2003 Particulate Summary

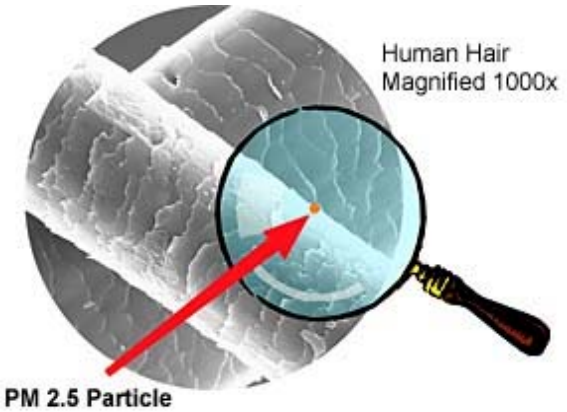
New Jersey Department of Environmental Protection

Nature and Sources

Particulate air pollution consists of both solid particles and liquid droplets suspended in the atmosphere. Suspended particles can range in size from 70 microns in diameter, approximately the size of a pinhead, to less than 1 micron in diameter. Particles can be directly emitted, or they can form in the atmosphere from gaseous emissions, such as sulfur dioxide (SO_2) and oxides of nitrogen (NO_x). Particles that originate as gases are referred to as secondary particulates.

Particulate matter is generally categorized according to the size of the particles. Coarse particles are defined as particles greater than 2.5 microns in diameter, while particles less than 2.5 microns in diameter are referred to as fine particles ($PM_{2.5}$) (See Figure 1). Coarse particles are further subdivided into Total Suspended Particulates (TSP), which include all but the largest particles, and PM_{10}, which include particles less than 10 microns in diameter. The human respiratory tract will usually trap particles above about 10 microns in diameter before they reach the lungs. Particles smaller than 10 microns (PM_{10}) are inhalable and are considered to be more harmful to human health than larger particles; fine particles are considered to be even more harmful as they can reach the deep recesses of the lungs.

Figure 1
Size of $PM_{2.5}$ Particle Compared to a Human Hair



Graphics Courtesy of the US Department of Energy

Both fine and coarse particles have anthropogenic, or man-made, as well as natural sources. Anthropogenic sources of coarse particles include industrial processes such as grinding operations, while anthropogenic sources of fine particles include soot from fuel combustion, and secondary particle formation from organic compounds, biomass burning, and emissions of sulfur dioxide (SO_2) and oxides of nitrogen (NO_x). Natural sources of coarse particles include windblown dust, sea salt, and biological debris; and natural sources of fine particles include biogenic gases, which result in the formation of secondary particles.

Environmental Effects

In addition to health effects, particulate matter is the major cause of reduced visibility in many parts of the United States. Figure 2 provides an example of reduced visibility recorded by our WebCam site in Newark (accessible via the Internet at www.state.nj.us/dep/airmon). Airborne particles can also impact vegetation and aquatic ecosystems, and can cause damage to paints and building materials. More information is provided in the Regional Haze section of this report.

Figure 2
Visibility WebCam

View of New York City Skyline from Newark

Health Effects

Inhalable particles (PM_{10}) and especially fine particles ($PM_{2.5}$) are a health concern because they easily reach the deepest recesses of the lungs. Various health problems are associated with both long and short-term exposures. When inhaled, these particles can accumulate in the respiratory system and are associated with increased hospital admissions and emergency room visits for heart and lung conditions, such as asthma, bronchitis, cardiac arrhythmias, heart attacks, and even premature death. Groups that appear to be at the greatest risk from particulates include children, the elderly, and individuals with heart and lung diseases, such as asthma (*US EPA, 2001).*

Standards

In 1971, EPA set primary (health based) and secondary (welfare based) standards for total suspended particulate matter (TSP). These standards, known as the National Ambient Air Quality Standards (NAAQS), were based on maximum 24-hour and annual concentrations (*US EPA, 1997)*. The annual standards were based on the geometric mean concentrations over a calendar year, and the 24-hour standards were based on the arithmetic average concentration from midnight to midnight. The primary 24-hour average standard for TSP was set at 260 micrograms per cubic meter ($\mu g/m^3$) and the annual geometric mean health standard was set at 75 $\mu g/m^3$. The 24-hour secondary standard was set at 150 $\mu g/m^3$. While EPA did not establish a secondary annual standard for TSP they did set a guideline of 60 $\mu g/m^3$ to be used to ensure that the secondary 24-hour standard was being met throughout the year. Although New Jersey still maintains state standards for TSP, the national standards have been replaced with standards for smaller particles as described below. As a result, monitoring for TSP has largely been discontinued, with the exception of one station, where TSP samples are taken to analyze for lead (Pb). See the Lead Summary section for more details.

In 1987, EPA replaced the TSP standards with standards that focused only on inhalable particles. Inhalable particles are defined as particles less than 10 microns in diameter (PM_{10}). The 24-hour PM_{10} primary and secondary standards were set at 150 $\mu g/m^3$, and the annual primary and secondary standards were set at 50 $\mu g/m^3$. The annual standard for PM_{10} is based on the arithmethic mean, as opposed to the geometric mean that was used for TSP.

In 1997, EPA promulgated new standards for fine particulates, which it defined as particles less than 2.5 microns in diameter ($PM_{2.5}$). They kept the existing standards for PM_{10} as well. The $PM_{2.5}$ annual primary and secondary standards were set at 15 $\mu g/m^3$ and the 24-hour standard was set at 65 $\mu g/m^3$. Table 1 provides a summary of the Particulate Matter standards.

Table 1
National and New Jersey
Ambient Air Quality Standards for Particulate Matter

Micrograms Per Cubic Meter ($\mu g/m^3$)

Standard	Averaging Period	Type	New Jersey	National
Total Suspended Particulates (TSP)	12-Month‡	Primary	75 $\mu g/m^3$	---
	24-Hour	Primary	260 $\mu g/m^3$	---
	12-Month‡	Secondary	60 $\mu g/m^3$	---
	24-Hour	Secondary	150 $\mu g/m^3$	---
Inhalable Particulates (PM_{10})	Annual†	Primary & Secondary	---	50 $\mu g/m^3$
	24-Hour Average	Primary & Secondary	---	150 $\mu g/m^3$
Fine Particulates ($PM_{2.5}$)	Annual†	Primary & Secondary	----	15 $\mu g/m^3$
	24-Hour Average	Primary & Secondary	----	65 $\mu g/m^3$

‡ Annual Geometric Mean
† Annual Arithmetic Mean

Particulate Monitoring Network

New Jersey's Particulate Monitoring Network consists of 20 fine particulate monitoring sites, 7 PM10 monitoring sites, 1 TSP monitoring site, and 11 sites where smoke shade is monitored.

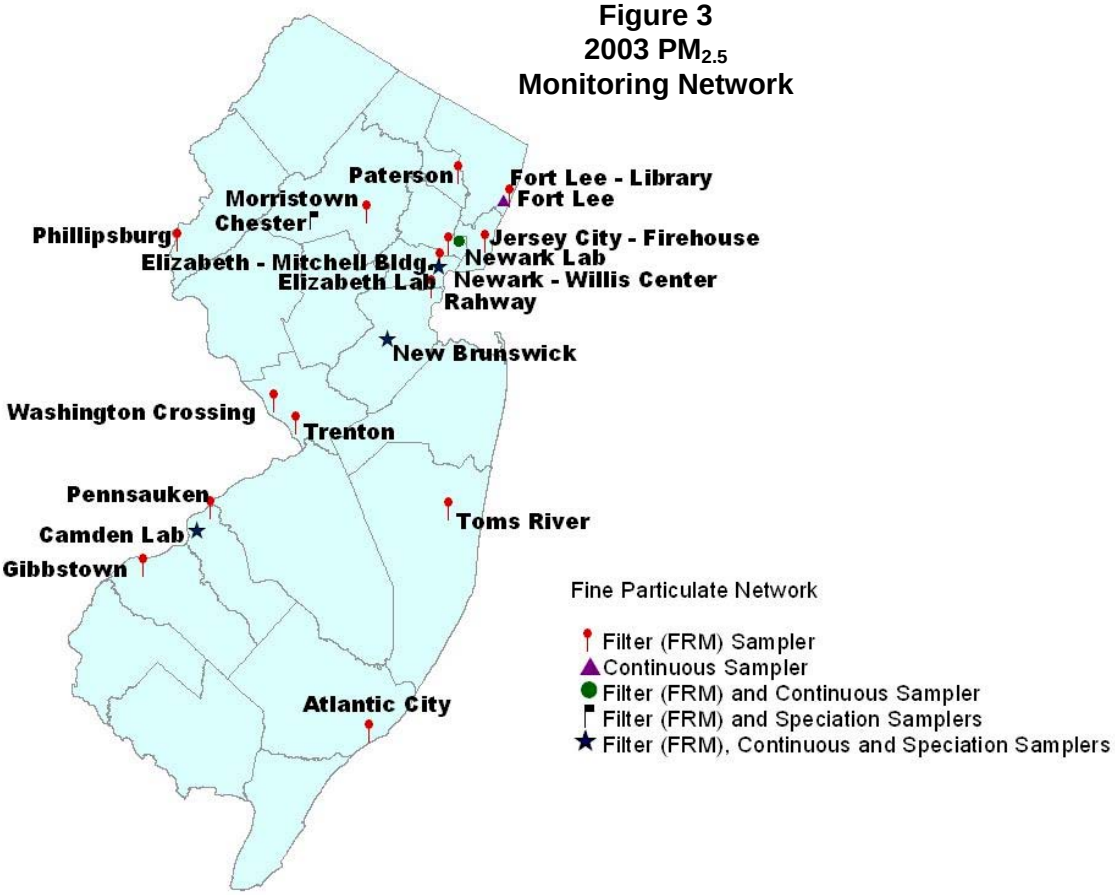
At some of these sites, samplers that comply with strict EPA specifications are used for collecting data that are submitted to a national database maintained by the EPA. These filter-based samplers, which are approved by the EPA and known as Federal Reference Method (FRM) samplers, collect particles on a filter over a 24-hour period. The filters are subsequently weighed under controlled environmental conditions. The data from the FRM samplers are used by the NJDEP and EPA to determine whether the state, or portions of the state, meet the federal health and welfare standards for particulate matter. Because the FRM samplers do not provide data in real time, the NJDEP employs additional samplers that continuously measure particulate concentrations. These samplers are used by the NJDEP to report current air quality to the public through the Air Quality Index (www.state.nj.us/dep/airmon). The NJDEP uses Tapered Element Oscillating Microbalance (TEOM) analyzers and smoke shade instruments for real-time particle reporting. The TEOM analyzers collect a sample of fine particles on an oscillating filter, and determine the concentration based on the change in the frequency at which the filter oscillates. Smoke shade instruments collect a sample of particles on a paper tape for one hour. At the end of each hour the amount of light that will pass through the spot that has formed on the tape is measured, the tape advanced, and the cycle started over. The amount of light transmittance measured is used as an estimate of actual particle concentrations.

Fine Particle Summary

Fine Particle Monitoring Sites

There are 19 monitoring sites in New Jersey where a filter-based (FRM) sampler routinely collects $PM_{2.5}$ 24-hour samples (see Figure 3). At 5 sites, continuous

Figure 3
2003 $PM_{2.5}$
Monitoring Network



particulate monitors measure the concentration of fine particles every minute and transmit the data to the Bureau of Air Monitoring's central computer, where it is made available on the Bureau's Public Website (www.state.nj.us/dep/airmon). Additionally, at four of these locations a separate sampler collects fine particles on three types of filter media which are subsequently analyzed using ion chromatography (IC), X-ray fluorescence (XRF), and Thermal Optical Analysis (TOA) to determine the concentrations of the chemical analytes that constitute the sample.

Fine Particle Concentration Summary

The annual mean concentration of PM2.5 ranged from 10.7 $\mu g/m^3$ in Chester to 16.3 $\mu g/m^3$ at Camden Lab. The maximum 24-hour concentrations ranged from 35.1 $\mu g/m^3$ at Newark Lab to 63.3 $\mu g/m^3$ at Phillipsburg.

Camden Lab was not in commission during the final quarter of 2003, and Newark Lab was not in commission during the final two quarters of the year. Therefore, the data collected from these sites may be somewhat biased. During the first three quarters of the year, Camden Lab has a lower concentration than Elizabeth Lab. However, the annual mean at Elizabeth Lab was 16.0, which was slightly lower than the annual mean of 16.3 at Camden. This can be partially attributed to the low concentrations recorded at Elizabeth Lab during the 4th quarter while Camden was out of commission. And, the maximum daily concentration at most of the sites was reached while Newark Lab was not in commission.

Figure 4 and Table 2 depict the mean and maximum concentrations at each site.

None of the sites exceeded the 24-hour standard of 65 µg/m3. Three years of data are required to determine compliance with the NAAQS for $PM_{2.5}$. NJDEP will be evaluating $PM_{2.5}$ data collected to date in making its final determination as to whether the annual NAAQS are being met.

Figure 4
2003 Fine-Particulate Concentrations

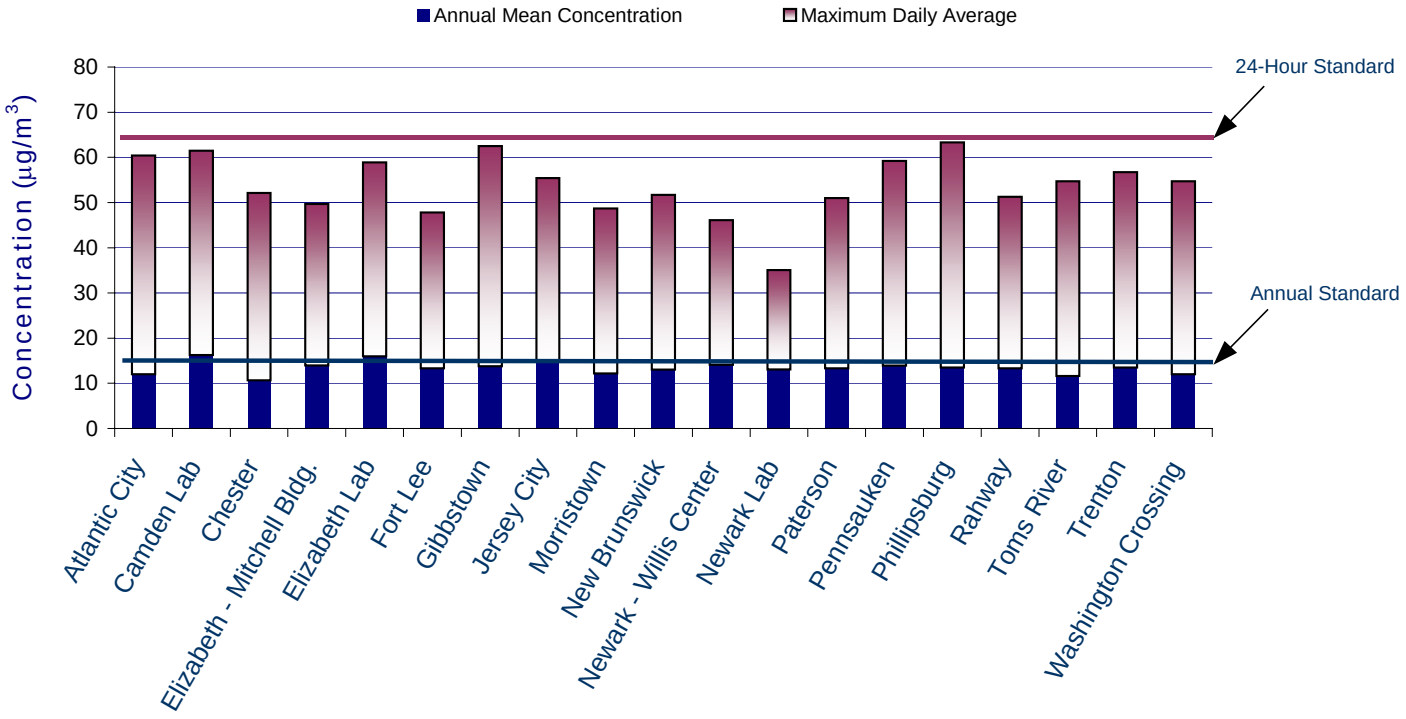


Table 2
$PM_{2.5}$ Summary Data – 2003

Concentration in Micrograms Per Cubic Meter (μg/m³)

Monitoring Site	Number of Samples	24-Hour Maximum	Second Highest	Annual Mean
Atlantic City	102	60.4	38.4	12.0[a]
Camden Lab	78	61.5	43.0	16.3[a, b]
Chester	111	52.1	44.8	10.7
Elizabeth Lab	111	49.7	45.1	16.0
Elizabeth (Mitchell)	316	58.9	49.3	14.0
Fort Lee	109	47.8	43.5	13.3
Gibbstown	112	62.5	35.3	13.8
Jersey City	109	55.4	49.8	14.8
Morristown	109	48.7	45.3	12.2
New Brunswick	111	51.7	45.3	13.0
Newark (Willis Center)	96	46.1	39.8	14.1[a]
Newark Lab	46	35.1	31.9	13.1[a, c]
Paterson	110	51.0	46.2	13.3
Pennsauken	119	59.2	44.5	13.9[a]
Phillipsburg	110	63.3	48.8	13.5
Rahway	109	51.3	38.3	13.3
Toms River	112	54.7	42.3	11.6
Trenton	114	56.7	42.3	13.5
Washington Crossing	104	54.7	42.1	12.0[a]

[a] Site did not record 75% valid samples during each quarter
[b] Site was out of commission from September through the end of the year
[c] Site was out of commission from June through the end of the year

Table 3
2003 Summary of Continuous PM2.5 Data

Concentration in Micrograms Per Cubic Meter (μg/m³)

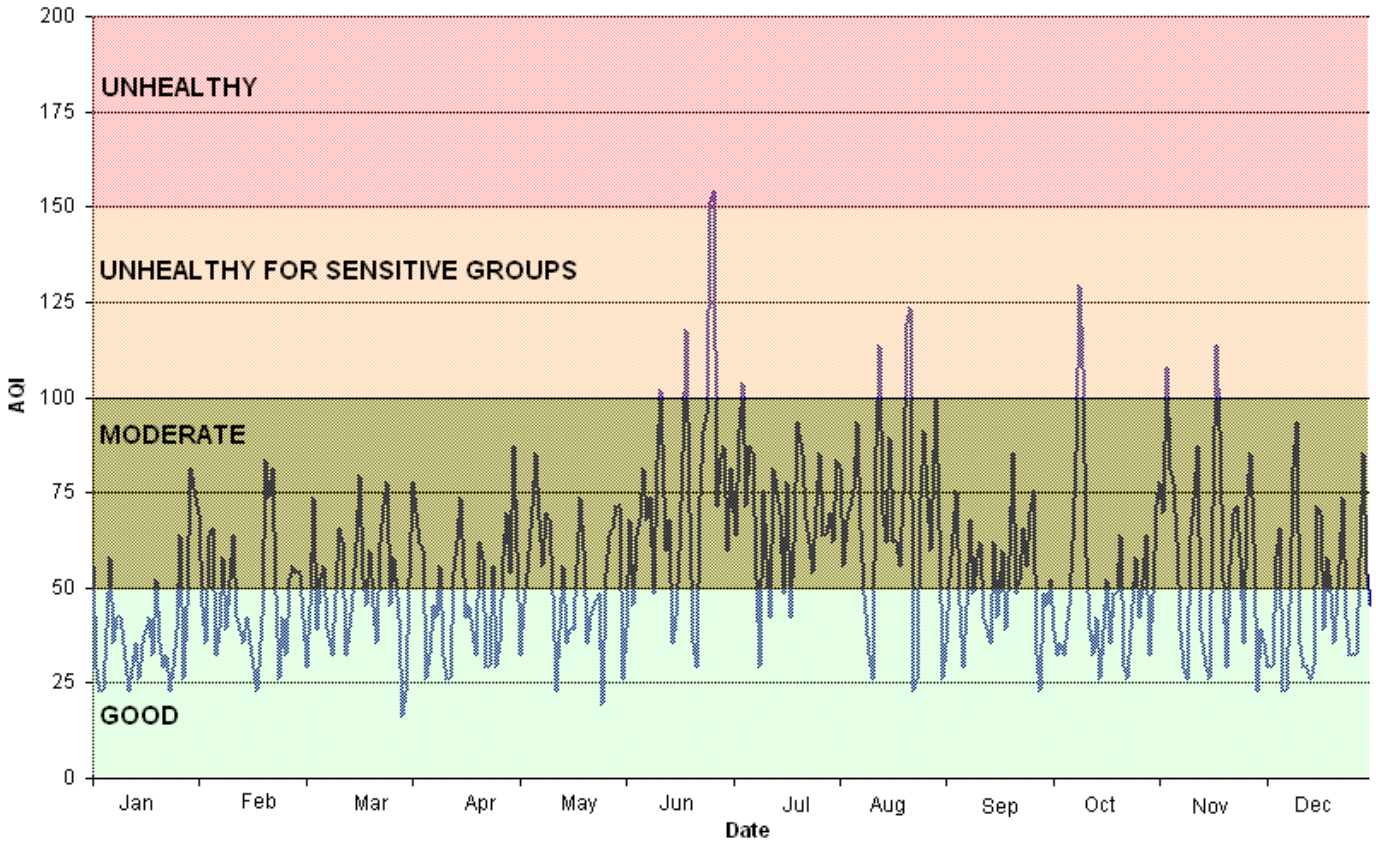
Monitoring Site	Maximum Daily Average	2nd Highest Daily Average	Annual Mean
Camden Lab[a]	67	57	--
Elizabeth Lab	61	54	16
Fort Lee	71	61	19
Newark Lab[b]	32	31	--
New Brunswick	60	57	12

[a] Data Not Available after September
[b] Data Not Available after June

$PM_{2.5}$ Real-Time Monitoring

New Jersey's continuous $PM_{2.5}$ monitoring network consists of 5 sites: Camden Lab, Elizabeth Lab, Fort Lee, New Brunswick, and Newark Lab. The data is transmitted once a minute to a central computer in Trenton, where it is averaged and automatically updated on the bureau's website every hour. Table 3 provides a summary of the data from these sites, and Figure 5 depicts the health level associated with the maximum daily fine particulate concentration recorded in the state each day for the entire year.

Figure 5
Maximum Daily Fine Particulate Air Quality Index (AQI)



Fine Particle Speciation Summary

New Jerseys Fine Particulate Speciation Network consists of 4 monitoring sites: Camden Lab, Elizabeth Lab, New Brunswick, and Chester. Samplers run every third day on a schedule concurrent with the FRM sampling network. Of the 55 measured analytes, organic carbon and sulfate combined make up over 60% of the total mass, and nitrate, ammonium, and elemental carbon make up an additional 38% of the particulate mass. Figure 6 depicts the typical chemical composition of fine particulate matter by showing the average percentage each analyte contributed to the total concentration of fine particles at New Brunswick in 2003. Figure 7 depicts the average concentration of each analyte at all the sites, with only the seven most prevalent constituents depicted. Appendix B shows the average, maximum, and 2nd highest concentrations for each compound for 2003.

Figure 6
2003 Fine Particulate Analyte Composition
(Highest 7 Analytes at New Brunswick)

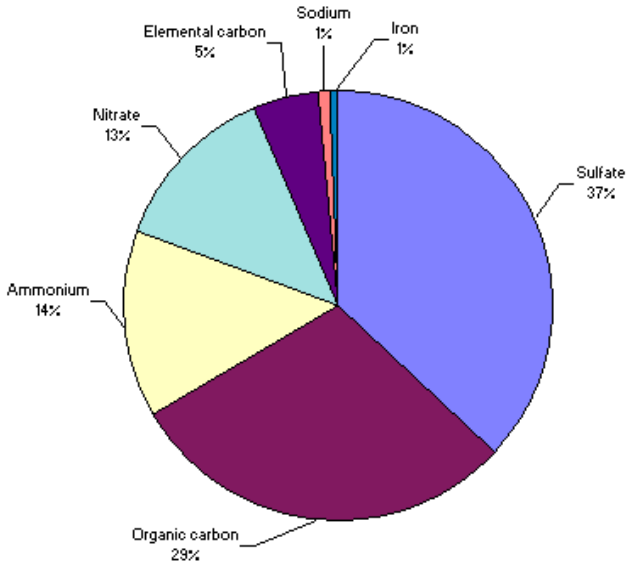
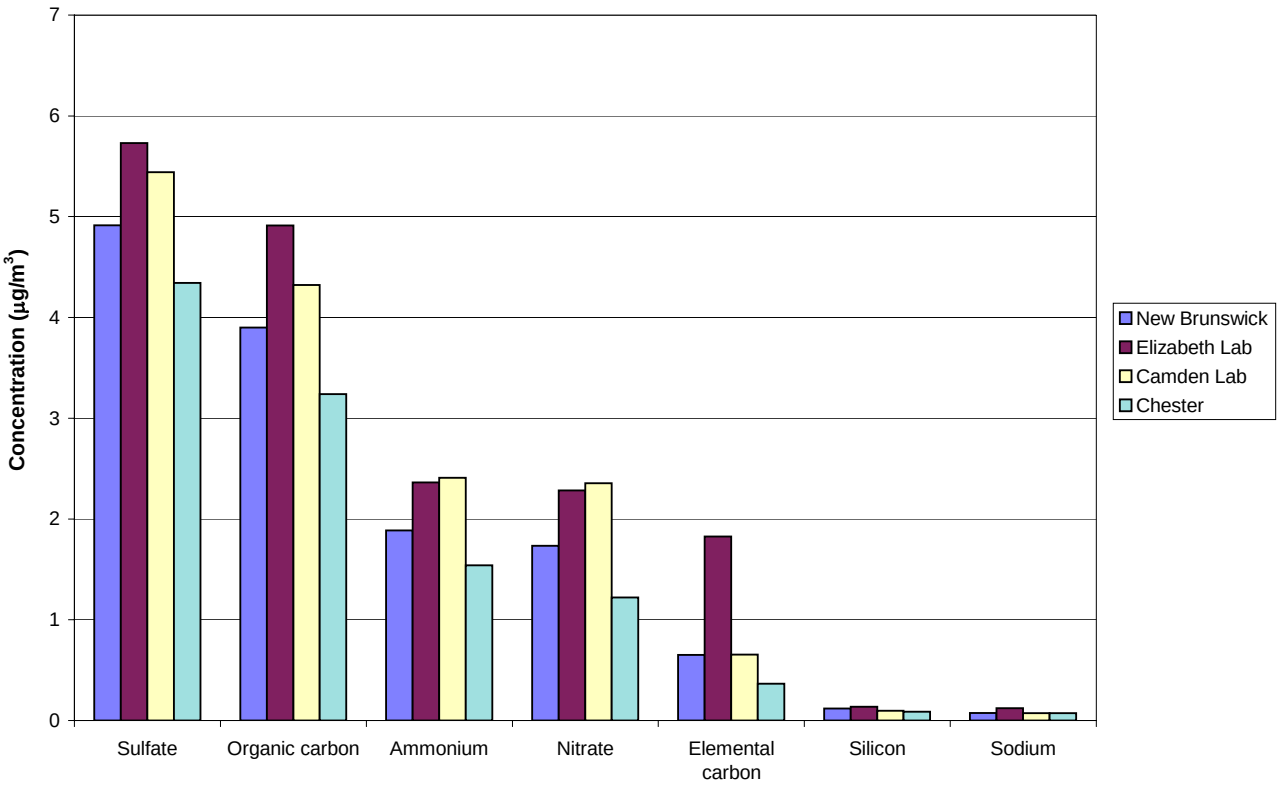


Figure 7
2003 Fine Particulate Analyte Composition
(Highest 7 Analytes Depicted)



2003 Coarse Particle Summary

Coarse Particle Monitoring Sites

The coarse particulate monitoring network is composed of PM_{10} sampling sites and TSP sampling sites. Samples are collected on a filter, which is weighed before and after sampling. The amounts of Sulfate and Nitrate are measured on some PM_{10} samples and Lead is measured on the TSP samples. Figure 8 depicts the PM_{10} particulate monitoring network in New Jersey.

Figure 8
2003 PM_{10}
Monitoring Network

TSP Concentration Summary

New Jersey currently operates one site, located in New Brunswick, mainly for the purpose of determining the concentration of lead in the atmosphere. For more information, see the 2003 Lead Summary section. In 2003, the annual geometric mean concentration of TSP in New Brunswick was 27.6 μg/m3, and the maximum 24-hour concentration recorded was 74 $\mu g/m^3$. The site was in attainment for the primary and secondary annual TSP standards of 75 $\mu g/m^3$ and 60 $\mu g/m^3$ respectively, and the site did not surpass the 24-hour primary standard of 260 $\mu g/m^3$ or the 150 $\mu g/m^3$ secondary standard.

PM_{10} Concentration Summary

In 2003, the annual mean concentration of PM_{10} ranged from 21.2 $\mu g/m^3$ at Atlantic City to 36.5 $\mu g/m^3$ at Fort Lee. Table 4 and Figure 9 show the annual mean and 24-hour maximum PM_{10} concentrations throughout the state. All areas of the state are in attainment for the annual PM_{10} standard of 50 $\mu g/m^3$, and no sites surpassed the 24-hour standard of 150 $\mu g/m^3$.

The concentration of Sulfate and Nitrate were also analyzed on some PM10 filters. The results showed that, on average, about 2% percent of PM10 is nitrate and 17% percent is sulfate; however, these percentages vary across sites and sampling dates. The contributions of sulfate and nitrate to PM10 are significantly less than their contributions to PM2.5. This is because PM10 is predominantly made up of larger particles most of which are directly emitted into the atmosphere. $PM_{2.5}$ is predominantly a secondary pollutant, forming in the atmosphere from gaseous emissions, such as SO_2 and NOx. For more details on the PM_{10} sulfate and nitrate results, see the section on atmospheric deposition.

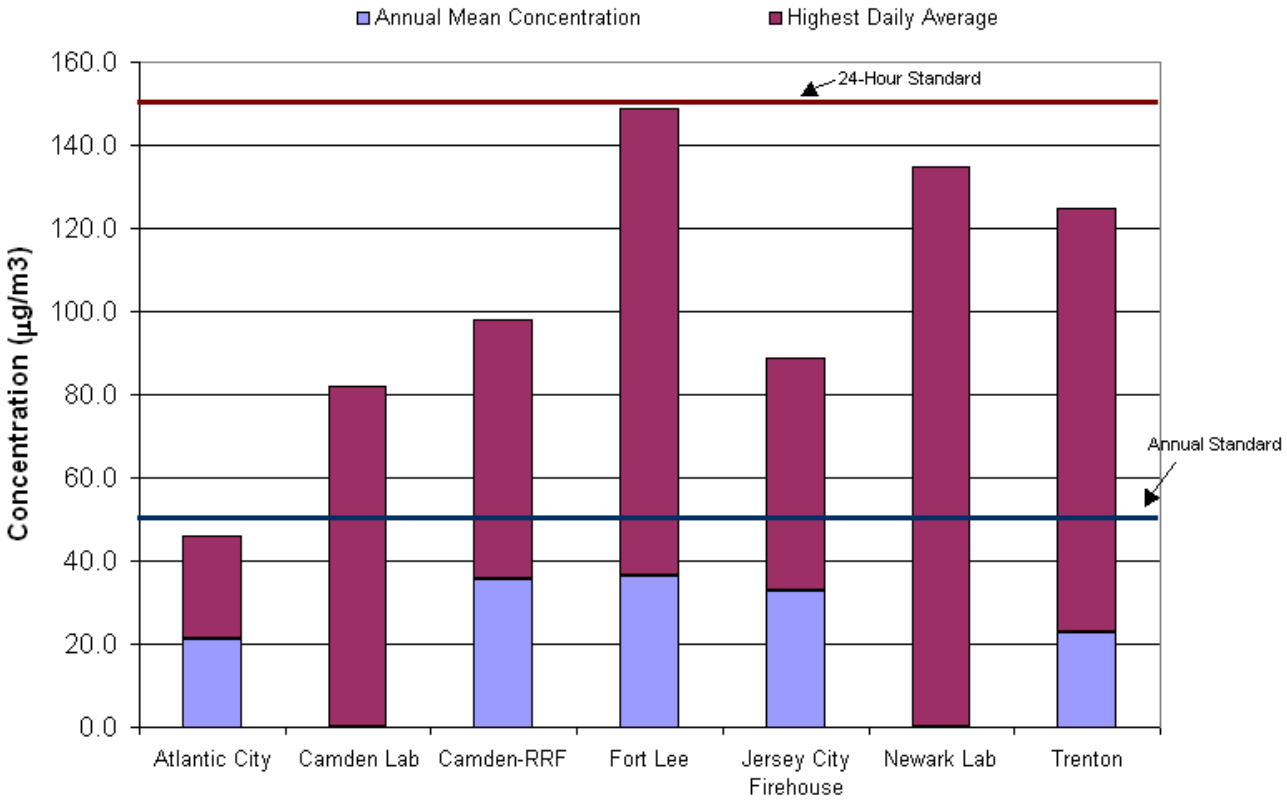
Table 4
PM10 Data-2003
24-Hour and Annual Averages

Micrograms Per Cubic Meter (μg/m^3)
24-Hour Standard = 150 μg/m^3
Annual Standard = 50 μg/m^3

Monitoring Site	Number of Samples	24-Hour Maximum	Second Highest	Annual Mean
Atlantic City	56	46	35	21.2
Camden Lab[a]	42	82	52	****
Camden RRF #1	56	98	56	35.5
Fort Lee	58	149	75	36.5
Jersey City - Firehouse	55	89	61	32.1
Newark Lab[b]	23	135	41	****
Trenton	57	125	70	22.7

[a] Data Not Available after September
[b] Data Not Available after May

Figure 9
Summary of PM_{10} Concentrations, New Jersey 2003



Smoke Shade Summary

Smoke Shade Monitoring Sites

In addition to fine and coarse particulate monitoring, smoke shade is also monitored at 11 stations around the state. Smoke shade, which is an indirect measurement of particles in the atmosphere, has been monitored in New Jersey for over 30 years. Smoke shade is primarily used for the daily reporting of particulate levels in the Air Quality Index. The sites monitoring smoke shade are shown in Figure 10.

Smoke Shade Concentration Summary

In 2003, the annual mean concentration of smoke shade ranged from 0.15 Coefficient of Haze units (COH) at Flemington to 0.54 COH at Elizabeth Lab. COH are units of light transmittance and smoke shade is not a direct measure of particle mass. A 24-hour average level of 2.0 COH is used as a benchmark. Readings above the 2.0 COH benchmark are reported as Unhealthy for Sensitive Groups on the daily Air Quality Index. For more details see the Air Quality Index section of this report. Table 5 lists the maximum and second highest daily average and annual mean smoke shade levels recorded at the monitoring sites in 2003.

Figure 10
2003 Smoke Shade Monitoring Network

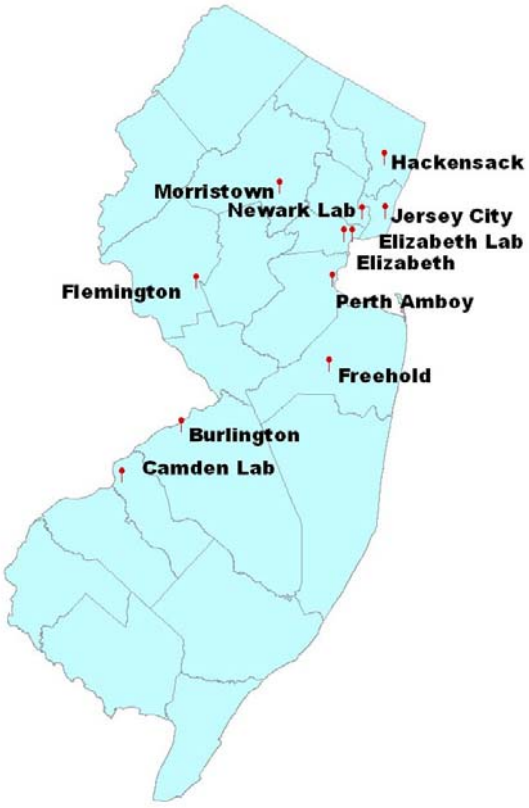


Table 5
Smoke Shade - 2003

Coefficient of Haze (COHs)
No Standard

Site	Maximum Daily Average	2nd Highest	Annual Mean
Burlington	0.92	0.58	0.17
Camden Lab[a]	0.74	0.55	----
Elizabeth	1.26	1.24	0.43
Elizabeth Lab	1.45	1.24	0.54
Flemington	0.52	0.49	0.15
Freehold	0.69	0.54	0.20
Hackensack	1.00	0.90	0.24
Jersey City	1.40	1.38	0.48
Morristown	1.13	0.80	0.24
Newark Lab[b]	0.84	0.74	----
Perth Amboy	1.28	0.87	0.27

[a] Data Not Available after September
[b] Data Not Available after June

TRENDS IN PARTICULATE CONCENTRATIONS

The longest continuously operating particle monitoring network in the state that is suitable for looking at trends is the smoke shade network. As noted earlier, this monitoring program has been in effect for over thirty years and still has 11 active sites. The trend graph for smoke shade, shown in Figure 11 indicates that particulate levels have steadily declined over the past thirty years. Smoke shade is not a direct measurement of particle mass, but can be related to TSP, PM_{10} and $PM_{2.5}$ health standards.

Figure 11
Long Term Trend in Particulate Levels
1971 - 2003

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