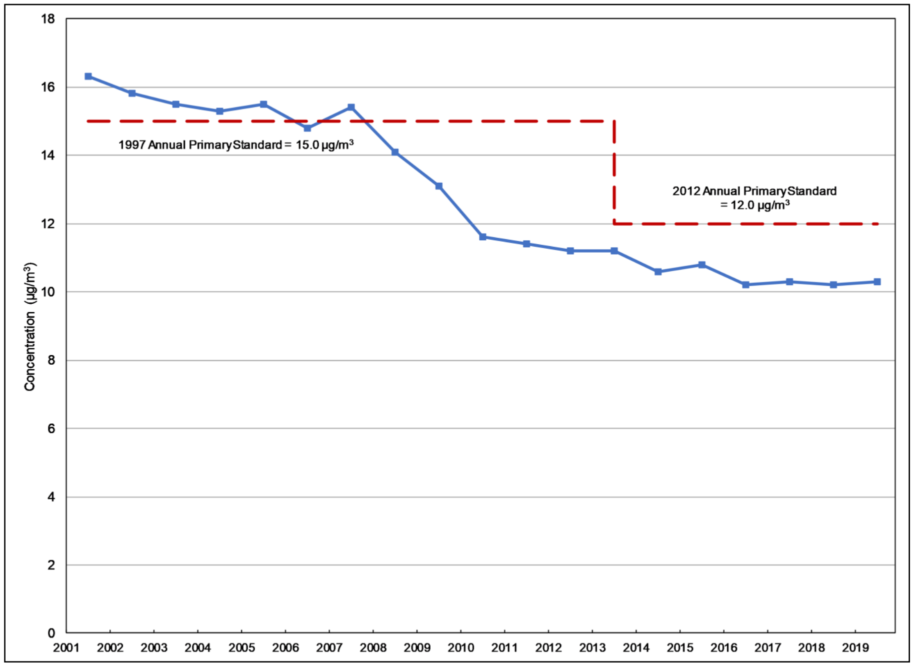

Figure 1. Maximum PM2.5 annual design value concentrations from statewide New Jersey sites 1999-2019.

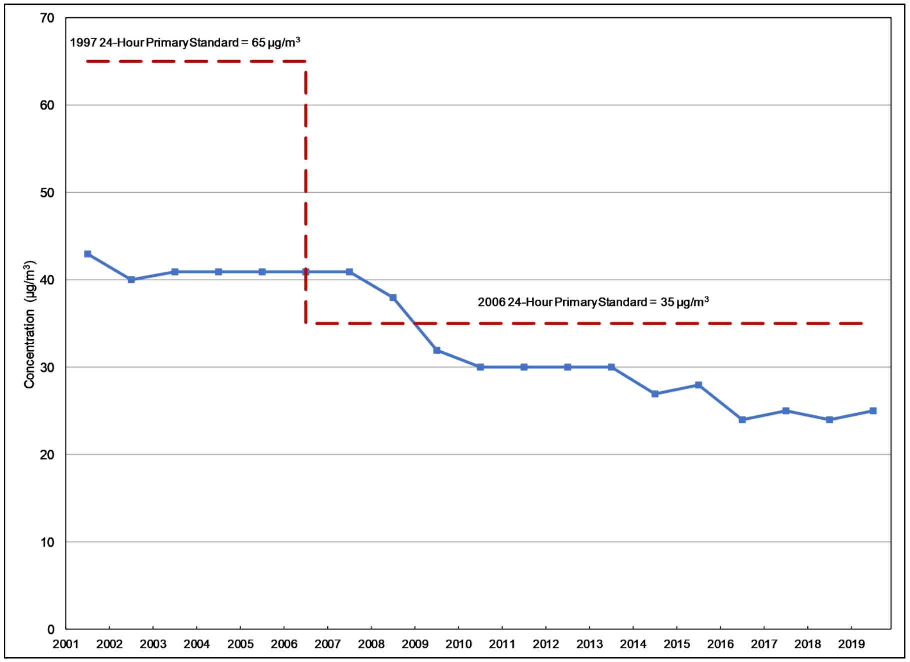

Figure 2. Maximum $PM_{2.5}$ 24-hour design value concentrations from statewide New Jersey sites 1999-2019.

DEP also measures the chemical composition of fine particles at four sites: Elizabeth Lab, Newark Firehouse, New Brunswick, and Chester. Elizabeth Lab and Chester 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.[7] At the Elizabeth site, there has been a statistically significant decrease in the concentration of sulfate, elemental and organic carbon, and nitrate from 2002 to 2018 (Kendall's tau = -0.919, -0.726, and -0.860, respectively; $p < 0.05$ for each, Figure 3).

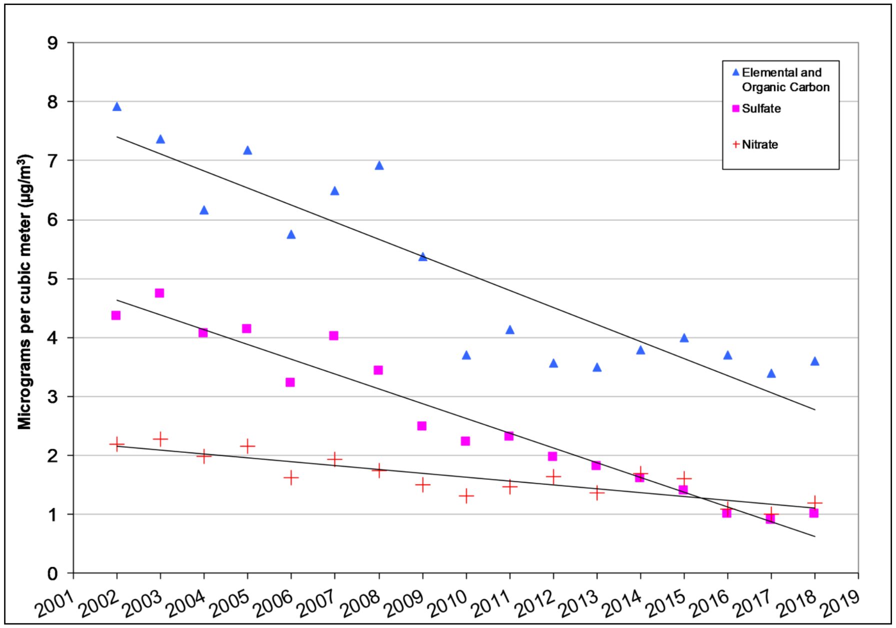

Figure 3. Annual average concentration of $PM_{2.5}$ major components at Elizabeth. (The solid lines show the statistically significant trends ($p<0.05$) with time as determined using the Kendall's Tau Correlation Test.)

At the Chester site, there has been a statistically significant decrease in the $PM_{2.5}$ concentration of sulfate, elemental and organic carbon, and nitrate from 2002 to 2018 (Kendall's tau = -0.908, -0.647, and -0.825, respectively; $p < 0.05$, Figure 4).

As shown in Figures 3 and 4, higher concentrations of carbon (elemental carbon (EC) and organic carbon (OC)) are observed at New Jersey's Elizabeth site compared to the Chester site, due to its proximity to a major roadway and motor vehicle traffic.

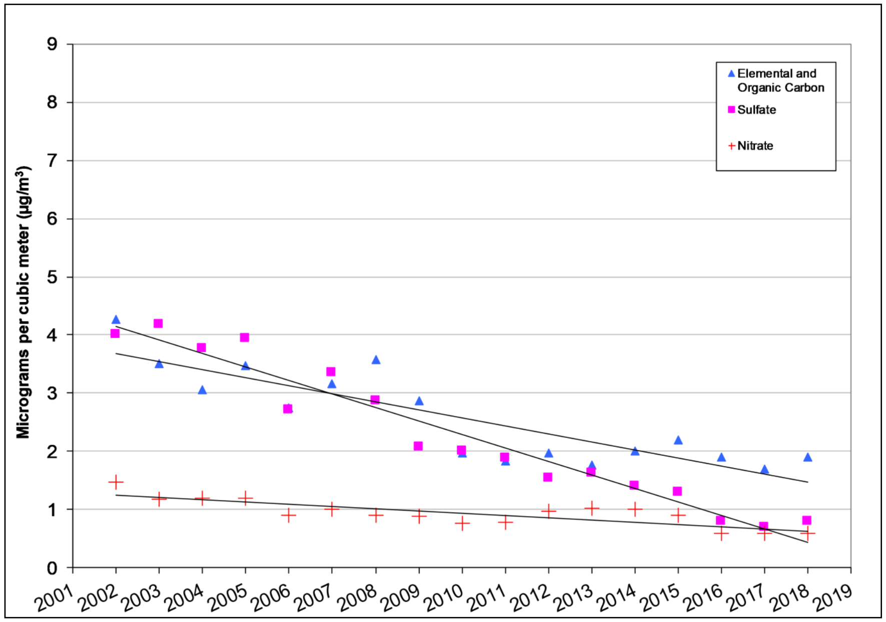

Figure 4. Annual average concentration of $PM_{2.5}$ major components at Chester. (The solid lines show the statistically significant trends ($p<0.05$) with time as determined using the Kendall's Tau Correlation Test.)

<u>Visibility - IMPROVE Program Monitoring at Brigantine</u>

The Interagency Monitoring of Protected Visual Environments (IMPROVE) program is a cooperative measurement effort managed by representatives from federal and regional-state organizations that was established in 1985 and has been working on implementing the Regional Haze rule. A long-term record of $PM_{2.5}$ data has been collected at the federal IMPROVE monitoring site at the Brigantine Wilderness Area, where DEP is working with federal and regional partners to improve visibility. Figure 6 below shows the total $PM_{2.5}$ 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 statistically significant decreasing trend in $PM_{2.5}$ concentrations, along with sulfate, elemental and organic carbon, nitrate, and soil (Kendall's tau = -0.884, -0.804, -0.757, -0.418, and -0.444, respectively; $p < 0.05$ for each, Figure 5).

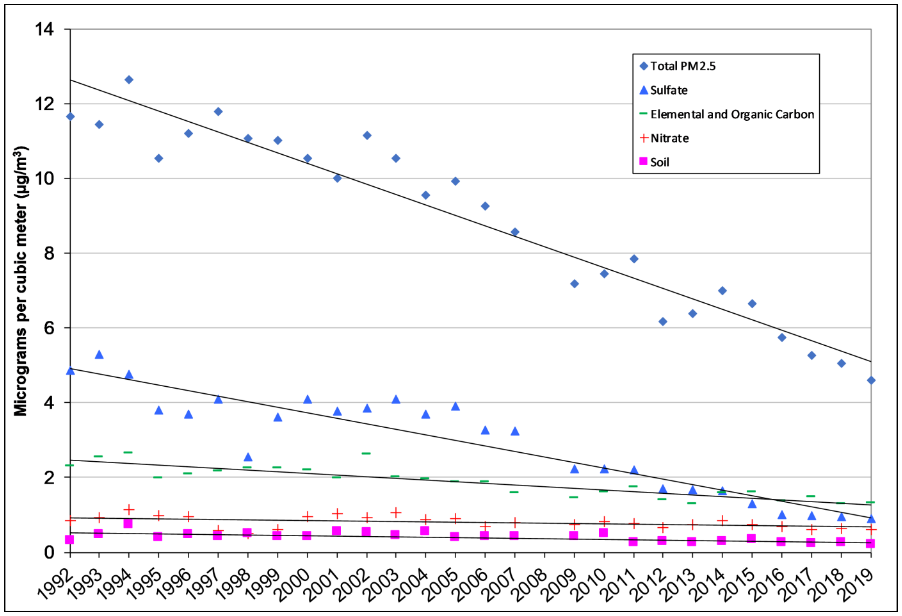

Figure 5. Annual average concentration of PM2.5 and its major components at Brigantine. (The solid lines show the statistically significant trends (p<0.05) with time as determined using the Kendall's Tau Correlation Test.)

Median annual values for the Brigantine Wilderness Area IMPROVE site are shown in Table 1 for the 1992 through 1999 period, the 2000 through 2009 period, and the 2010 through 2019 period. The data in Table 1 show evidence of improvement in $PM_{2.5}$ concentrations and components. This comparison reveals reductions over time in the median values of total $PM_{2.5}$, elemental carbon, organic carbon, total sulfate, total nitrate, and soil.

The data for annual arithmetic means in elemental carbon (EC) and organic carbon (OC) concentration are shown separately in Figure 6, below. Both EC and OC show improving linear trends that are statistically significant. The standard deviation for OC in 2002 is much larger than the other years due to an unusually high value of 55.98 µg/m^3 recorded on July 7, 2002. This elevated level of OC was caused by a large fire in eastern Canada with smoke and haze that affected the northeastern United States as far south as Washington, D.C.

Table 1. Comparison of Median Values for the 1992 – 1999, 2000-2009, and 2010-2019 periods at the Brigantine Wilderness Area IMPROVE Site

Particle type	Median, 1992 through 1999 µg/m^3	Median, 2000 through 2009 µg/m^3	Median, 2010 through 2019 µg/m^3
Total $PM_{2.5}$	9.56	7.84	5.24
Elemental carbon	0.50	0.38	0.22
Organic carbon	1.49	1.27	1.05
Total sulfate	3.13	2.67	1.17
Total nitrate	0.60	0.52	0.40
Soil	0.36	0.36	0.21

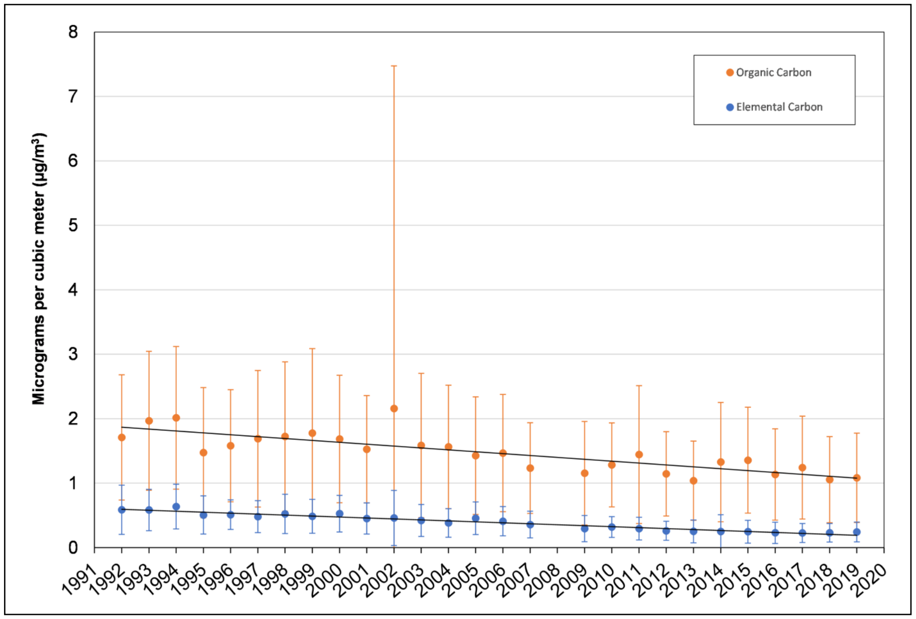

Figure 6. Annual Average Elemental and Organic Carbon at Brigantine. (The solid line shows the statistically significant trend (p<0.05) with time as determined using the Kendall's Tau Correlation Test. Data collection in 2008 was incomplete and therefore not included in this figure.)

Outlook and Implications

The data show a significant overall decreasing trend in $PM_{2.5}$ concentrations due to existing State and federal controls, especially those regulating SO_2 and NO_x from power plants, motor vehicles, heating oil and off-road vehicles and equipment. NJDEP expects additional emission reductions of $PM_{2.5}$ and its precursors (SO_2, NO_x, VOCs and ammonia) in the future due to State and Federal controls that have been adopted that will continue to reduce emissions from fleet and equipment turnover for new vehicles and off-road vehicles and equipment.

More Information

For more information, visit:
https://www.nj.gov/dep/airmon/

https://www.epa.gov/pm-pollution/particulate-matter-pm-implementation-regulatory-actions

https://hazecam.net/.

Information on the IMPROVE program is available at:
http://vista.cira.colostate.edu/improve/.

References

[1]*Particulate Matter (PM) Pollution – Health and Environmental Effects of Particulate Matter (PM),* USEPA, Office of Air and Radiation (OAR), Washington, D.C. April 2020, URL: https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm (Accessed 11/18/2020)

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

[3]NJDEP Bureau of Mobile Sources: https://www.state.nj.us/dep/stopthesoot/ (Accessed 11/18/2020)

[4]USEPA Health Assessment Document for Diesel Engine Exhaust, Final 2002: https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=29060 (Accessed 11/18/2020)

[5]USEPA Area Designations for the 2012 Annual Fine Particle ($PM_{2.5}$) Standard: https://www3.epa.gov/airquality/particlepollution/designations/2012standards/regs.htm (Accessed 11/18/2020)

[6]IMPROVE (Interagency Monitoring of Protected Visual Environments): http://vista.cira.colostate.edu/improve/ (Accessed 11/18/2020)

[7]NJDEP Air Monitoring Website: https://www.njaqinow.net/ (Accessed 11/18/2020)

[8]Global Fire Monitoring Center, UN Office for Disaster Risk Reduction. Forest Fires in Canada. http://gfmc.online/current/archive/ca/2002/07/ca_07082002.htm (Accessed 12/23/2020)

[9]New Jersey State Implementation Plan Revision for the Attainment and Maintenance of the Fine Particulate Matter ($PM_{2.5}$) National Ambient Air Quality Standards, Final Redesignation Request and Maintenance Plan, Annual 15 µg/m3 and Daily 35 µg/m3 $PM_{2.5}$ National Ambient Air Quality Standards, December 2012. https://www.state.nj.us/dep/baqp/newpm25/12013/PM2.5%20Redesignation%20SIP%20Final.pdf (Accessed 11/18/2020)