2002 Particulate Summary

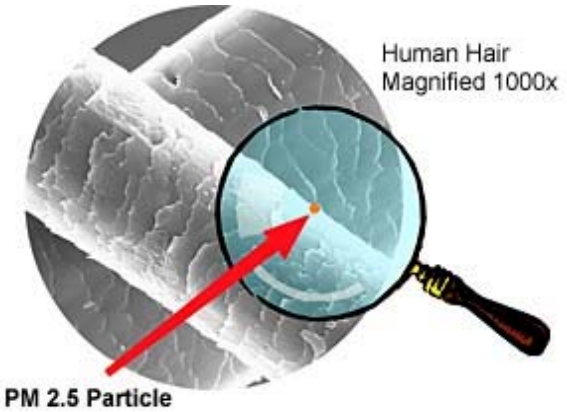
New Jersey Department of Environmental Protection

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

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, 8 PM_{10} monitoring sites, 1 TSP monitoring site, and 11 sites where smoke shade is monitored.

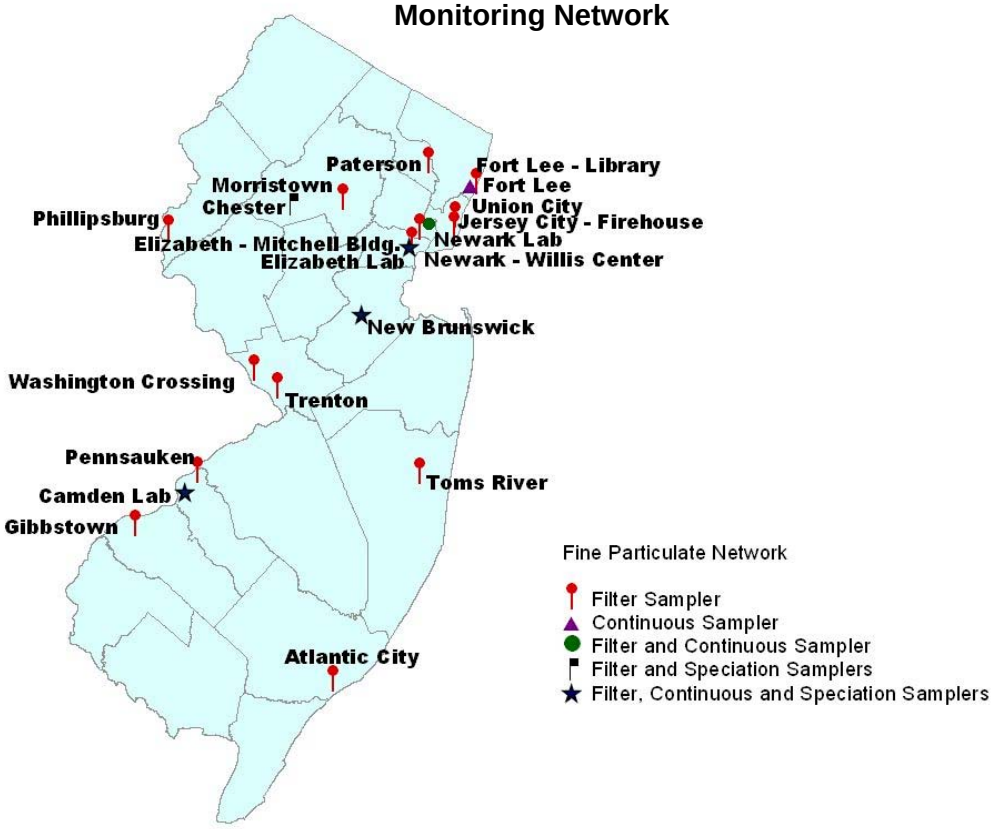
At some of these sites, samplers that comply with strict EPA specifications are used for collecting data that are submitted to a national database maintained by the EPA. These filter-based samplers, which are approved by the EPA and known as Federal Reference Method (FRM) samplers, collect particles 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 particulate standards. 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 20 monitoring sites in New Jersey where an FRM, collects a $PM_{2.5}$ 24-hour sample (see Figure 3). At 5 sites, continuous particulate monitors measure the

Figure 3
2002 $PM_{2.5}$
Monitoring Network



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 $PM_{2.5}$ ranged from 11.1 $\mu g/m^3$ in Chester to 15.1 $\mu g/m^3$ at Elizabeth Lab. Each site recorded its maximum 24-hour concentration on July 7th during the forest fire episode, with the exception of the Union City and Elizabeth (Mitchell) site, which did not record a reading on that date. During this episode, fine particle concentrations ranged from 66.0 $\mu g/m^3$ in Washington Crossing State Park to 106.7 $\mu g/m^3$ in Atlantic City. Due to the rare nature of this event, the concentrations during this episode were flagged as being affected by an exceptional event, and are not used in the planning process. More information on the forest fire episode is presented later in this section. Excluding this event, maximum 24-hour concentrations ranged from 37.2 $\mu g/m^3$ at Fort Lee to 59.0 $\mu g/m^3$ at Elizabeth Lab. Figure 4 and Table 2 depict the mean and maximum concentrations at each site.

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
2002 Fine-Particulate Concentrations

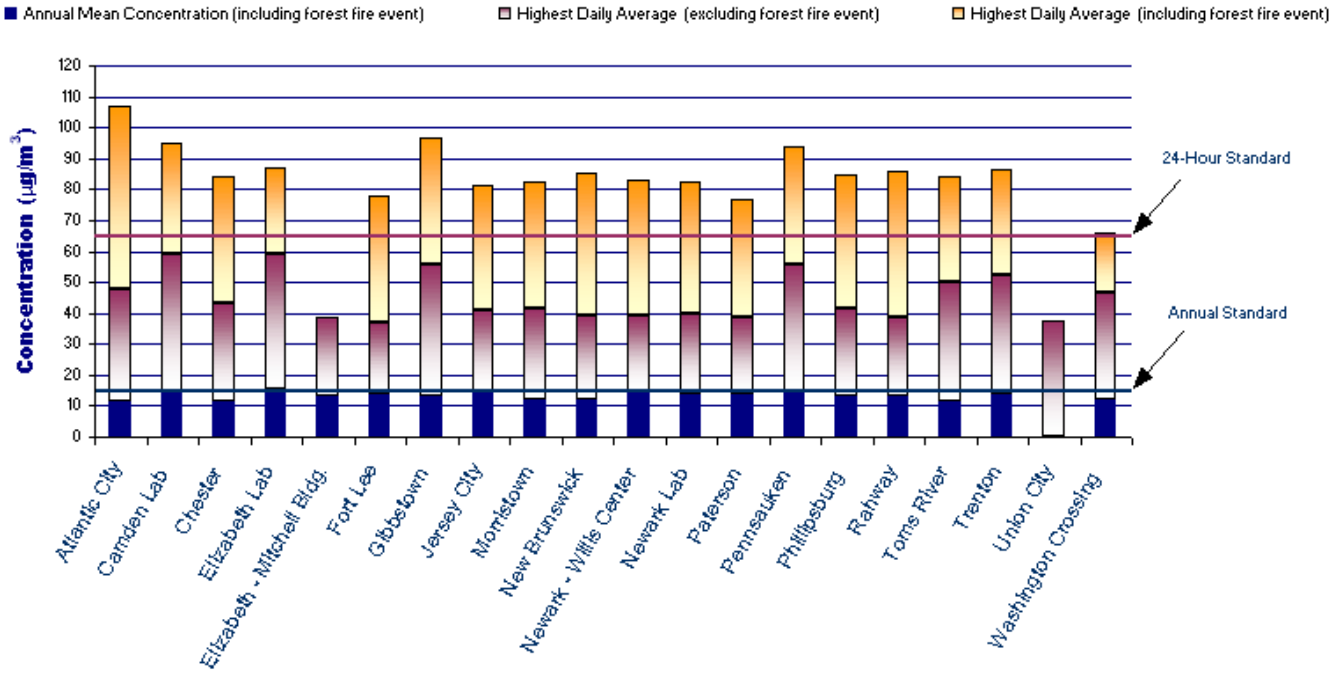


Table 2
$PM_{2.5}$ Summary Data – 2002

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

Monitoring Site	Number of Samples	Annual Mean[†]	Maximum Daily Average During Forest Fire Episode	Maximum Daily Average Excluding Forest Fire Episode
Atlantic City	114	11.6	106.7	47.7
Camden Lab	114	14.0	95.0	58.9
Chester	114	11.1	83.9	43.5
Elizabeth Lab	330	15.1	86.8	59.0
Elizabeth (Mitchell)[a]	110	13.1	*****	38.4
Fort Lee	119	13.5	77.8	37.2
Gibbstown	109	13.0	96.9	55.8
Jersey City	116	14.9	81.3	41.0
Morristown	115	12.1	82.6	41.5
New Brunswick	103	11.8	85.5	39.3
Newark (Willis Center)	115	14.6	83.1	39.1
Newark Lab	112	13.7	82.4	40.0
Paterson	114	13.4	76.5	38.8
Pennsauken	109	14.6	94.1	55.8
Phillipsburg	117	13.3	84.8	41.3
Rahway	200	13.1	86.0	38.9
Toms River	117	11.5	84.0	50.0
Trenton	106	13.7	86.2	52.2
Union City[b]	21	*****	*****	37.6
Washington Crossing	112	12.0	66.0	46.6

[†] Annual average includes forest fire event
[a] Indicates site did not run during the forest fire episode
[b] Indicates site did not run during the forest fire episode; and data was unavailable March 15 through December 31

$PM_{2.5}$ 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.

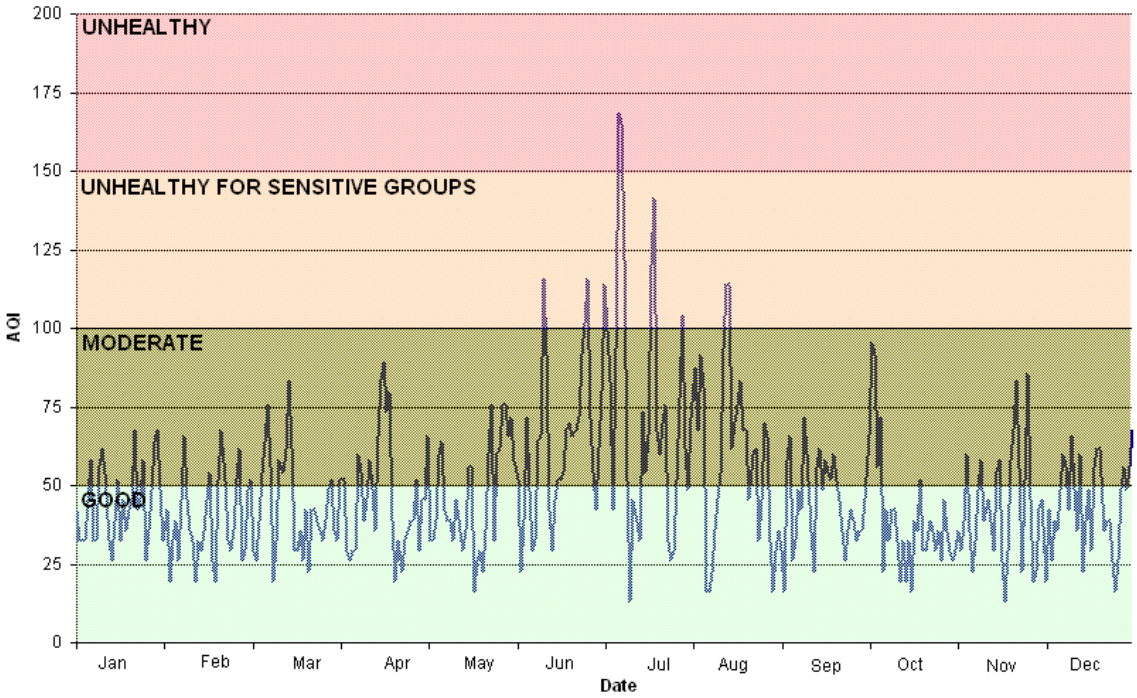
Table 3
2002 Summary of Continuous PM2.5 Data

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

Monitoring Site	Maximum Daily Average	2nd Highest Daily Average	Annual Mean
Camden Lab	96	90	14
Elizabeth Lab	85	58	15
Fort Lee[a]	48	38	---
Newark Lab	81	52	14
New Brunswick	84	65	12

[a] Data unavailable June 30th through August 30th

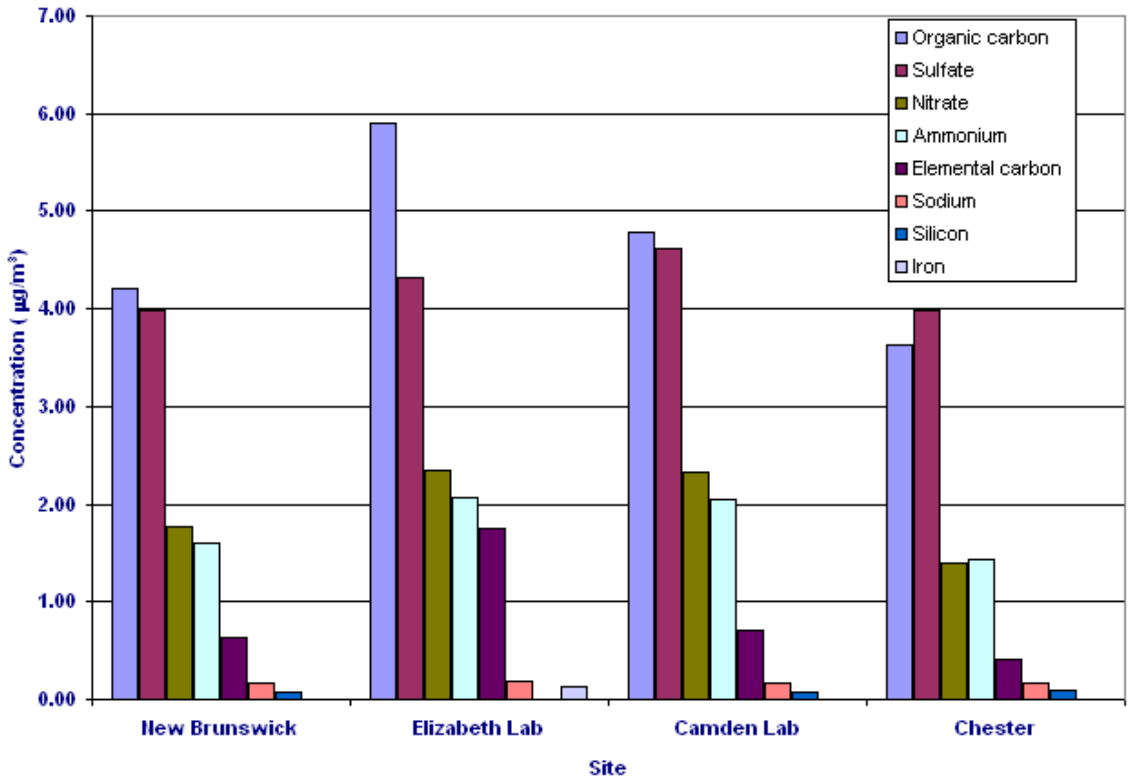
Figure 5
Maximum Daily Fine Particulate Air Quality Index (AQI)



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% (98% total) of the particulate mass. Figure 6 shows the average concentration of each analyte, with only the eight most prevalent constituents depicted. Appendix B shows the average, maximum, and 2nd highest concentrations for each compound for 2002.

Figure 6
2002 -Average Fine Particle Analyte Concentrations
(Highest 7 Analytes at Each Site)



2002 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 7 depicts the PM_{10} particulate monitoring network in New Jersey.

Figure 7
2002 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 2002 Lead Summary section. In 2002, the annual geometric mean concentration of TSP in New Brunswick was 28.1 $\mu g/m^3$, and the maximum 24-hour concentration recorded was 139 $\mu g/m^3$. 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 2002, the annual mean concentration of PM_{10} ranged from 21.4 $\mu g/m^3$ at Trenton to 36.8 $\mu g/m^3$ at Camden RRF. Table 4 and Figure 8 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 $\mu g/m^3$.

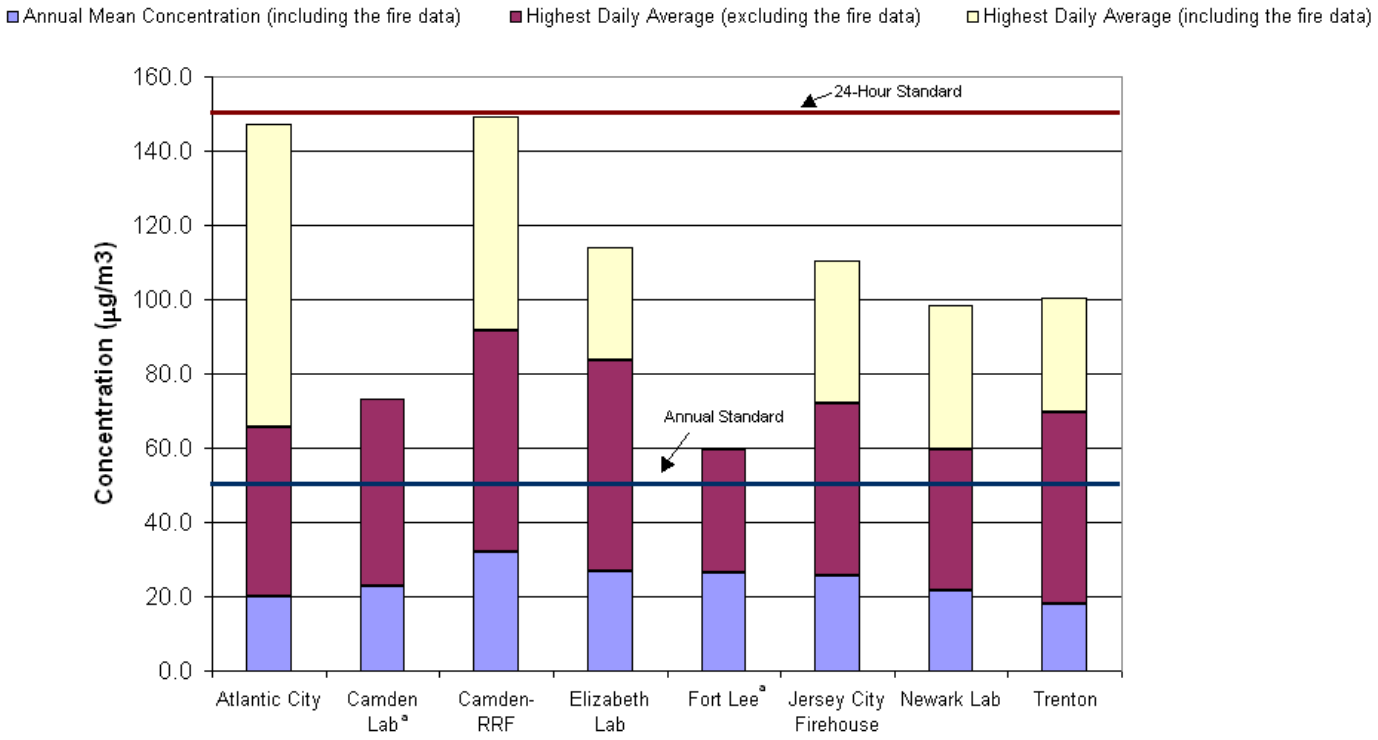
Table 4
PM10 Data-2002
24-Hour and Annual Averages

Micrograms Per Cubic Meter ($\mu g/m^3$)
24-Hour Standard = 150 $\mu g/m^3$
Annual Standard = 50 $\mu g/m^3$

Monitoring Site	24-Hour Average During Forest Fire	24-Hour Maximum Excluding Forest Fire	Annual Average[†]
Atlantic City	147	66	22.7
Camden Lab[a]	****	73	24.4
Camden RRF #1	149	92	36.8
Elizabeth Lab	114	84	30.2
Fort Lee[b]	****	60	****
Jersey City - Firehouse	110	72	29.2
Newark Lab	98	60	25.0
Trenton	101	70	21.4

[†] Annual average includes forest fire event
[a] There was no sample during the forest fire event
[b] Data unavailable June 30th through August 30th (no sample during forest fire)

Figure 8
Summary of PM_{10} Concentrations, New Jersey 2002



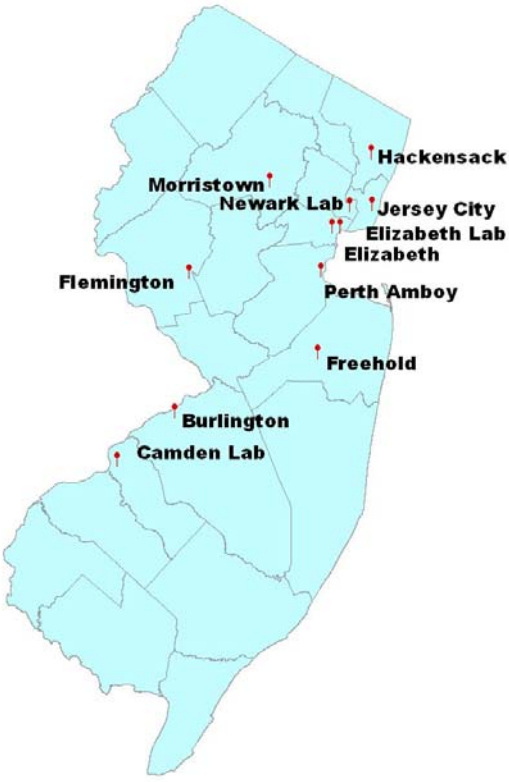
The concentration of Sulfates and Nitrates were also analyzed on some PM_{10} filters. The results showed that, on average, about 2% percent of PM_{10} is nitrate and about between 11% and 15% percent is sulfate. The contributions of sulfate and nitrate to PM_{10} are significantly less than their contributions to $PM_{2.5}$. This is because PM_{10} 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.

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 9.

Figure 9
2002 Smoke Shade Monitoring Network



Smoke Shade Concentration Summary

In 2002, the annual mean concentration of smoke shade ranged from 0.14 Coefficient of Haze units (COH) at Flemington to 0.64 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 2002.

Table 5
Smoke Shade - 2002

Coefficient of Haze (COHs)

Site	Maximum 24-Hour Average	2nd Highest	Annual Mean
Burlington	0.65	0.61	0.18
Camden Lab[a]	0.77	0.51	-----[b]
Elizabeth	1.41	1.12	0.32
Elizabeth Lab	1.94	1.69	0.64
Flemington	0.72	0.62	0.14
Freehold	0.79	0.63	0.21
Hackensack	0.78	0.73	0.23
Jersey City	1.51	1.32	0.47
Morristown	0.68	0.61	0.21
Newark Lab	1.06	0.91	0.30
Perth Amboy	0.70	0.65	0.23

[a] There was no sampling during the forest fire event
[b] Insufficient data

Canadian Forest Fire Episode

A July 2nd lightning storm ignited as many as 85 separate fires in 2 areas southeast of James Bay in Quebec, Canada. The fires were in a region approximately 200-400 miles north of the U.S. border, and destroyed more than 250,000 acres of forest. Ten of the fires burned out of control for days. On July 7th, 2002 northwesterly winds carried the plume of smoke over parts of the Northeast United States, including New Jersey, prompting health advisories. The smoke plume reached as far south as Washington D.C.

During this episode New Jersey recorded its highest $PM_{2.5}$ concentrations on record, with the highest concentrations being reported in the Southern Delaware Valley and Southern Coastal regions. The highest FRM reading was recorded in Atlantic City, which recorded a 24-hour concentration of 106.7 $\mu g/m^3$. The 1-hour average TEOM levels reached as high as 159 $\mu g/m^3$ at the Camden Lab. As expected, Organic Carbon was the most prevalent compound, contributing between 86% and 89% of the $PM_{2.5}$ particle mass. Typically organic carbon makes up between 34% and 36% of the total $PM_{2.5}$ particulate mass (Figure 10 & Figure 11).

Figure 10
Speciated PM2.5 Particles at Camden Lab New Jersey 7/7/02 (Canadian forest fire)

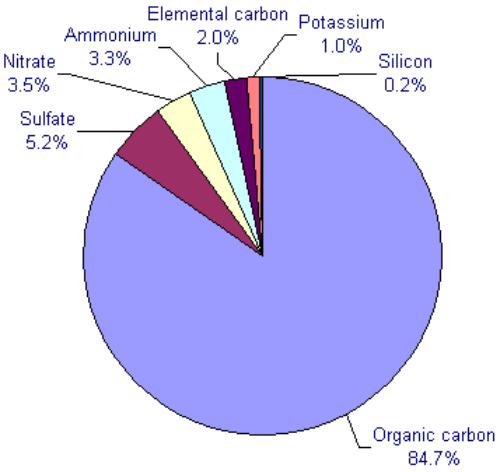


Figure 11
Speciated Fine Particles at Camden Lab New Jersey 2002

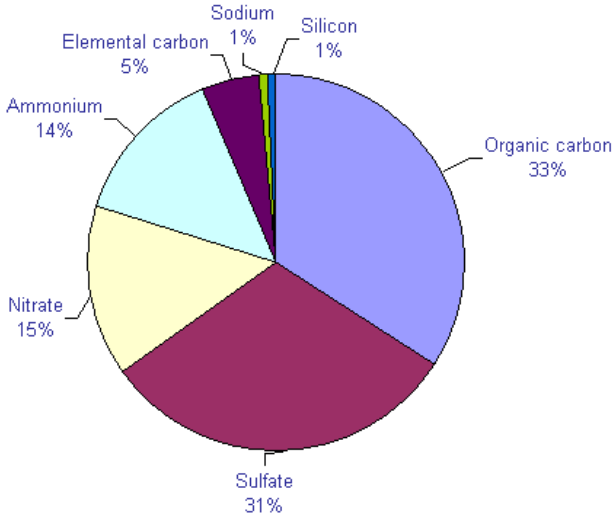
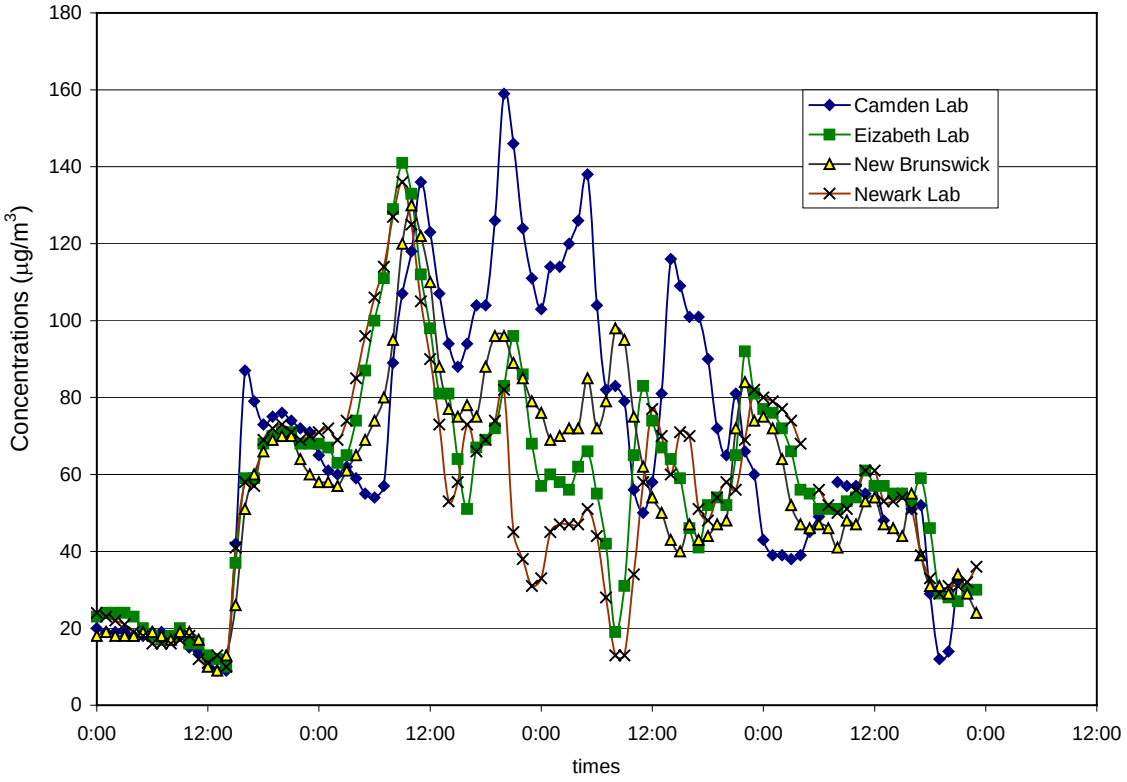


Figure 12 depicts the average hourly particulate concentrations, illustrating the duration and intensity of the particulate concentrations during this episode.

In the southern and central sections of the state fine particle levels remained at an unhealthy level the following day. Camden Lab recorded a 24-hour average TEOM concentration of 90 $\mu g/m^3$, while New Brunswick recorded a 24-hour average of 65 $\mu g/m^3$. TEOM readings at Elizabeth Lab and Newark Lab were slightly below 65 $\mu g/m^3$, the cutoff level for unhealthy particle concentrations. On July 9th, changing winds cleared out the remaining smoke and the particulate levels returned to more normal summertime concentrations.

Figure 12
Hourly PM2.5 Data from Forest Fire Episode
(7/6/02-7/9/02)

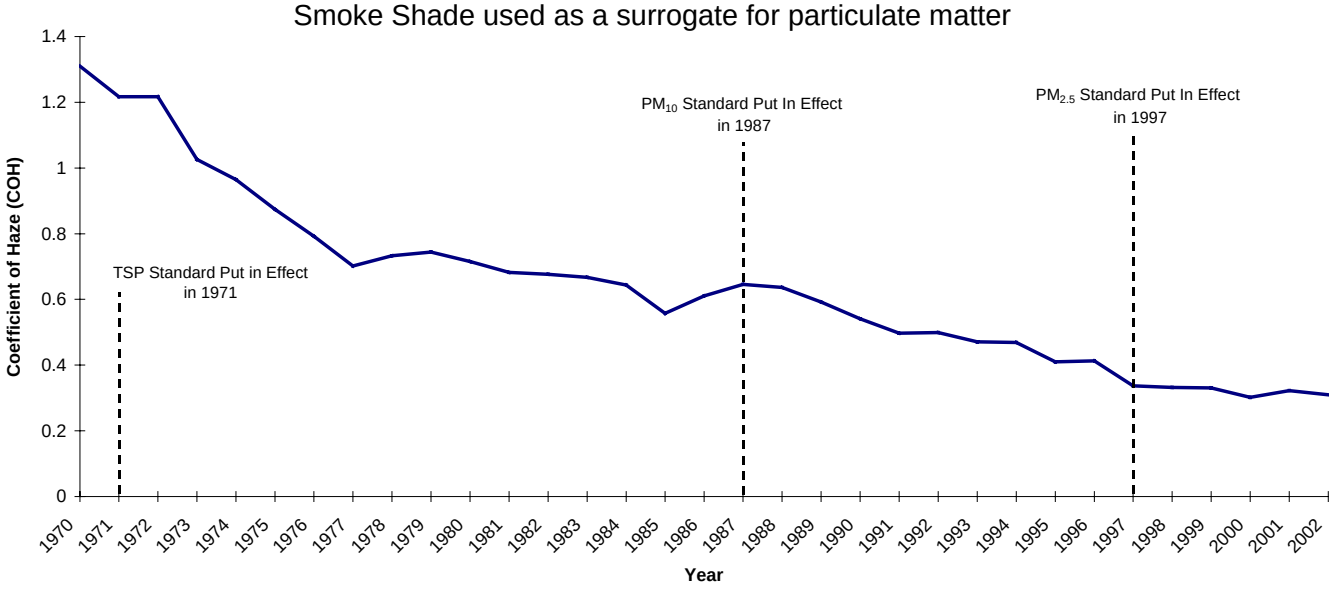


TRENDS IN PARTICULATE CONCENTRATIONS

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 13 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 13
Long Term Trend in Particulate Levels
1970 - 2002

Smoke Shade used as a surrogate for particulate matter



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