

Particulate Matter in the Air

Question 2:
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What is the current concentration of particulate matter in the air of the Southern Appalachians?

Violations of the particulate matter National Ambient Air Quality Standard (NAAQS) have not occurred at any monitoring site in the Southern Appalachians. Within the rural environment, regional planners need to know existing particulate matter concentrations for two possible reasons: first, if emissions of particulate matter increase in localized areas, they may violate the existing NAAQS; and secondly, if NAAQS for particulate matter is lowered to protect human health, current monitored levels may violate the standard. Some natural resource managers want to know current particulate matter levels because they want to increase prescribed burning, which can be an important localized short duration source of particulate matter.

This chapter addresses current levels of particulate matter within the Southern Appalachians in order that others may be able to assess whether an increase in particulate matter sources, such as large stationary sources (for example, power plants) or unpaved roads, would exceed regulated limits. The chapter also considers whether particulate matter emissions from prescribed fires are likely to cause a violation of NAAQS.

The Clean Air Act (CAA), along with its Amendments of 1977 and 1990, addresses both a large variety of air pollution sources and a number of specific pollutants. The U.S. Environmental Protection Agency (EPA) maintains NAAQS for six common air pollutants: particulate matter, carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, and lead. NAAQS is a two-part standard, with a primary standard that protects public health and a secondary standard for public welfare. The NAAQS primary standard for particulate matter is: no more than 50 microns per cubic meter ($\mu\text{g}/\text{m}^3$) on a yearly average basis and a

maximum of $150 \mu\text{g}/\text{m}^3$ for a 24-hour average. The secondary NAAQS protects public welfare, which means: forest and agricultural productivity, stability of ecosystems, transportation safety, maintenance of man-made improvements, and enjoyment of recreational opportunities. The secondary standard for particulate matter is identical to the primary standard. In both parts, "particulate matter" refers only to those airborne particles and aerosols that are less than or equal to 10 microns in size (PM₁₀).

Particulate matter is a leading pollutant responsible for declines in visibility throughout the United States. Also, forest fire smoke can cause dangerous situations for brief periods of time when a portion of the visible plume drifts across a highway or other sensitive site. Along with the NAAQS for sulfur dioxide and nitrogen dioxide, the CAA provides specific programs to deal with visibility and acid deposition problems. These two issues are discussed in Chapters 4 and 5 of this report.

Particulate Matter Assessment Techniques

The information presented in this assessment can also be found in greater detail in a report by Wergowske (1995). The data used in this assessment are taken from particulate matter summaries in the EPA Aerometric Information Retrieval System (AIRS) database for 1985-1994, for the following states – Alabama, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, and Virginia. Information is also presented on particulate-matter-monitoring data collected near prescribed fires.

The 1985 through 1994 data sets contain several peculiarities because the focus of particulate-matter monitoring underwent a shift from total suspended particulate (TSP) to PM₁₀. The advancement of medical science has, and continues to, increase the detail of the knowledge regarding the public health impacts of airborne particles; this progress in turn requires monitoring of smaller particles. The change in

NAAQS from TSP to PM10 initiated a gradual replacement of TSP-monitoring equipment by PM10 equipment. The number of TSP monitors decreased while the number of PM10 monitors increased during the period of interest for this report. Both data sets are presented. Wergowske (1995) examined monitoring data from urban areas and rural (called background-proxy sites) areas. The analysis indicated that particulate-matter concentrations appear to be similar for both areas. Therefore, the following analysis will present particulate-matter information using all available particulate-matter-monitoring data within the assessment area, and 40 to 80 miles beyond the assessment boundary.

To determine how close current monitored levels of particulate matter are to the NAAQS for particulate matter, this study examined the records, by year, for trends or extremes in the means and maxima of those two statistics that gage compliance with both particulate matter exposure standards. For PM10, the standards for average annual exposure and maximum 24-hour exposure are 50 and 150 ug/m³, respectively. For TSP, using accepted conversions, those figures would be 79 and 300 ug/m³, respectively.

Wergowske also noted by year the number of stations where observations showed exceedence of, or encroachment on (within 90 percent), the particulate matter standards. For PM10, 90 percent of the annual and 24-hour standards are 45 and 135 ug/m³, respectively. Converting to TSP, those figures would be 71 and 270 ug/m³, respectively (Wergowske 1995).

Current Particulate Matter Concentrations

Annual Average Particulate-Matter Concentrations versus the Annual Average NAAQS for Particulate Matter

One of the summary statistics available for each station-year of record is the arithmetic average of the 24-hour measurements made throughout the year. This annual average statistic shows how well air quality at the station measures against the annual NAAQS for particulate matter. Table 3.1 shows a summary, by year, of all stations in the Southern Appalachian

Table 3.1 A summary of annual average particulate matter measurements at all air-quality monitoring stations in the Southern Appalachians.

Year	PM10				TSP			
	Count	Mean (ug/m ³)	Maximum (ug/m ³)	#Obs. GT.45	Count	Mean (ug/m ³)	Maximum (ug/m ³)	#Obs. GT.71
1985	8	44	53	4	197	47	94	2
1986	17	44	57	8	205	52	92	12
1987	35	38	52	8	189	50	101	5
1988	37	35	47	2	166	52	91	7
1989	58	33	61	1	100	45	89	2
1990	78	30	50	2	85	46	94	2
1991	85	30	42	0	67	45	85	5
1992	92	26	39	0	53	39	79	1
1993	102	25	40	0	46	38	57	0
1994	106	24	40	0	37	39	58	0

Count = The number of station-years of record available for analysis.

Mean = The mean of all the station annual averages.

Maximum = The maximum station annual average out of all the station annual averages.

#Obs. GT. xx = The number of station annual averages which are greater than a value equivalent to 90 percent of the National Ambient Air Quality Standard for particulate matter.

delimited data set. This information shows:

1. During the period 1985-1994, the average annual particulate matter concentrations for the region appear to be declining when measured by both the mean of station PM10 averages and the mean of station TSP averages. The rate of decline is very steep (44 to 24 ug/m³) for PM10.
2. The particulate matter trend is also declining when measured by the maximum of station PM10 and TSP averages (53 to 40 ug/m³, and 94 to 57 ug/m³). Although it is not nearly as steep as is indicated by the mean of station PM10 averages.
3. In recent years there have been few occurrences when the average annual PM10 and TSP statistic exceeded the 90 percent of the annual NAAQS for PM10 or its TSP equivalent.

When station annual average particulate matter statistics are sorted and summarized by state, there do not appear to be substantial differences by state in average particulate-matter concentrations. Another summary of the sea-

sonal station averages shows that spring and summer tend to have higher particulate-matter measurements, averaging about 12 percent above the overall mean. The spring and summer averages are higher since soils are usually dryer and more dust and soils are present in the atmosphere.

Maximum Annual Particulate Matter Values versus the 24-Hour NAAQS for Particulate Matter

Summary statistics for each station-year of record contain the highest of the individual 24-hour values recorded throughout the year. These values show how well air quality at the station measures against the 24-hour NAAQS for particulate matter. Table 3.2 shows a summary of these statistics, by year, for all stations in the Southern Appalachian data set.

1. The maximum yearly particulate-matter concentrations for the area are declining when measured by both the mean of station-year PM10 maximum and the mean of station-year TSP maximum (98 to 58 ug/m³, and 110 to 84 ug/m³).
2. Maximum particulate-matter concentrations are declining rapidly during the

Table 3.2 A summary, by year, of maximum 24-hour particulate matter measurements at all air-quality monitoring stations in the Southern Appalachians.

Year	PM10				TSP			
	Count	Mean (ug/m ³)	Maximum (ug/m ³)	#Obs. GT.135	Count	Mean (ug/m ³)	Maximum (ug/m ³)	#Obs. GT.270
1985	8	98	130	0	197	110	467	4
1986	17	92	163	2	204	120	460	2
1987	36	76	154	2	204	112	308	1
1988	38	80	147	1	182	117	298	2
1989	59	74	159	1	116	108	345	2
1990	79	72	148	2	103	99	369	3
1991	86	73	134	0	82	114	214	0
1992	92	55	142	1	70	83	320	1
1993	95	65	101	0	62	88	238	0
1994	100	58	132	0	53	84	147	0

Count = The number of station-years of record available for analysis.
 Mean = The average of the individual 24-hour maximum, from all stations, throughout the year.
 Maximum = The highest of the individual 24-hour maximum, from all stations, throughout the year.
 #Obs. GT. xx = The number of station annual averages which are greater than a value equivalent to 90 percent of the National Ambient Air Quality Standard for particulate matter.

period of interest when measured by the highest of station annual TSP maximum (467 to 147 $\mu\text{g}/\text{m}^3$). This trend is declining slowly, if not holding steady, when measured by the highest of station annual PM10 maximum (130 to 132). This disparity will be discussed in a later section.

3. During 1985-1994, there were few occurrences when the annual maximum PM10 and TSP statistic exceeded 90 percent of 24-hour NAAQS for PM10 or its TSP equivalent.

As with station-year average particulate matter values, the maximum values were examined for seasonal patterns and for patterns among the states. However, no clear patterns were discernible in these data.

Particulate-Matter Concentrations in the Immediate Vicinity of a Prescribed Fire

There are very few particulate-matter monitors located in forested areas of the Southern Appalachians. Furthermore, forest fires rarely occur in the immediate vicinity of a particulate-matter-monitoring station in the network. However, two studies have been reported in southern states where portable PM10 monitors were briefly (2-12 hours) set up adjacent to prescribed fires. One study was conducted by the Florida Department of Environmental Protection and the Apalachicola National Forest (Florida Department of Environmental Protection 1993), and the other was done by the Texas Forest Service and the USDA Forest Service on the National Forests in Texas (Hunt and others 1994). Not surprisingly, both projects showed that the likelihood of exceeding the 24-hour NAAQS for particulate matter of 150 $\mu\text{g}/\text{m}^3$ increased in close proximity to the fire.

In nine-tenths of the cases, particulate-matter concentrations were less than 150 $\mu\text{g}/\text{m}^3$ one mile from the control line. In two-thirds of the cases, the standard was maintained as close as one-half mile from the control line. In a few cases, PM10 concentrations did not exceed the 24-hour standard even at the control line. In both studies, prior to burning, the PM10 concentrations in the air mass were measured

between 15 and 30 $\mu\text{g}/\text{m}^3$ – well below both the annual and 24-hour standards. It is clear that PM10 concentrations associated with prescribed burns are dependent on weather, fuel conditions, and the duration of burn.

Summary of Current Particulate-Matter Concentrations and Trends

1. In recent years, particulate-matter concentrations have seldom approached the 24-hour standard for PM10 or its TSP equivalent. Even less frequently have particulate-matter concentrations approached the annual standard.
2. A comparison of quarterly average particulate-matter values shows that spring and summer tend to have higher values than fall and winter. A review of the months in which the yearly first and second maxima occurred at each station, however, does not reveal any strong seasonal pattern.
3. A review of the average annual and yearly maxima data by state does not show any strong spatial patterns in PM concentrations across the SAA area.

In as much as there are no strong spatial or seasonal patterns for peak PM concentrations, managers responsible for infrequent and exceptionally large PM emissions will have trouble finding a “safe” season or locality where such emissions can be released without consideration.

4. The PM10 and TSP data give the appearance of a declining trend in annual PM concentrations. As discussed in the following paragraph, caution is advised before relying heavily on this apparent trend.

The revision of the NAAQS for particulate matter in 1987 not only focused attention on PM10, but also lowered the standard to a limited degree. This lowering, as well as other CAA regulatory efforts, may have led to true reductions in particulate matter. However, information in Chapter 2 notes that particulate-matter emissions from all sources has remained level since the 1960s. There is a possibility that

because of differences in measuring equipment, monitored particulate-matter concentrations have not really been declining. The change-over from TSP equipment to PM10 was done over an extended period of time to reduce the financial burden on monitoring agencies. Areas with the greatest likelihood of exceeding the particulate matter standard switched from TSP to PM10 monitors first. This selective replacement of equipment, which put priority on those sites with high particulate matter concentrations, could have made a level trend in particulate matter appear as downward trends in both PM10 and TSP. Therefore, until the data are examined more closely, it is possible that PM10 trends may be level instead of declining.

Particulate Matter Concentrations – Future Regulations Regarding Prescribed Fires

Changing of the NAAQS to PM2.5

The EPA is considering a lowering of the NAAQS for particulate matter if new information shows stronger standards are needed to protect public health from small airborne particles. A revised standard might focus on particulate matter smaller than 2.5 microns in diameter (PM2.5). At a recent workshop on environmental regulation and prescribed fire, a representative of the American Lung Association presented evidence that the current PM10 standard does not adequately protect public health. He reported that “a significant number of recent epidemiological research studies have found a correlation between levels of PM10 well below the current standard with a broad spectrum of adverse health effects, including death” (White 1995).

Visibility is also affected by fine particulates. Most of the haze in the Southern Appalachians can be attributed to PM2.5 (see Chapter 4). Due to this, the EPA is developing regional haze regulations concurrently with the particulate-matter standard review.

The EPA's ongoing review of NAAQS may result in regulating particulate matter to a level well below the current PM10 24-hour standard of 150 ug/m³.

With changes on the horizon, it is clear that future land management decisions can no longer be made as in the past. Regional planners, and other people who conduct open burning or prescribed fires, must be prepared to accommodate these changes.

Particulate Matter Emissions from Prescribed Fires

Forests are usually seen as having a positive effect on air quality, but forest fires emit air pollutants. Prescribed fire is widely used by natural resources managers to benefit timber production, wildlife, rare and endangered species, and to reduce wildfires. Even before this century, inhabitants of the forested and rural southeast used controlled burning for a variety of purposes including: land clearing, game and domestic animal forage improvement, safety/protection, and forest fuel reduction. The Terrestrial Technical Report of the Southern Appalachian Assessment (SAMAB 1996c) discusses the prevalence of pre- and post-European settlement fires in the area. It is increasingly apparent that fire is an important process in many ecosystems, and that, in order to restore and manage terrestrial ecosystems, the use of prescribed fire may increase.

All forest fires emit air pollutants. The advantage of controlled prescribed burns over wild-fire is that the timing, location, and intensity of the burns are moderated. This moderation reduces public health and safety hazards, limits property damage, and minimizes adverse effects on environmental resources such as air quality.

Emissions from prescribed fires could contribute to violations of several NAAQS-regulated substances: carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, and particulate matter. As with most poorly controlled combustion processes, carbon monoxide is emitted in large amounts, approximately 140 lb/ton of fuel (EPA 1988). Carbon monoxide is not generally a threat in rural areas beyond the immediate vicinity of the fire. With the possible exception of “peat” and “muck soil” sites, forest fires emit only negligible amounts of sulfur (USDA Forest Service 1976). Nitrogen and volatile organic compounds are emitted at approximate rates of 4 and 24 lb/ton of fuel, respectively (EPA 1988). The amounts of nitrogen and volatile organic compounds emitted from prescribed fires in the

Southern Appalachians are insignificant in comparison with other natural and man-caused sources of these pollutants. However, both of these pollutants are precursors to the formation of ground-level ozone and may become significant where ozone problems already exist. Emissions of both nitrogen oxides and volatile organic compounds from open burning have been targeted for reduction in state plans to achieve the ozone standard in areas where ozone is persistently high (Georgia Environmental Protection Division 1994). Chapter 6 of this report discusses the current status of ground-level ozone and its potential effect on forest trees.

Particulate-matter emissions from forest fires vary widely depending on the type and amount of accumulated fuel, weather, fuel moisture, and the fire's rate of spread. The average emission rate for particulate matter is estimated at 17 lb/ton of fuel consumed. At an average consumed-fuel load of approximately 9 tons/acre, fires could yield as much as 153 lb/acre of particulate matter (EPA 1988). Forest managers will need to be cautious if either the size or number of acres burned in prescribed fires is increased. A large increase in particulate-matter emissions could lead to a violation of the particulate matter NAAQS. As mentioned previously, PM10 NAAQS have been exceeded downwind of prescribed fires.

Particulate matter formation in forest fire smoke is a complex process. Coagulation and condensation of solid and gaseous organic compounds form the bulk of particles in the smoke. These particles are almost always less than 5 microns in size. Larger particles of ash and unburned fuel are carried aloft, but they usually settle to the ground within a distance of 1/2 to 1 mile of the burn. Approximately 80 percent of the particulate matter mass carried aloft from forest fires is in particles less than 1 micron in size. Particles found by aircraft samplings of smoke plumes are rarely larger than 10 microns (USDA Forest Service 1976). Based on National Research Council (1993) information, Wergowske (1995) has estimated that current levels of forest fire smoke contribute about 1.5 percent to overall fine particle mass on an annual basis. It is important to note that prescribed fires could receive greater attention in the future if the NAAQS is lowered to PM2.5 and emissions from prescribed fire are increased.

Key Findings

1. **Particulate-matter concentrations in the Southern Appalachian area are distributed uniformly, but have some seasonal variation. Spring and summer mean concentrations are approximately 12 percent above the annual mean.**
2. **At most monitoring stations, particulate-matter concentrations are well below current air-quality standards. New sources which emit small amounts, or even modest amounts, of particulate matter probably will not cause a violation of the annual standard.**
3. **If tighter particulate matter standards are implemented, prescribed fires may cause a violation of air-quality standards since the prescribed fire emissions of particulate matter are predominantly less than 1 micron in size.**