

Characterization of Ambient PM10 and PM2.5 in California

**Technical Report
June 2005**

California Environmental Protection Agency



Air Resources Board

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Executive Summary

Reducing particulate matter (PM) air pollution is one of the California Air Resources Board's (ARB or Board) highest public health priorities. Exposure to particulate pollution is linked to increased frequency and severity of asthma attacks, pneumonia and bronchitis, and even premature death in people with pre-existing cardiac or respiratory disease. Those most sensitive to particle pollution include infants and children, the elderly, and persons with heart and lung disease. Particulate matter pollution consists of very small liquid and solid particles suspended in the air and includes particles smaller than 10 microns in size (PM10), as well as the subset of fine particles smaller than 2.5 microns in size (PM2.5). Particles with a size between 2.5 and 10 microns are often referred to as coarse particles.

In 2003, the Legislature enacted Senate Bill 656 (SB 656, Sher), to reduce public exposure to PM10 and PM2.5. The legislation requires the ARB, in consultation with air pollution control and air quality management districts (air districts), to adopt a list of the most readily available, feasible, and cost-effective control measures that can be implemented by air districts to reduce PM10 and PM2.5. The legislation establishes a process for achieving near-term reductions in PM throughout California, especially in those areas that have not had federal planning requirements. This will ensure continuing focus on PM and progress towards attaining California's health protective air quality standards. The Board approved the list of control measures on November 18, 2004. Over 100 possible measures covering a broad spectrum of sources are included on the list. Air districts must now develop implementation schedules by July 31, 2005. The implementation schedules will identify a subset of measures from the list that are appropriate to the severity and nature of the PM problem in each area.

The purpose of this report is to assist air districts in evaluating the nature of their PM problem. This document presents information from the perspective of the State standards. The report describes the characteristics of PM10 and PM2.5 in each of California's air districts within each air basin including: ambient concentrations; spatial, seasonal, and hourly variations; and indication of broad source categories leading to the observed ambient particle concentrations. Abundant information is currently available from the ongoing PM10 monitoring network, the PM2.5 monitoring network in place since 1999, the advent of continuous PM2.5 monitoring, as well as part of special studies such as the California Regional PM10 and PM2.5 Air Quality Study, the Southern California Children's Health Study, and the South Coast Air Quality Management District's PM Enhancement Programs of 1995 and 1998-1999. This report presents these air monitoring results, including information about the frequency of exceedances and the severity of the PM problem based on ambient data (2001-2003) used to designate areas for the State PM10 and PM2.5 standards. The report is based on the best available information. However, the extent of data varies among the different areas. In areas where special studies have been conducted, the level of

available data is more extensive, but in general data are sufficient throughout the State to characterize each region's PM problem.

The main findings are summarized below:

- Most air districts in the State are currently nonattainment for the State PM10 standards. Only the Lake County and the Siskiyou County air districts meet these standards.
- Air districts in fourteen air basins exceeded the State 24-hour PM10 standard of $50 \mu\text{g}/\text{m}^3$, with air districts in ten of these air basins recording designation values over $75 \mu\text{g}/\text{m}^3$. The Great Basin Unified air district recorded the highest 24-hour PM10 concentrations, with values of approximately one hundred times the level of the State standard. The San Joaquin Valley air district and air districts in the Salton Sea Air Basin recorded PM10 concentrations of approximately four to six times the level of the standard. On the other hand, 24-hour PM10 concentrations in the Lake Tahoe Air Basin are approaching the level of the standard.
- Air districts in twelve air basins are also nonattainment for the State annual PM10 standard of $20 \mu\text{g}/\text{m}^3$, with air districts in five of these air basins recording designation values above $35 \mu\text{g}/\text{m}^3$. The Great Basin Unified air district recorded the highest annual average PM10 concentrations, with values of approximately eight times the level of the State standard. The South Coast and San Joaquin Valley air districts and air districts in the Salton Sea Air Basin recorded PM10 concentrations of approximately three to four times the level of the standard. However, annual PM10 concentrations in air districts in the North Coast Air Basin are approaching the level of the standard.
- Most urban areas, as well as some rural areas, are nonattainment for the State annual PM2.5 standard of $12 \mu\text{g}/\text{m}^3$. The South Coast and the San Joaquin Valley air districts recorded the highest annual average concentrations, with values nearly twice the State standard. However, annual PM2.5 concentrations in all of the other nonattainment areas are approaching the level of the standard.
- The size, concentration, and chemical composition of PM vary by region and by season. A number of areas exhibit strong seasonal patterns. Other areas have a much more uniform distribution - PM concentrations remain high throughout the year. In yet other areas, isolated high PM concentrations can occur at any time of the year.
- Regions such as the San Joaquin Valley, the San Francisco Bay Area, and many areas in the Sacramento Valley display strong seasonal variations in PM, with higher PM10 and PM2.5 concentrations in the fall and winter months due to increased activity for some emissions sources and meteorological

conditions that are conducive to the buildup of PM. During the winter, the PM_{2.5} size fraction drives the PM concentrations. In the urban areas, NO_x emitted from mobile sources and stationary combustion sources combines with ammonia to form ammonium nitrate. Wood smoke and direct particle emissions from motor vehicles are also major contributors to high levels of ambient PM.

- In areas such as the Antelope Valley, Mojave Desert, and Coachella Valley, the higher PM₁₀ concentrations occur during the spring through early fall and are mostly driven by the coarse fraction. The coarse fraction is primarily due to activities that resuspend dust, such as emissions from paved and unpaved roads and construction, as well as windblown dust. In some coastal areas, sea salt can also contribute to the coarse particulate fraction.
- In the eastern South Coast and the southern portion of the South Central Coast air basins, PM₁₀ and PM_{2.5} concentrations remain high throughout the year. The more uniform activity patterns of emission sources, as well as less variable weather patterns, lead to this more uniform concentration pattern. In these areas, secondary ammonium nitrate and ammonium sulfate, direct particle emissions from motor vehicles and other carbon sources, and road and other dust sources contribute to the high particulate levels.
- In other areas, high PM is generally caused by isolated emission activities or weather conditions. For example, in Owens Lake in the Great Basin Valleys Air Basin, episodic fugitive dust events lead to very high PM₁₀ levels, with soil dust as the major contributor to ambient PM₁₀. This also occurs in areas in the Coachella Valley and the Imperial County air district.
- In addition to seasonal variations, PM_{2.5} concentrations can also vary diurnally. For example, in the San Joaquin Valley, PM₁₀ levels varied significantly in urban Fresno during the course of a winter day, with the highest concentrations occurring at nighttime. The rise in PM_{2.5} concentrations in Fresno corresponded mostly to significant nighttime peaks in residential wood burning and mobile source activity. However, at the rural Angiola site, PM_{2.5} levels were highest from mid-day into the evening and were primarily caused by the formation of secondary particulate matter.

I. Statewide Overview

A. Objectives

Reducing particulate matter (PM) air pollution is one of the California Air Resources Board's (ARB or Board) highest public health priorities. Exposure to particulate pollution is linked to increased frequency and severity of asthma attacks, pneumonia and bronchitis, and even premature death in people with pre-existing cardiac or respiratory disease. Those most sensitive to particle pollution include infants and children, the elderly, and persons with heart and lung disease. Particulate matter pollution consists of very small liquid and solid particles suspended in the air and includes particles smaller than 10 microns in size (PM10), as well as the subset of fine particles smaller than 2.5 microns in size (PM2.5). Particles with a size between 2.5 and 10 microns are often referred to as coarse particles.

In 2003, the Legislature enacted Senate Bill 656 (SB 656, Sher), to reduce public exposure to PM10 and PM2.5. The legislation requires the ARB, in consultation with air pollution control and air quality management districts (air districts), to adopt a list of the most readily available, feasible, and cost-effective control measures that can be implemented by air districts to reduce PM10 and PM2.5. The legislation establishes a process for achieving near-term reductions in PM throughout California, especially in those areas that have not had federal planning requirements. This will ensure continuing focus on PM and progress towards attaining California's health protective air quality standards. The ARB approved the list of control measures on November 18, 2004, which can be found at the following web site:

<http://www.arb.ca.gov/pm/pmmeasures/pmmeasures.htm>

Over 100 possible measures covering a broad spectrum of sources are included on the list. Air districts must now develop implementation schedules by July 31, 2005. The implementation schedules will identify a subset of measures from the list that are appropriate to the severity and nature of the PM problem in each area.

The purpose of this report is to assist air districts in evaluating the nature of their PM problem. The report describes the characteristics of PM10 and PM2.5 in each of California's air districts within each air basin including: ambient concentrations; spatial, seasonal, and hourly variations; and indication of broad source categories leading to the observed ambient particle concentrations.

B. Data Used

This section describes the data used and analyses conducted to assess the severity and nature of the particulate matter problem in each of the thirty-five air

districts in the State. We used data obtained from California's routine PM10 (Figure 1) and PM2.5 (Figure 2) monitoring networks, as well as data collected as part of special, short-term studies conducted in various areas of the State. Such studies include the 2000 California Regional PM10 and PM2.5 Air Quality Study (CRPAQS), the Southern California Children's Health Study (CHS), and the South Coast Air Quality Management District's PM Enhancement Programs of 1995 (PTEP95) and 1998-1999 (TEP98-99). Specific data sources include:

- To assess the spatial and temporal characteristics of PM10 and PM2.5 concentrations, we analyzed PM10 data collected from California's network of size selective inlet (SSI) monitors (from 2001 to 2003); PM2.5 information from the Federal Reference Method (FRM) monitoring network (from 2001 to 2003), hourly PM2.5 concentration data from the network's beta attenuation monitors (BAM) (through September 2004); and data from CRPAQS, which was conducted from December 1999 through February 2001. Information on the State's monitoring network and available data can be found on the following web pages:

<http://www.arb.ca.gov/aqd/aqdpagaealt.htm>

<http://www.arb.ca.gov/aqd/almanac/almanac05/almanac05.htm>

and

<http://www.arb.ca.gov/pm/pm.htm>

- For assessing the chemical composition of ambient PM10 and PM2.5, we reviewed information available from: the State's PM10 and PM2.5 monitoring networks - data were downloaded from the United States Environmental Protection Agency's (U.S. EPA) Aerometric Information Retrieval System (AIRS); the Southern California Children's Health Study; and CRPAQS. The following web sites provide further information on these studies:

<http://www.arb.ca.gov/research/abstracts/94-331.htm>

and

<http://www.arb.ca.gov/airways/ccaqcs.htm>

- To identify emission sources leading to ambient PM levels, chemical mass balance modeling based on special studies conducted in Sacramento, the San Francisco Bay Area, Santa Barbara, the San Joaquin Valley (CRPAQS), and the South Coast Air Basin (PTEP95) provided detailed source apportionment details. Further information can be found in the 2003 PM10 State Implementation Plan (SIP) for the San Joaquin Valley Air Pollution Control District and the 2003 South Coast Air Quality Management District PM10 SIP at the following web sites:

<http://www.arb.ca.gov/planning/sip/scsip03/scsip03.htm>

and

<http://www.arb.ca.gov/planning/sip/sjvpm03/sjvpm03.htm>

Figure 1. California's PM10 Monitoring Network

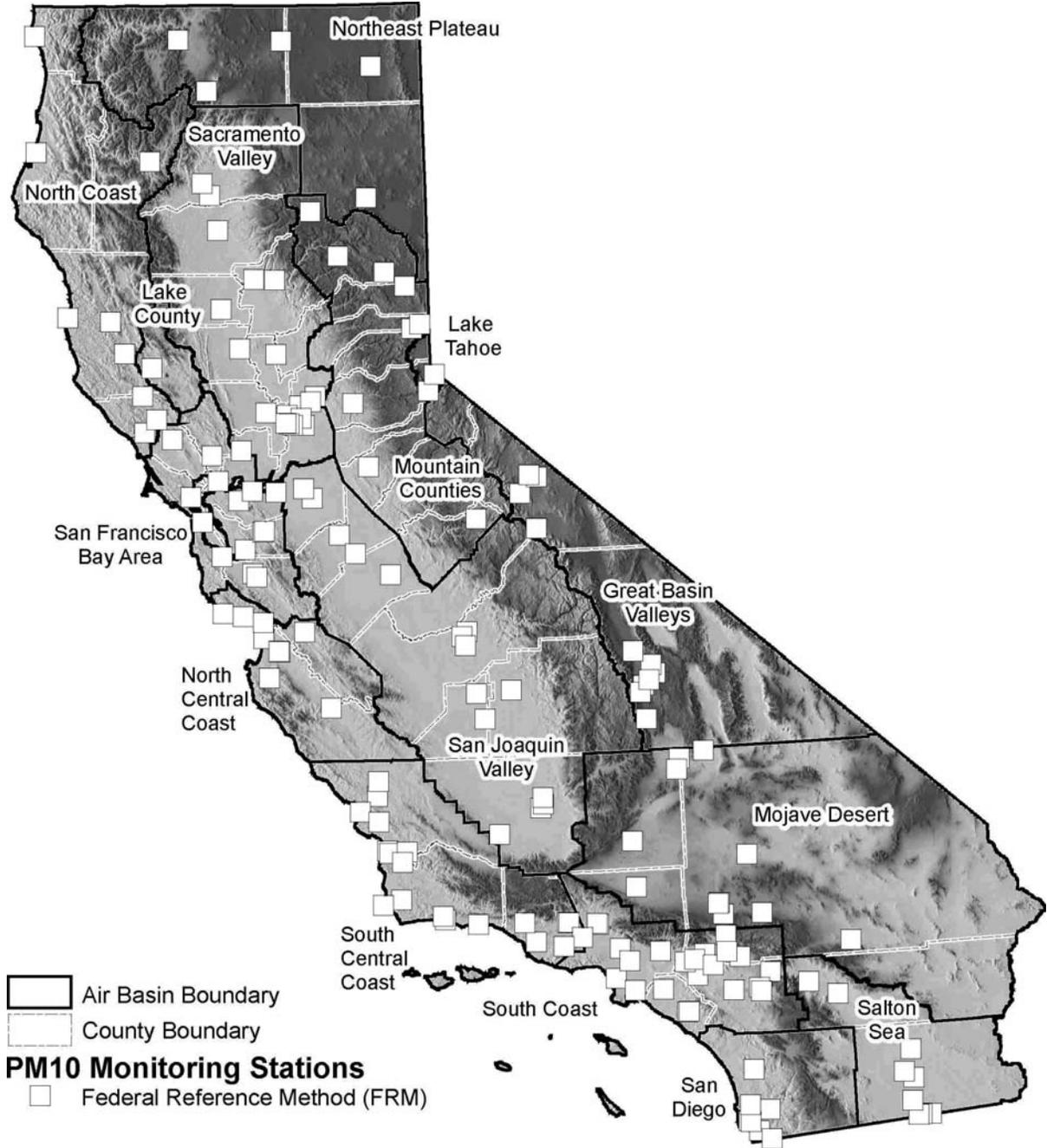
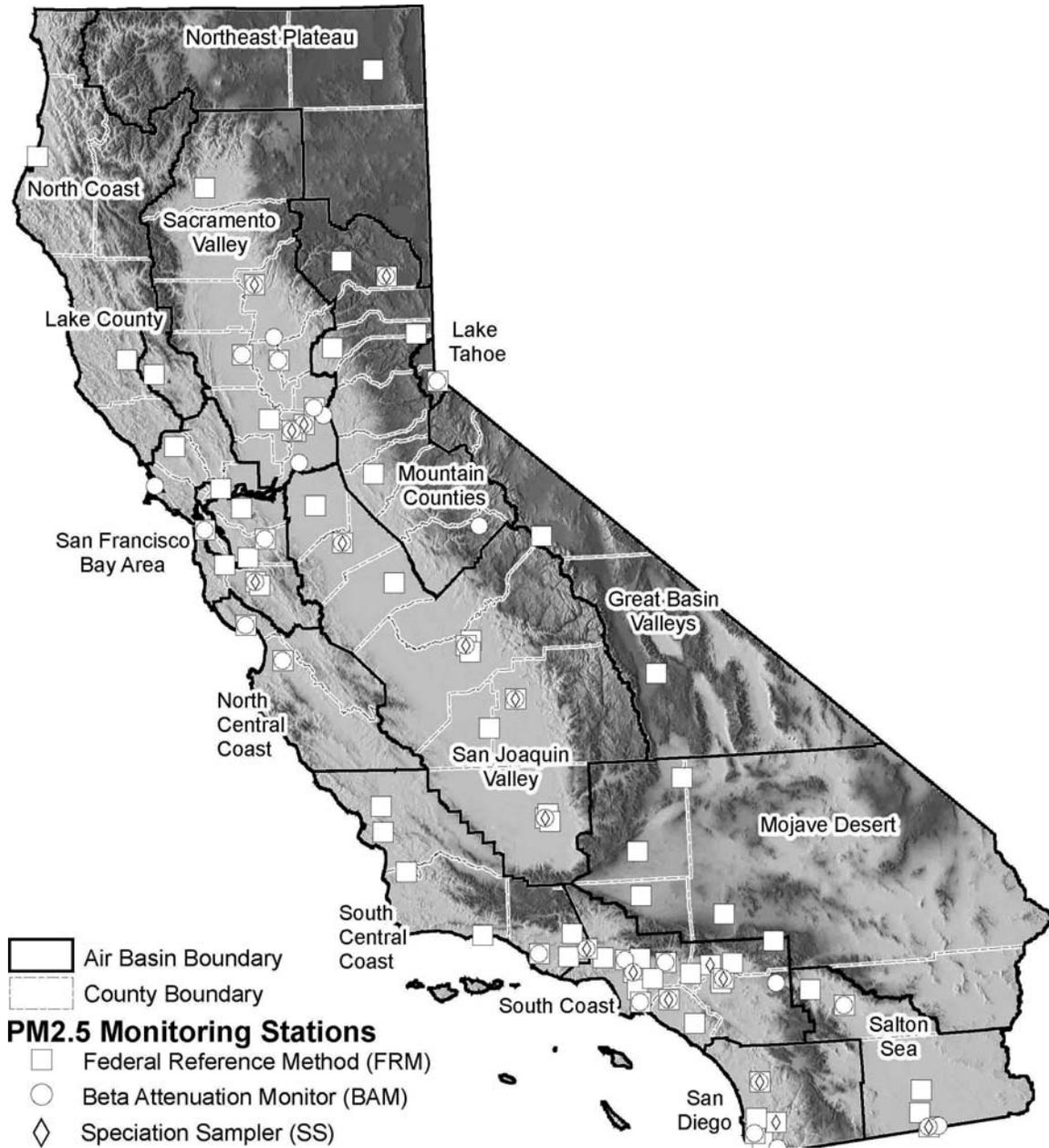


Figure 2. California's PM2.5 Monitoring Network



For other urban and rural areas, we used a combination of available data on the chemical composition of ambient particulate matter and emission inventory data. Emission inventory data can be found on the following web site:

<http://www.arb.ca.gov/ei/ei.htm>

- To assess a range of background PM10 and PM2.5 values representative throughout the State, we used annual average concentrations from 1995-2002 reported by the Interagency Monitoring of Protected Visual Environments (IMPROVE) program. These data can be obtained from the following web site:

<http://www.vista.cira.colostate.edu/views>

C. Area Designations for State and National PM Standards

The U.S. Environmental Protection Agency (U.S. EPA) and the ARB have adopted ambient air quality standards for PM10 and PM2.5 (Table 1). California's standards are the most health-protective standards in the nation, and are designed to provide additional protection for the most sensitive groups of people, including infants and children, the elderly, and persons with heart or lung disease. Attainment of California's standards is expected to result in the yearly prevention of an estimated 6,500 premature deaths, approximately 400,000 incidences of lower respiratory symptoms among children ages seven to fourteen, and over two million lost workdays.

Table 1. State and National Particulate Matter Ambient Air Quality Standards. The levels of the standards are expressed in micrograms per cubic meter ($\mu\text{g}/\text{m}^3$).

	California ($\mu\text{g}/\text{m}^3$)	National ($\mu\text{g}/\text{m}^3$)
PM10		
Annual	20	50
24-hour	50	150
PM2.5		
Annual	12	15
24-hour	-----	65

Virtually the entire State is nonattainment for the State PM10 standard, with most urban areas and several isolated sub-areas nonattainment for the State PM2.5 standard (Figure 3). With respect to the national standards, the San Joaquin Valley, the South Coast, and several desert areas are nonattainment for the federal PM10 standard. National PM2.5 nonattainment areas include the San Joaquin Valley and the South Coast. Further information on State and national designations can be found at:

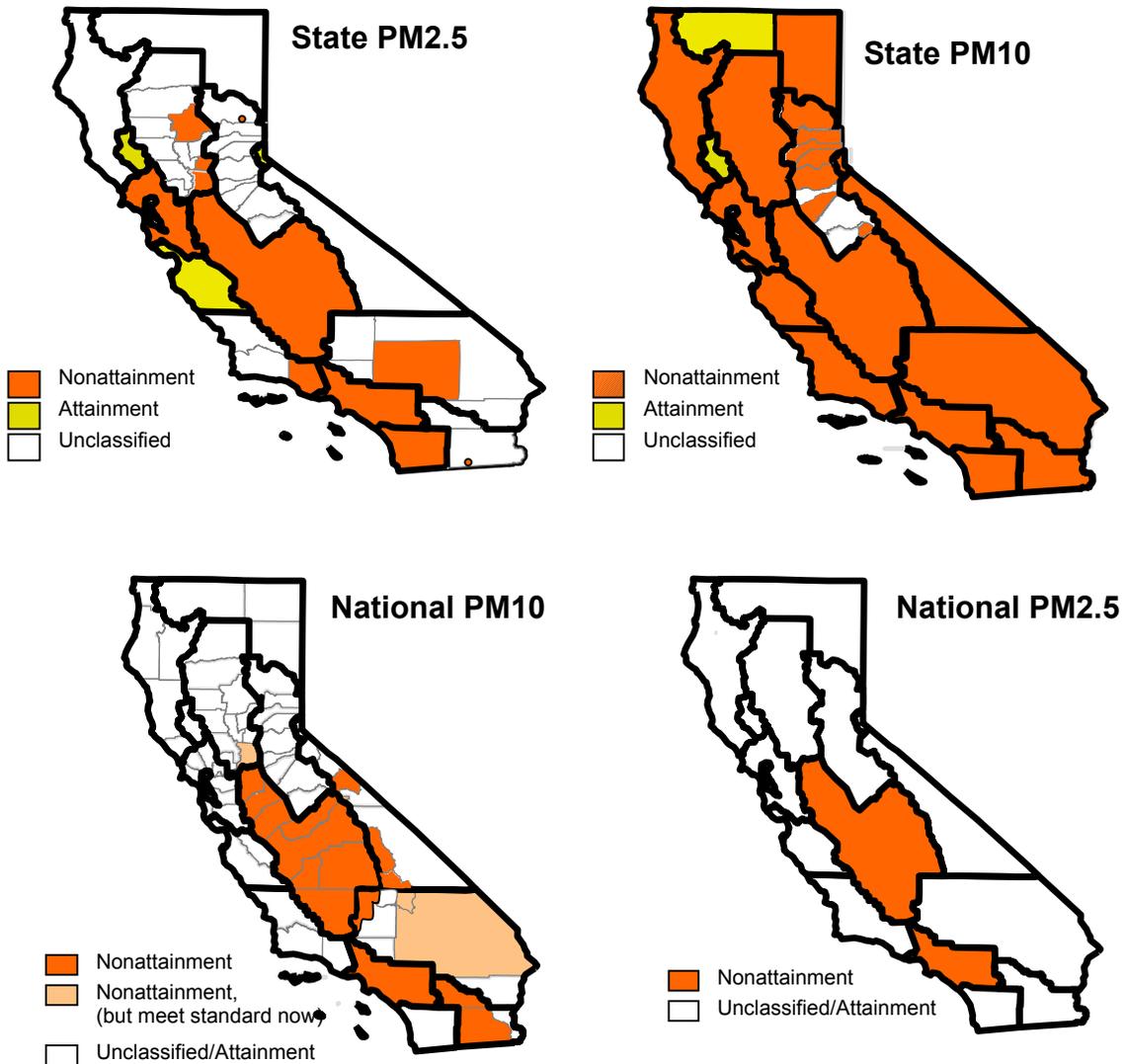
<http://www.arb.ca.gov/desig/adm/adm.htm>

and

<http://www.arb.ca.gov/desig/pm25desig/pm25desig.htm>

Area designations for the State PM standards are based on air quality data for the most recent three-year period collected at each monitoring site in the State. The designation value is the measured concentration that is used to determine the designation status of an area. The process to designate an area consists of the following steps: evaluating if the data gathered at each monitoring site are representative and complete; identifying and excluding high values that are affected by highly irregular or infrequent events (e.g., wildfires, extremely high winds); and determining the designation value for each monitoring site in the area. The designation value reflects the highest concentration over a three-year period. The highest designation value for any site in the area becomes the designation value for that area. A single value at any site over the level of the appropriate standard is sufficient to determine nonattainment. However, three years of complete data at all sites with concentrations below the level of the appropriate standard are generally required to determine attainment.

Figure 3. State and National PM Area Designations



D. Nature and Severity of the PM Problem

Ambient PM is comprised of both directly emitted PM such as dust or soot, known as primary PM, as well as PM formed in the atmosphere from the reactions of precursor gases, known as secondary PM. These precursor gases include nitrogen oxides (NO_x), sulfur oxides (SO_x), volatile organic compounds (VOC), and ammonia. NO_x, SO_x, and ammonia combine to form secondary ammonium nitrate and sulfate. VOC can form secondary organic aerosols, as well as participate in the production of secondary ammonium nitrate. NO_x and VOC are also precursors of ambient ozone. Sources of ambient PM include combustion sources such as trucks and passenger cars, off-road equipment, industrial processes, residential wood burning, and forest and agricultural burning; fugitive dust from paved and unpaved roads, construction, mining and agricultural activities; and ammonia from sources such as livestock operations, fertilizer application, and motor vehicles. In general, combustion processes form fine particles, whereas emissions from dust sources tend to be predominantly coarse particles.

1. Severity of Problem Based on the State PM Standards

Currently, the Lake County Air Basin and Siskiyou County in the Northeast Plateau Air Basin attain the State PM₁₀ standards. However, as discussed in section C, almost every other area in California experiences PM₁₀ concentrations above the level of the State standards. Table 2 lists the severity of each region's PM₁₀ problem based on 2001-2003 air quality data at the region's monitoring site recording the highest concentrations. The Lake Tahoe and Northeast Plateau Air Basins exceed only the 24-hour PM₁₀ standard of 50 µg/m³. All other listed regions exceed both PM standards, the 24-hour standard and the annual average standard of 20 µg/m³.

The Lake County, Lake Tahoe, and North Central Coast Air Basins attain the State annual average PM_{2.5} standard of 12 µg/m³. Table 3 summarizes the severity of the PM_{2.5} problem in the seven regions exceeding the standard: the San Diego, San Francisco Bay, San Joaquin Valley, and South Coast Air Basins; portions of the Sacramento Valley and South Central Coast Air Basins, the western portion of the Mojave Desert Air Basin; the Portola region in the Mountain Counties Air Basin; and the city of Calexico in the Salton Sea Air Basin.

Table 2. Severity of PM10 Problem

Area	Above Annual Standard (20 µg/m³)
NC	Slightly (21-25 µg/m ³)
MC, MD, NCC, SCC, SFB, SV	Moderately (26 – 35 µg/m ³)
GBV, SC, SD, SJV, SS	Far (>35 µg/m ³)
Area	Above 24-Hour Standard (50 µg/m³)
LT	Slightly (51-65 µg/m ³)
NC	Moderately (66-75 µg/m ³)
GBV, MC, MD, NCC, NEP, SC, SCC, SD, SFB, SJV, SS, SV	Far (>75 µg/m ³)

Air Basins: GBV = Great Basin Valleys; LT = Lake Tahoe; MD = Mojave Desert; MC = Mountain Counties; NCC = North Central Coast; NEP = Northeast Plateau; NC = North Coast; SV = Sacramento Valley; SS = Salton Sea; SD = San Diego; SFBA = San Francisco Bay; SJV = San Joaquin Valley; SCC = South Central Coast; SC = South Coast.

Table 3. Severity of PM2.5 Problem

Area	Above Annual Standard (12 µg/m³)
MC (Portola), MD (Western portion), SCC (Ventura), SD, SFB, SS (Calexico), SV (Butte, Placer, Sacramento)	Slightly (13-16 µg/m ³)
None	Moderately (17-20 ug/m3)
SC, SJV	Far (>20 µg/m ³)

2. Statewide Background PM Concentrations

Background monitoring sites are intended to quantify regionally representative PM concentrations located away from populated areas. The major sources of background PM include windblown dust from non-urban and non-agricultural soils, sea salt spray, organic particles resulting from wildfires, and organic particles formed from VOC emissions from vegetation. To assess a range of background PM₁₀ and PM_{2.5} values representative throughout the State, we used annual average concentrations from 1995-2002 reported by the Interagency Monitoring of Protected Visual Environments (IMPROVE) program for seventeen sites located in National and State parks in California.

Long-term (six to eight years) data are available for seven of these sites (Death Valley, Lassen, Pinnacles, Point Reyes, Redwoods, San Geronio, and Yosemite). One to three years of data are available for the remaining ten sites (Agua Tibia, Bliss, Dome, Joshua Tree, Lava Beds, San Rafael, Trinity, Hoover, and Kaiser). Statewide annual average PM₁₀ concentrations estimated using the data for all of these IMPROVE sites range from 9.0 $\mu\text{g}/\text{m}^3$ to 12.5 $\mu\text{g}/\text{m}^3$, with an eight-year average of 10.9 $\mu\text{g}/\text{m}^3$. Statewide PM_{2.5} concentrations range from 3.3 $\mu\text{g}/\text{m}^3$ to 6.2 $\mu\text{g}/\text{m}^3$, with an overall average of 5.0 $\mu\text{g}/\text{m}^3$.

However, depending on the meteorological conditions, even monitors located in pristine park areas can be influenced by transport from upwind man made sources (e.g., San Geronio may be impacted by emission sources in the South Coast Air Basin). Therefore, the averages estimated above using IMPROVE data for all sites provide an upper-bound estimate of a value representative of background PM levels throughout the State.

Three of the IMPROVE sites (Lava Beds at an elevation of 1,469 m, Lassen at an elevation of 1,755 m, and Bliss at an elevation of 2,116 m) record the lowest annual average PM₁₀ and PM_{2.5} concentrations. These are the least likely sites to be impacted by transport from upwind man made sources within the State. It should be noted, however, that sites located at higher altitudes are regularly impacted by fine dust transported from Asia – which typically accounts for 0.2 $\mu\text{g}/\text{m}^3$ to 1.0 $\mu\text{g}/\text{m}^3$ (Van Curen and Cahill, 2003). The Bliss site has been in operation since 2000 and the Lava Beds site since 2001. Long term monitoring records are only available at Lassen. Using data from these three sites, we estimate a three-year (2000 –2002) PM₁₀ average of 5.5 $\mu\text{g}/\text{m}^3$ and a PM_{2.5} average of 3.3 $\mu\text{g}/\text{m}^3$. At Lassen, the eight-year (1995-2002) PM₁₀ average is also 5.5 $\mu\text{g}/\text{m}^3$ and the PM_{2.5} average is 3.3 $\mu\text{g}/\text{m}^3$. Therefore, the averages estimated using data for these three IMPROVE sites provide a lower-bound estimate of background PM levels in the State.

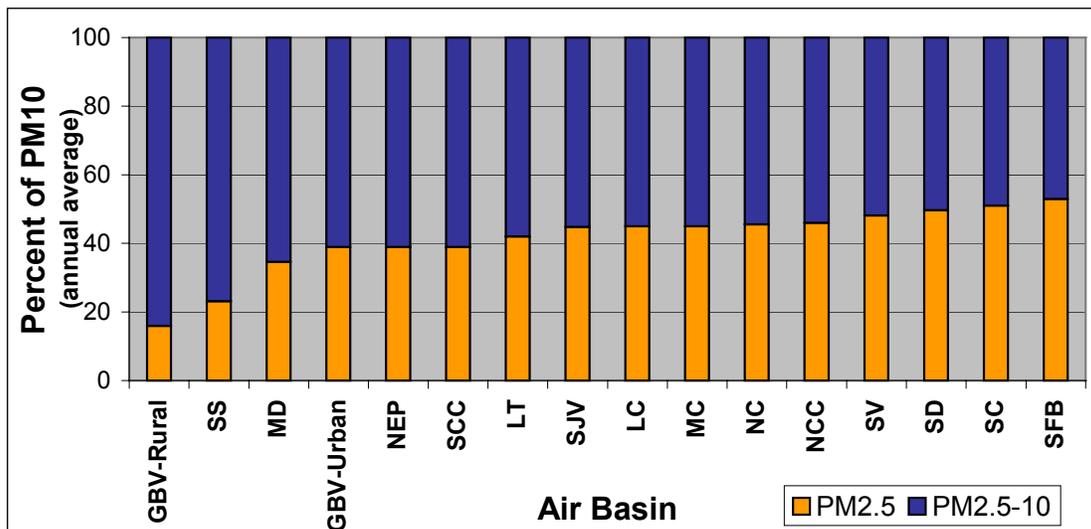
Based on this information, we estimate background annual average PM₁₀ concentrations range from 5.5 $\mu\text{g}/\text{m}^3$ to 10.9 $\mu\text{g}/\text{m}^3$ and annual average PM_{2.5} concentrations range from 3.3 $\mu\text{g}/\text{m}^3$ to 5.0 $\mu\text{g}/\text{m}^3$.

In comparison, the 2001-2003 average PM10 concentration from the Lakeport monitor in Lake County is 11.1 $\mu\text{g}/\text{m}^3$ and the 3-year average PM2.5 concentration is 4.9 $\mu\text{g}/\text{m}^3$.

3. PM2.5 Fraction of PM10

We estimated the fraction of PM10 that is PM2.5 using 2000-2003 FRM data for PM2.5 and SSI data for PM10. Figure 4 illustrates the variation of the PM2.5 fraction of PM10 on an annual average basis among California's air basins. PM2.5 ranges from 10 percent of PM10 in rural areas of the Great Basin Valleys Air Basin, to 50 percent in the more urban areas such as the South Coast and San Francisco Bay Area Air Basins.

Figure 4. Annual Average PM2.5 Fraction in PM10 by Air Basin.

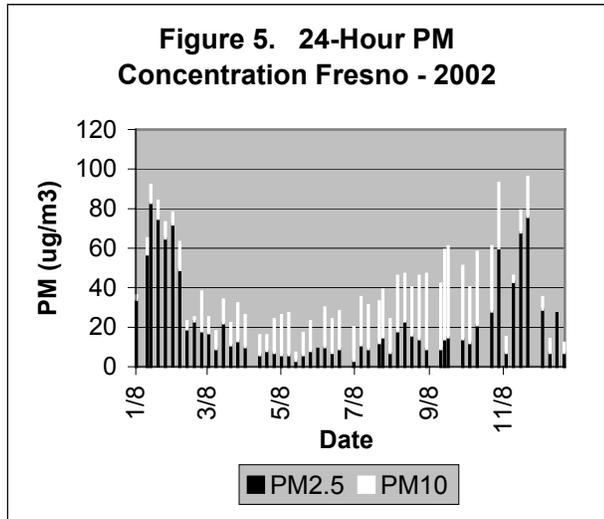


4. Spatial and Temporal Variations

The size, concentration, and chemical composition of PM vary by season and by region depending upon the mix of contributing sources and meteorology. Plots showing seasonal variation in ambient PM concentrations were generated using FRM data for PM2.5 and SSI data for PM10 collected on the same dates. These seasonality plots are included in the subsections of the following chapter describing PM air quality in each air district by air basin. The total height of the bars represents the PM10 concentration, while the black bars (bottom portion) represent the PM2.5 fraction.

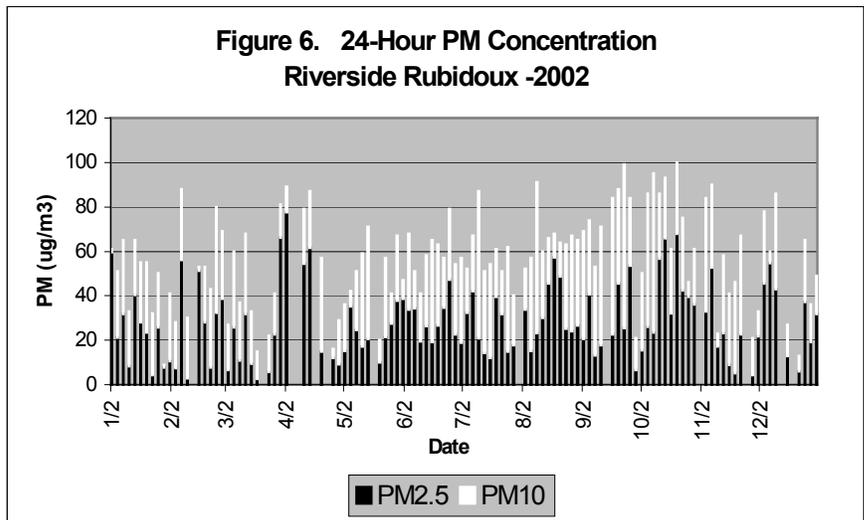
A number of areas exhibit strong seasonal patterns. Other areas have a much more uniform distribution -- PM concentrations remain high throughout the year. In yet other areas, isolated PM exceedances can occur at any time of the year.

For example, in the San Joaquin Valley (Figure 5), the San Francisco Bay Area, and the Sacramento Valley, there is a strong seasonal variation in PM, with higher PM10 and PM2.5 concentrations in the fall and winter months. In the winter, PM10 and PM2.5 concentrations can remain elevated for extended periods. The PM2.5 size fraction drives the PM concentrations and a major contributor to high levels of ambient PM2.5 in these regions in the winter is the

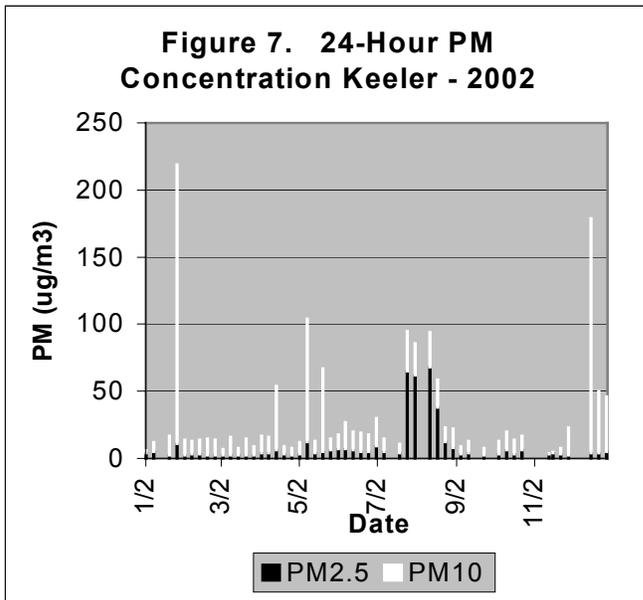


secondary formation of ammonium nitrate from precursors emitted by stationary and mobile combustion sources. Increased activity for some emission sources (e.g. wood-combustion in stoves and fireplaces) and meteorological conditions are also conducive to the build-up of PM during the winter.

In the eastern South Coast region (Figure 6), PM concentrations remain high



throughout the year. The more consistent activity patterns of emission sources, as well as less variability in weather patterns in the South Coast, leads to this more uniform concentration pattern.



In other areas, high PM can be more episodic than seasonal. For example, in Owens Lake in the Great Basin Valleys Air Basin, episodic fugitive dust events lead to very high PM₁₀ levels, with soil dust as the major contributor to ambient PM₁₀ (Figure 7).

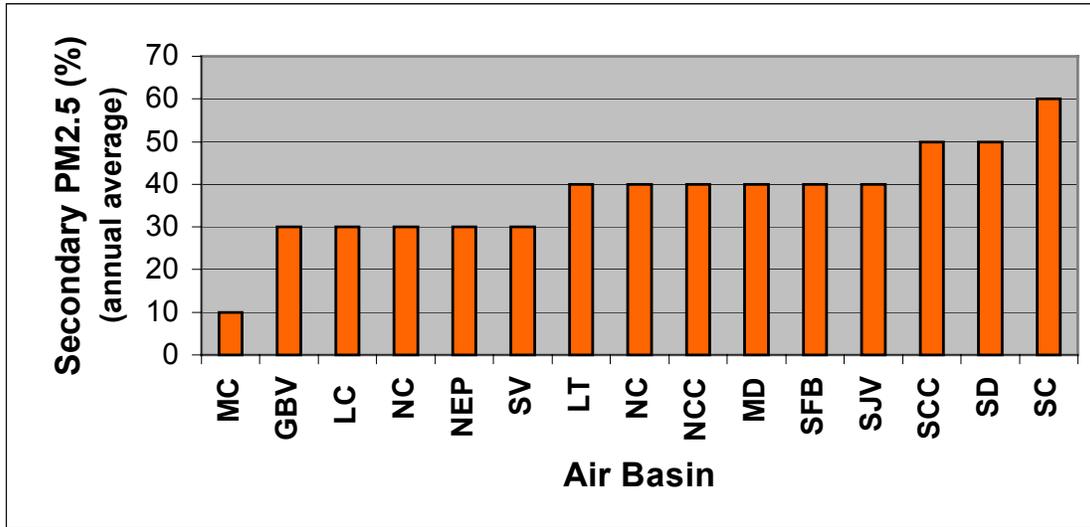
5. Secondary Fraction of PM_{2.5}

The relative contribution of primary versus secondary PM also varies by region and by season. Analysis of PM chemical composition data collected from a variety of routine and special monitoring programs provides an insight into the fraction of PM_{2.5} that is secondary. Data were obtained from the PM₁₀ and PM_{2.5} monitoring networks, CRPAQS, the Children’s Health Study, and South Coast Air Quality Management District’s PM Technical Enhancement Programs of 1995 and 1998-1999. Most secondary PM is in the PM_{2.5} fraction. Accordingly, the secondary contribution to PM is reported as a fraction of PM_{2.5}. Secondary PM_{2.5} estimates include ammonium nitrate and ammonium sulfate components, which form through reactions in the atmosphere of nitrogen oxides (NO_x) and sulfur oxides (SO_x) emitted by mobile sources and other combustion processes.

Throughout the State, on an annual basis, the fraction of PM_{2.5} comprised of secondary ammonium nitrate and sulfate can range between 10 and 60 percent of the PM_{2.5} mass (Figure 8) - with ammonium nitrate contributing between 5 and 50 percent and ammonium sulfate contributing between 5 and 25 percent of the PM_{2.5} mass. The fraction contributed by secondary ammonium nitrate and ammonium sulfate can be even higher on a 24-hour basis. Only limited information is available on how much of the measured PM_{2.5} organic carbon component is secondary organic aerosols. In most areas, the majority of organic carbon is primary, and has been directly emitted from sources such as wood combustion, mobile sources, and commercial cooking. However, available studies suggest that in the South Coast on an annual average basis, secondary

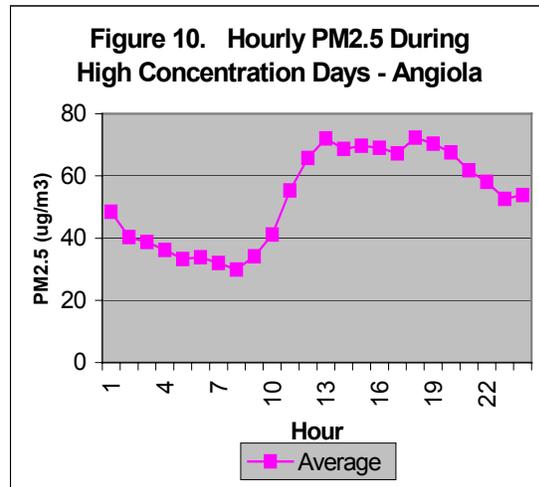
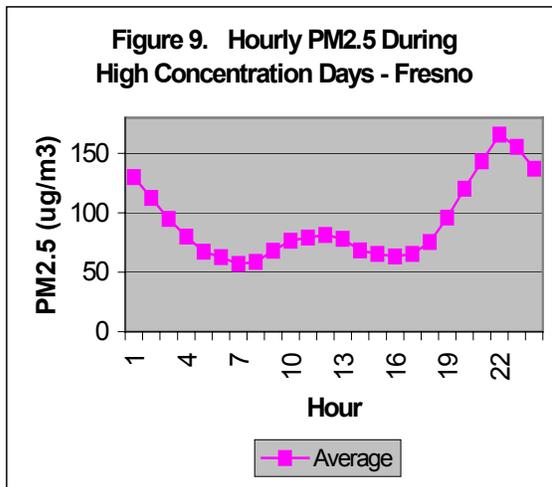
organic aerosols may constitute 6 to 16 percent of PM_{2.5} (Schauer et. al. 1996). In urban areas of the San Joaquin Valley during the winter, secondary organic aerosols may contribute up to an average of 8 percent of PM_{2.5} (Schauer and Cass, 1998).

Figure 8. Fraction of PM_{2.5} Comprised of Ammonium Nitrate and Ammonium Sulfate by Air Basin, based on annual average.



6. Hourly Variations

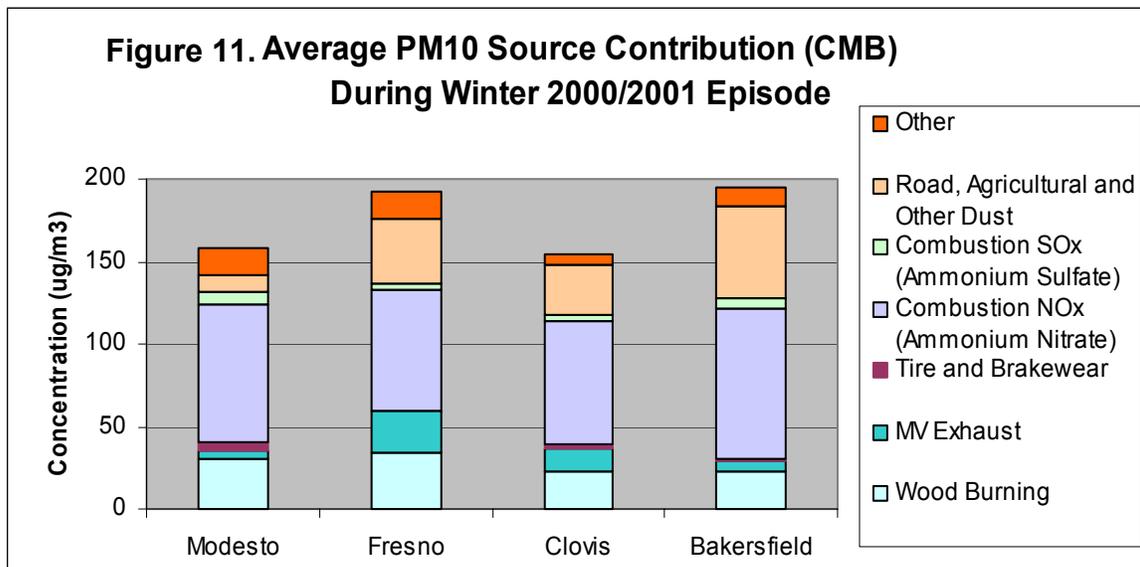
We used data collected with continuous Beta Attenuation Monitors located at various sites throughout the State to analyze hourly variations in PM_{2.5} levels. A number of different patterns can exist depending upon the nature of the sources and meteorology. For example, during the winter, PM_{2.5} levels in the San Joaquin Valley varied significantly during the day. In urban Fresno, the highest concentrations most often occur during the night (Figure 9).



In contrast, in rural San Joaquin Valley (Figure 10), PM_{2.5} concentrations are highest during the afternoon and evening. Chemical composition data reported in earlier studies (Magliano et. al, 1999) indicate diurnal variations in ammonium nitrate were the primary cause of the PM variations in rural areas in the San Joaquin Valley. Peak evening concentrations generally reflect the influence of lowering inversion heights which trap pollutants close to the surface, as well as increased activity from evening commute traffic and residential wood combustion during winter months.

7. Linking Emissions Sources with Ambient PM₁₀ and PM_{2.5}

Chemical Mass Balance models are used to establish which sources and how much of their emissions contribute to ambient PM concentrations and composition (Figure 11). The models use chemical composition data from ambient PM samples and emission sources. The source attribution data presented in this report were derived from a variety of studies with differing degrees of chemical speciation. In general, however, the source categories can be interpreted in the following manner: the soil, woodsmoke, cooking, motor vehicle, and marine categories represent primary, or directly emitted particulate matter. The marine category represents sea salt. Soil represents the combination of mechanically disturbed soil (paved and unpaved roads, agricultural activities) and windblown dust. Woodsmoke or burning represents residential wood combustion, and can also represent other biomass



burning such as agricultural or prescribed burning, as well as cooking. The motor vehicle category represents directly emitted particles from motor vehicle exhaust from both gasoline and diesel vehicles. Nitrate (or ammonium nitrate) and sulfate (or ammonium sulfate) represent secondary species, i.e. they form in the atmosphere from the primary emissions of NO_x, SO_x, and ammonia.

Stationary combustion sources and mobile sources contribute to the NOx that forms ammonium nitrate and to the SOx that forms ammonium sulfate. The "other" category represents the mass that cannot be accounted for by the identified source categories. It can include water, as well as sources not included in the source apportionment analysis.

For several areas, specific source apportionment analysis has not been conducted; instead, the primary chemical components have been associated with possible emission sources based on available emission inventory data. This is the case for network sites equipped with PM2.5 speciation monitors (e.g., Figure 12) and Childrens Health Study monitoring sites (e.g., Figure 13).

Figure 12.

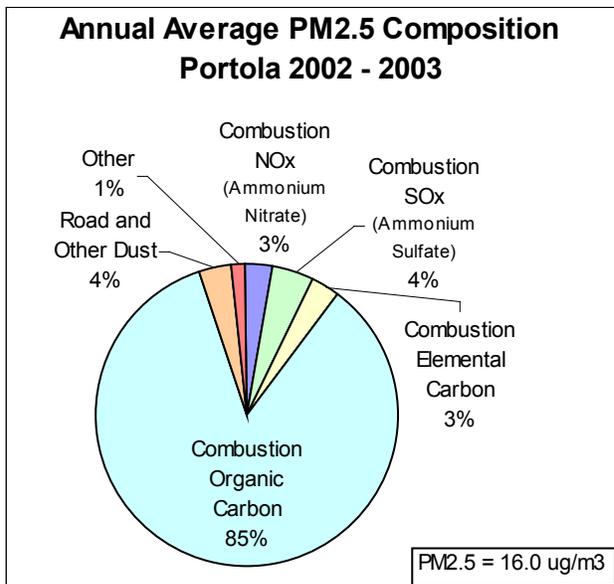
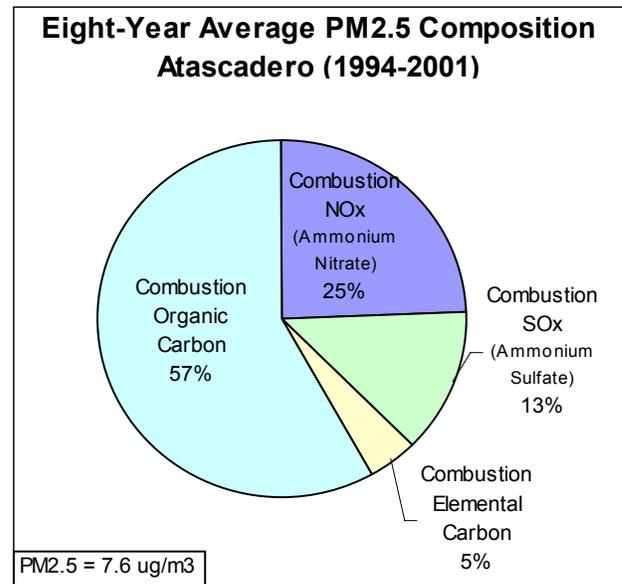


Figure 13.



In these cases, the measured carbon is not attributed to specific sources, but instead is specified as percentages of organic and elemental carbon. The majority of organic carbon is expected to be due to directly emitted carbon from combustion sources. Key sources include vehicles, residential wood combustion, biomass burning, and other stationary combustion sources. However, a fraction may be due to secondary organic aerosol formation from anthropogenic and biogenic VOC emissions. Elemental carbon, in contrast, is entirely directly emitted from combustion sources.

The emission inventory for each area in the State can provide further information on the detail and breakdown of emission sources of each chemical component identified. In general, PM chemical components can be associated with the examples of emission sources as follows:

Organic and elemental carbon

- Throughout the State, diesel-fueled vehicles and equipment are major contributors. Specific sources include: trucks, transit buses, school buses, waste collection vehicles, construction equipment, and farm equipment. Gasoline vehicles and off-road equipment (e.g., lawn and garden) are also contributors.
- In rural areas, organic and elemental carbon in the form of smoke originates from combustion sources including: residential fuel combustion, waste burning and disposal (non-agricultural burning), and prescribed burning.
- In urban areas, smoke originates from combustion sources including: residential fuel combustion and commercial cooking (e.g., charbroiling operations).
- Organic and elemental carbon can also be emitted from industrial facilities such as refineries and manufacturing facilities, as well as other stationary combustion sources.
- Overall, secondary organic carbon is formed in the atmosphere from organic gases emitted from combustion sources and evaporated into the air from: vehicles and off road equipment, coating operations (e.g., architectural, non-architectural) and related solvent use, consumer products, and various industrial processes (e.g., petroleum marketing, oil and gas production, pesticide application).

Dust

- Throughout the State, sources of dust include dust resuspended by vehicle traffic on paved and unpaved roads, construction and demolition operations, and bulk material handling and storage.
- In rural areas, dust may also originate from agricultural activities, wood working, weed abatement activities, activities on disturbed land in non-agricultural areas, and windblown dust. Mineral processes such as mining and cement manufacturing may also contribute.
- In urban areas, dust may also originate from disturbed open residential areas. Mineral processes such as cement manufacturing may also contribute.

Secondary ammonium nitrate

a) NOx precursor

- Throughout the State, diesel-fueled vehicles, off-road equipment, and trains, as well as gasoline vehicles and off-road equipment are major contributors of NOx.
- In rural areas, NOx is also emitted from farm equipment.
- In urban areas, NOx originates from combustion sources such as residential fuel combustion.
- NOx is also emitted from industrial facilities such as refineries and manufacturing facilities as well as other stationary combustion sources.
- In coastal areas, ships and commercial boats are major NOx contributors.

b) VOC precursor

- Statewide, gasoline-fueled vehicles, off-road equipment, and consumer products are major VOC contributors.
- In rural areas, VOC sources may include: livestock operations, pesticide application, recreational boats, and prescribed burning.
- In urban areas, VOC may originate from architectural and non-architectural coatings and residential fuel combustion.
- VOC is also emitted from combustion processes and evaporative losses at industrial facilities such as refineries and manufacturing facilities, as well as other stationary combustion sources. Evaporative losses from petroleum marketing also contribute.

Secondary ammonium sulfate

a) SOx precursor

- Statewide, trains and heavy-duty diesel trucks contribute to SOx emissions.
- Petroleum refining facilities, as well as other combustion sources such as industrial and manufacturing, petroleum refining, mining, and cement manufacturing facilities are also contributors.
- In coastal areas, ships and commercial boats are major SOX sources.

The following web site provides detailed emission inventory data for sources of direct PM10, and PM2.5 and for each of the secondary PM precursors (NOx, SOx, VOC). The site includes emission inventory data for the top 25 emission sources, as well as inventory data for all emission sources in each air district.

<http://www.arb.ca.gov/ei/emissiondata.htm>

II. Characterization of Ambient PM in Each Air District by Air Basin

This section describes the characteristics of ambient PM₁₀ and PM_{2.5} for each of the thirty-five air districts in the State by air basins. The information presented includes:

- Map of the district's air basin showing the location of PM₁₀ monitoring sites.
- Map of the district's air basin showing the location of PM_{2.5} monitoring sites.
- Table listing 2001-2003 PM₁₀ and PM_{2.5} statistics as presented in the 2005 California Almanac of Emissions and Air Quality with respect to the State standards. The statistics include the calculated days of exceedances at the site measuring the highest 24-hour PM₁₀ concentration from those sites with valid annual average PM₁₀ concentrations, and maximum 24-hour and annual average PM₁₀ and PM_{2.5} concentrations recorded in the district each year. In general, PM₁₀ concentrations are measured once every sixth day and the calculated days of exceedances are derived by multiplying the number of days on which exceedances were measured by six.
- Table listing the PM₁₀ and PM_{2.5} designation values with respect to the State standards for the 2001-2003 period for the air district. Data are reported under local conditions.
- Table listing the PM₁₀ and PM_{2.5} designation values with respect to the State standards for the 2001-2003 period for each monitoring site in the air district. Data are reported under local conditions.
- Percent contribution of PM_{2.5} to ambient PM₁₀ and the fraction of PM_{2.5} that is secondary, comprised of ammonium nitrate and ammonium sulfate.
- Plots illustrating seasonal variations in daily PM_{2.5} and PM₁₀ levels.
- Where data are available, plots illustrating hourly variations in PM_{2.5} concentrations.
- Source attribution information obtained from chemical mass balance modeling for areas where this type of analysis has been performed.
- For areas where source attribution analyses have not been performed, information on the primary chemical composition of ambient PM₁₀ or PM_{2.5} is associated with possible general emission sources.

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Acronyms

AIRS	Aerometric Information Retrieval System
APCD	Air Pollution Control District
AQMD	Air Quality Management District
ARB	Air Resources Board
BAM	Beta Attenuation Monitor
CHS	Children's Health Study
CRPAQS	California Regional Particulate Air Quality Study
FRM	Federal Reference Method
GBV	Great Basin Valleys
IMPROVE	Interagency Monitoring of Protected Environments
LT	Lake Tahoe
MC	Mountain Counties
MD	Mojave Desert
NC	North Coast
NCC	North Central Coast
NEP	Northeast Plateau
NOx	Nitrogen oxides
PM	Particulate Matter
PM10	Particles smaller than 10 microns in size
PM2.5	Particles smaller than 2.5 microns in size. Also referred to as fine particles.
PTEP95	1995 PM10 Enhancement Program
SB 656	Senate Bill 656
SC	South Coast
SCC	South Central Coast
SD	San Diego
SFBA	San Francisco Bay Area
SIP	State Implementation Plan
SJV	San Joaquin Valley
SOx	Sulfur Oxides
SS	Salton Sea
SSI	Size Selective Inlet
SV	Sacramento Valley
U.S. EPA	United State Environmental Protection Agency
VOC	Volatile Organic Compounds