

# Criteria Pollutants — National Trends

<http://www.epa.gov/oar/aqtrnd99/chapter2.pdf>

This chapter presents national and regional trends for each of the pollutants for which the United States Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards (NAAQS). NAAQS are in place for the following six criteria pollutants: carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO<sub>2</sub>), ozone (O<sub>3</sub>), particulate matter (PM), and sulfur dioxide (SO<sub>2</sub>). Table 2-1 lists the NAAQS for each pollutant in terms of the level and averaging time of the standard used to evaluate compliance.

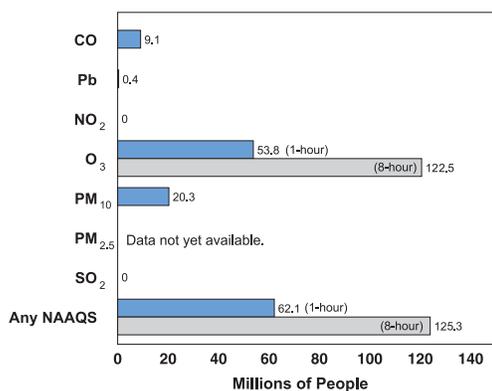
There are two types of standards: primary and secondary. Primary standards protect against adverse human health effects, whereas secondary standards protect against welfare effects such as damage to crops, ecosystems, vegetation, buildings, and decreased visibility. There are primary standards for all of the criteria pollutants. Some pollutants (PM and SO<sub>2</sub>) have primary standards for both long-term (annual average) and short-term (24 hours or less) averaging times. Short-term standards most directly protect people from adverse health effects associated with peak short-term exposures to air pollution, while long-term standards can protect people from adverse health effects associated with short- and long-term exposures to air pollution.

**Table 2-1.** NAAQS in effect as of December 2000.

Pollutant	Primary Standard (Health Related)		Secondary Standard (Welfare Related)	
	Type of Average	Standard Level Concentration <sup>a</sup>	Type of Average	Standard Level Concentration
CO	8-hour <sup>b</sup>	9 ppm (10 µg/m <sup>3</sup> )	No Secondary Standard	
	1-hour <sup>b</sup>	35 ppm (40 µg/m <sup>3</sup> )	No Secondary Standard	
Pb	Maximum Quarterly Average	1.5 µg/m <sup>3</sup>	Same as Primary Standard	
NO <sub>2</sub>	Annual Arithmetic Mean	0.053 ppm (100 µg/m <sup>3</sup> )	Same as Primary Standard	
O <sub>3</sub>	Maximum Daily 1-hour Average <sup>c</sup>	0.12 ppm (235 µg/m <sup>3</sup> )	Same as Primary Standard	
	4th Maximum Daily 8-hour Average <sup>d</sup>	0.08 ppm (157 µg/m <sup>3</sup> )	Same as Primary Standard	
PM <sub>10</sub>	Annual Arithmetic Mean	50 µg/m <sup>3</sup>	Same as Primary Standard	
PM <sub>2.5</sub>	24-hour <sup>b</sup>	150 µg/m <sup>3</sup>	Same as Primary Standard	
	Annual Arithmetic Mean <sup>e</sup>	15 µg/m <sup>3</sup>	Same as Primary Standard	
SO <sub>2</sub>	24-hour <sup>f</sup>	65 µg/m <sup>3</sup>	Same as Primary Standard	
	Annual Arithmetic Mean	0.03 ppm (80 µg/m <sup>3</sup> )	3-hour <sup>b</sup>	0.50 ppm (1,300 µg/m <sup>3</sup> )
	24-hour <sup>b</sup>	0.14 ppm (365 µg/m <sup>3</sup> )		

<sup>a</sup> Parenthetical value is an approximately equivalent concentration. (See 40 CFR Part 50).  
<sup>b</sup> The short-term (24-hour) standard of 150 µg/m<sup>3</sup> is not to be exceeded more than once per year on average over three years.  
<sup>c</sup> The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than one, as determined according to Appendix H of the Ozone NAAQS.  
<sup>d</sup> Three-year average of the annual 4th highest daily maximum 8-hour average concentration.  
<sup>e</sup> Spatially averaged over designated monitors.  
<sup>f</sup> The form is the 98th percentile.

Secondary standards have been established for each criteria pollutant except CO. Secondary standards are identical to the primary standards, with the exception of SO<sub>2</sub>. Approximately 125 million people in the United States reside in counties that did not meet the primary standard for at least one of the criteria pollutants for the single year 1999.



Number of people living in counties with air quality concentrations above the level of NAAQS in 1999.

On July 18, 1997, EPA revised the ozone and PM NAAQS. The averaging time of the ozone standard changed from a 1-hour average to an 8-hour average to protect against longer exposure periods that are of concern for both human health and welfare. The primary PM standards were revised to change the form of the PM<sub>10</sub> standards and to add two new PM<sub>2.5</sub> standards to protect against fine particles.

In May 1999, however, the U.S. Court of Appeals for the D.C. Circuit issued an opinion affecting these revised standards. In particular, the court remanded the ozone standard back to EPA for further consideration. The court also vacated the revised PM<sub>10</sub> standard and remanded the PM<sub>2.5</sub> standards back to EPA for further consideration. Following the

denial of a petition for a rehearing by the D.C. Circuit, the Justice Department has filed a petition for review before the Supreme Court. Refer to <http://www.epa.gov/airlinks> for up-to-date information concerning actions surrounding the revised standards.

The trends information presented in this chapter is based on two types of data: ambient concentrations and emissions estimates. Ambient concentrations are measurements of pollutant concentrations in the ambient air from monitoring sites across the country. This year's report contains trends data accumulated from 1990–1999 on the criteria pollutants at thousands of monitoring stations located throughout the United States. The trends presented here are derived from the composite average of these direct measurements. The averaging times and air quality statistics used in the trends calculations relate directly to the NAAQS.

The second type of data presented in this chapter are national emissions estimates. These are based largely on engineering calculations of the amounts and kinds of pollutants emitted by automobiles, factories, and other sources over a given period. In addition, some emissions estimates are based on measurements from continuous emissions monitors (CEMs) that have recently been installed at major electric utilities to measure actual emissions. This report incorporates data from CEMs collected between 1994 and 1999 for NO<sub>x</sub> and SO<sub>2</sub> emissions at major electric utilities. [The emissions data summarized in this chapter and in Appendix A were obtained from the National Emission Inventory data located at <http://www.epa.gov/ttn/chief>. For assistance call INFO CHIEF (919 541-1000).]

Changes in ambient concentrations do not always track changes in national emissions estimates. There are five known reasons for this. First, because most monitors are positioned in urban, population-oriented locales, air quality trends are more likely to track changes in urban emissions rather than changes in total national emissions. Urban emissions are generally dominated by mobile sources, while total emissions in rural areas may be dominated by large stationary sources such as power plants and smelters.

Second, emissions for some pollutants are calculated or measured in a different form than the primary air pollutant. For example, concentrations of ozone are caused by VOC emissions as well as NO<sub>x</sub> emissions.

Third, the amount of some pollutants measured at monitoring locations depends on what chemical reactions, if any, occur in the atmosphere during the time it takes the pollutant to travel from its source to the monitoring station.

Fourth, meteorological conditions often control the formation and buildup of pollutants in the ambient air. For example, peak ozone concentrations typically occur during hot, dry, stagnant summertime conditions. CO is predominately a cold weather problem. Also, the amount of rainfall can affect particulate matter levels.

Finally, emission estimates have uncertainties and may not reflect actual emissions. In some cases, estimation methods are not consistent across all 20 years presented in this report.

For a more detailed discussion of the methodology used to compute the trend statistics in this chapter, please refer to Appendix B.

## Carbon Monoxide

Air Quality Concentrations	
1980–99	57% decrease
1990–99	36% decrease
1998–99	3% decrease

Emissions	
1980–99	21% decrease
1990–99	2% decrease
1998–99	1% increase

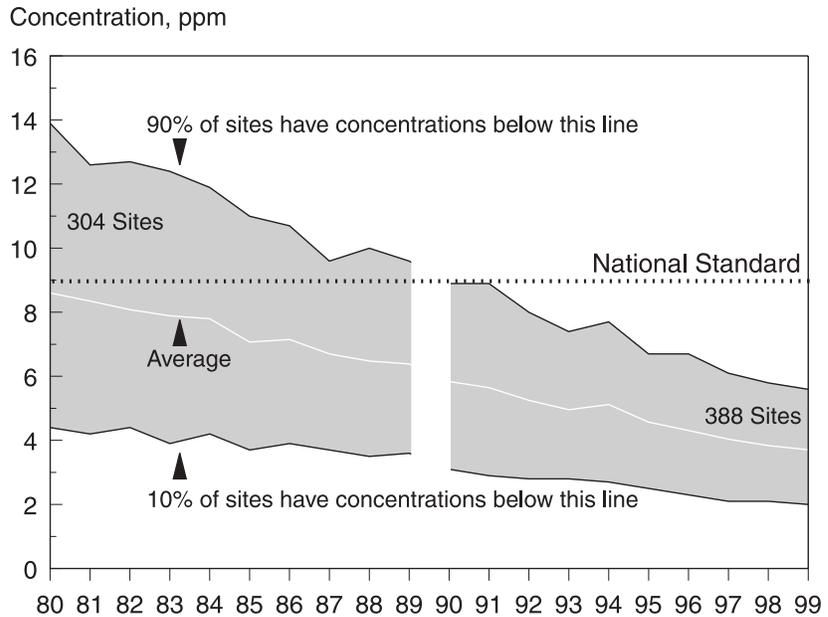
### Worth Noting

- Nationally, carbon monoxide (CO) levels for 1999 are the lowest recorded in last 20 years and this air quality improvement is consistent across all regions of the country.
- Presently, only six areas have CO levels violating the NAAQS (three of these are previous nonattainment areas).
- The National Academy of Sciences is currently initiating a study of persistent CO problem in Fairbanks, Alaska.

### Nature and Sources

Carbon monoxide is a colorless, odorless, and (at much higher levels) poisonous gas, formed when carbon in fuels is not burned completely. It is a product of motor vehicle exhaust, which contributes about 60 percent of all CO emissions nationwide. High concentrations of CO generally occur in areas with heavy traffic congestion. In cities, as much as 95 percent of all CO emissions may emanate from automobile exhaust. Other sources of CO emissions include industrial processes, non-transportation fuel combustion, and natural sources such as wildfires. Woodstoves, cooking, cigarette smoke, and space heating are sources of CO in indoor environments. Peak CO concentrations typically occur during the colder months of the year when CO

**Figure 2-1.** Trend in 2nd maximum non-overlapping 8-hour average CO concentrations, 1980–1999.



automotive emissions are greater and nighttime inversion conditions are more frequent.

### Health Effects

Carbon monoxide enters the bloodstream through the lungs and reduces oxygen delivery to the body's organs and tissues. The health threat from lower levels of CO is most serious for those who suffer from cardiovascular disease, such as angina pectoris. At much higher levels of exposure, CO can be poisonous, and healthy individuals may also be affected. Impairment of cognitive skills, vision and work capacity may occur at elevated CO levels in healthy individuals.

### Primary Standards

There are two primary NAAQS for ambient CO: a 1-hour average of 35 ppm, and an 8-hour average of 9 ppm. These concentrations are not to be exceeded more than once per

year. There currently are no secondary standards for CO.

### National Air Quality Trends

Nationally, CO concentrations have consistently declined over the last 20 years. Figure 2-1 reveals a 57-percent improvement in composite average ambient CO concentrations from 1980 to 1999 and a 36 percent reduction over the last 10 years.<sup>1</sup> Following an upturn in 1994, the nation has experienced year-to-year reductions in peak 8-hour CO concentrations through the remainder of the decade. In fact, the 1999 CO levels are generally the lowest recorded during the past 20 years of monitoring. Exceedances of the 8-hour CO NAAQS (which are simply a count of the number of times the level of the standard is exceeded) have declined 93 percent since 1990.

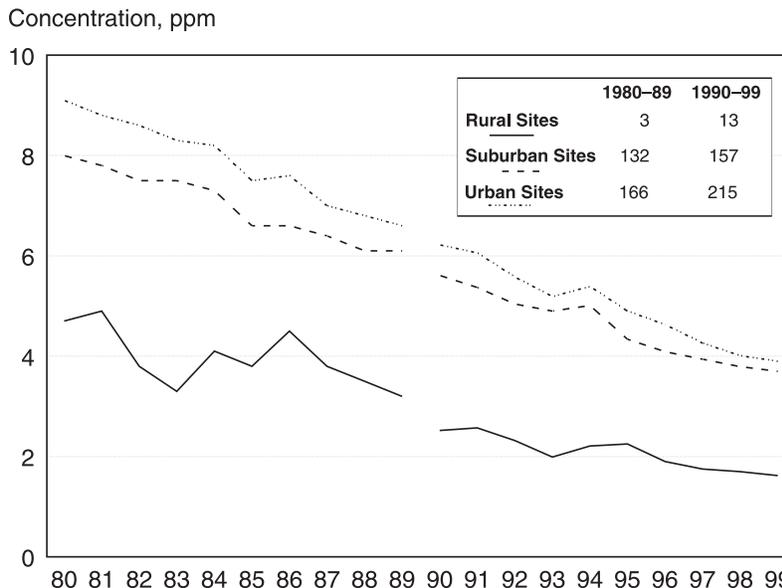
Long-term reductions in ambient CO concentrations have been measured across all monitoring environ-

ments—rural, suburban, and urban sites. Figure 2-2 shows that on average, urban monitoring sites record higher CO concentrations than suburban sites, with the lowest levels found at 16 rural sites. During the past 20 years, the 8-hour CO concentrations decreased 65 percent at 16 rural monitoring sites, 54 percent at 289 suburban sites, and 57 percent at 381 urban sites.

### Regional Air Quality Trends

The map in Figure 2-3 shows regional trends in ambient CO concentrations during the past 20 years, 1980–1999. All 10 EPA Regions recorded 20-year improvements in CO levels as measured by the regional composite mean concentrations. Significant 20-year concentration reductions of 50 percent or more are evidenced across the nation except in

**Figure 2-2.** Trend in 2nd maximum non-overlapping 8-hour average CO concentrations by type of location, 1980–1999.



**Note:** When the total number of rural, suburban, and urban sites are summed for either the 1980–89 or 1990–99 time periods in Figure 2-2, this number may not equal the total number of sites shown in Figure 2-1 for the same time periods. This is due to a few monitoring sites falling outside the definitions of rural, suburban, or urban sites.

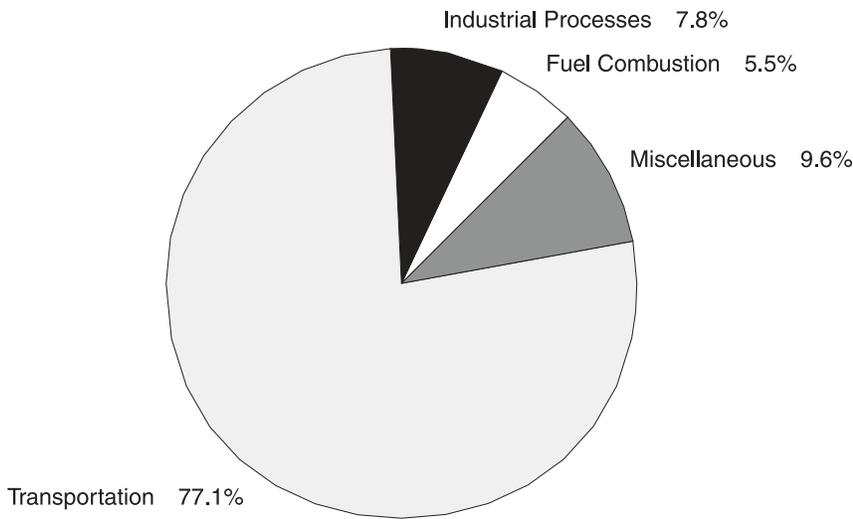
**Figure 2-3.** Trend in CO 2nd maximum non-overlapping 8-hour concentrations by EPA region, 1980–1999.



**Note:** These trends are influenced by the distribution of monitoring locations in a given region and, therefore, can be driven largely by urban concentrations. For this reason, they are not indicative of background regional concentrations.

Alaska is in EPA Region 10; Hawaii, EPA Region 9; and Puerto Rico, EPA Region 2. Concentrations are ppm.

**Figure 2-4.** CO emissions by source category, 1999.

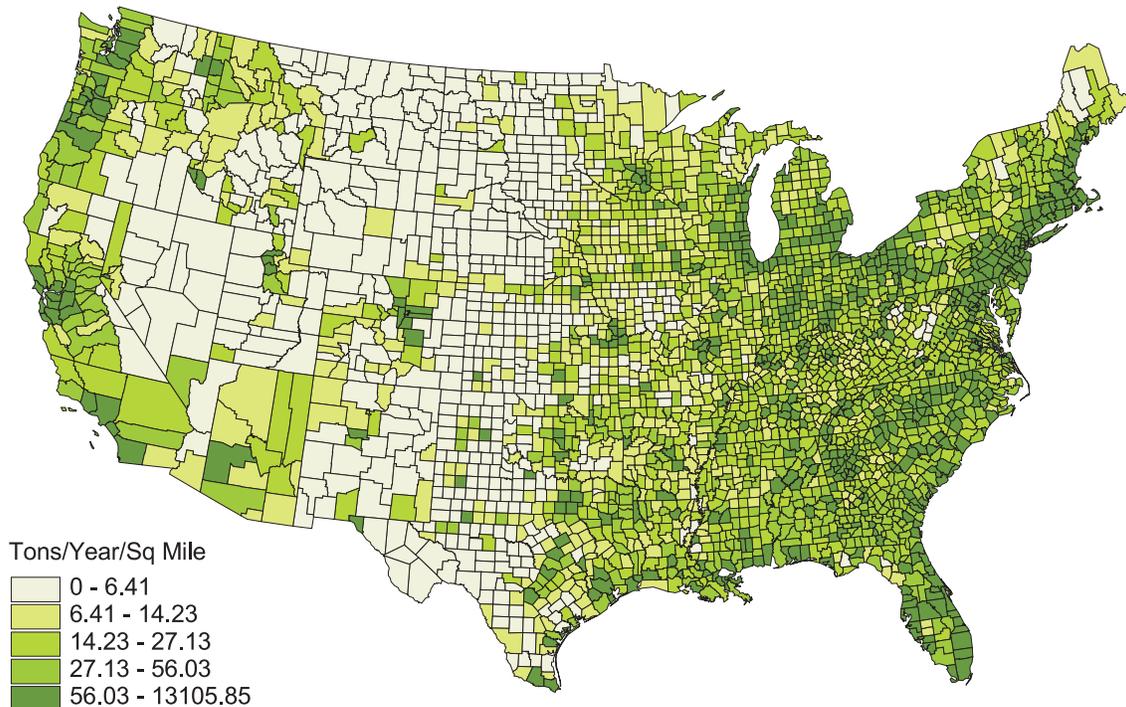


the Midwest where reductions were only slightly smaller.

**National Emissions Trends**

Figure 2-4 shows that the transportation category, composed of onroad and nonroad sources, accounted for 77 percent of the nation’s total CO emissions in 1999. Figure 2-5 presents the broad geographic distributions of 1999 CO emissions based on the tonnage per square mile for each county. This visualization clearly shows that the eastern third of the country and the west coast emitted more CO (on a density basis) than the western two-thirds of the continental United States. National total CO emissions have decreased 21 percent since 1980 as shown in Figure 2-6.<sup>2</sup> Despite a 57-percent increase in vehicle miles traveled (VMT), emissions from onroad vehicles decreased 56

**Figure 2-5.** Density map of 1999 carbon monoxide emissions, by county.



percent during the past 20 years as a result of automotive emissions control programs. However, emissions from all transportation sources have decreased only 23 percent over the same period, primarily due to a 42-percent increase in off-road emissions, which has offset the gains realized in reductions of onroad vehicle emissions.

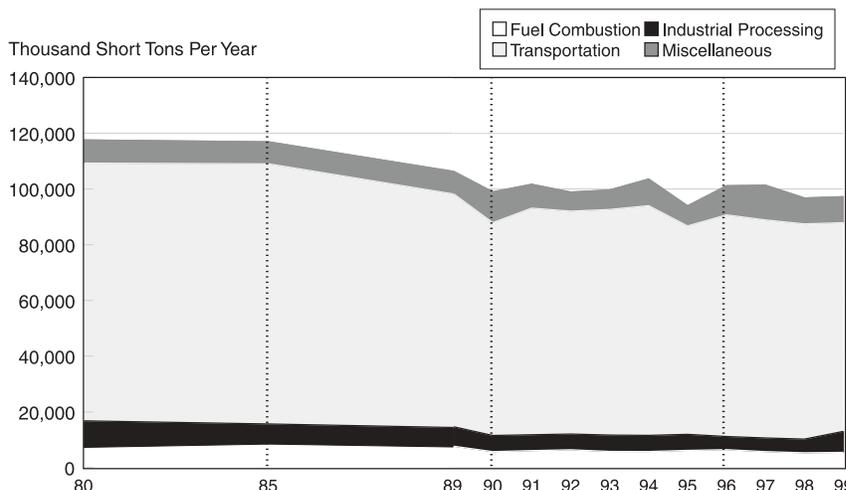
Table 2-2 lists some of the major milestones in the control of emissions from automobiles starting with the Clean Air Act (CAA) of 1970. At the national level, these measures, which have led to reductions in emissions of CO as well as other pollutants, include establishing national standards for tailpipe emissions, new vehicle technologies, and clean fuels programs. State and local emissions reduction measures include inspection and maintenance (I/M) programs and transportation management programs.

In the area of clean fuels, the 1990 Clean Air Act Amendments (CAAA) require oxygenated gasoline programs in several regions of the country during the winter months. Under the program regulations, a minimum oxygen content (2.7 percent by weight) is required in gasoline to ensure more complete fuel combustion.<sup>3,4</sup> Of the 36 CO nonattainment areas that initially implemented the program in 1992, 17 areas participated in the program during 1999.<sup>5</sup>

### Blue Ribbon Panel on Oxygenates in Gasoline

In November 1998, in response to the public concern regarding the detection of MTBE (methyl tertiary butyl ether—one of two fuel oxygenates used in reformulated gasoline to help improve air quality) in water, EPA announced the creation of a blue

**Figure 2-6.** Trend in national total CO emissions, 1980–1999.<sup>2</sup>



**Notes:** Emissions data not available for consecutive years 1980–1989.

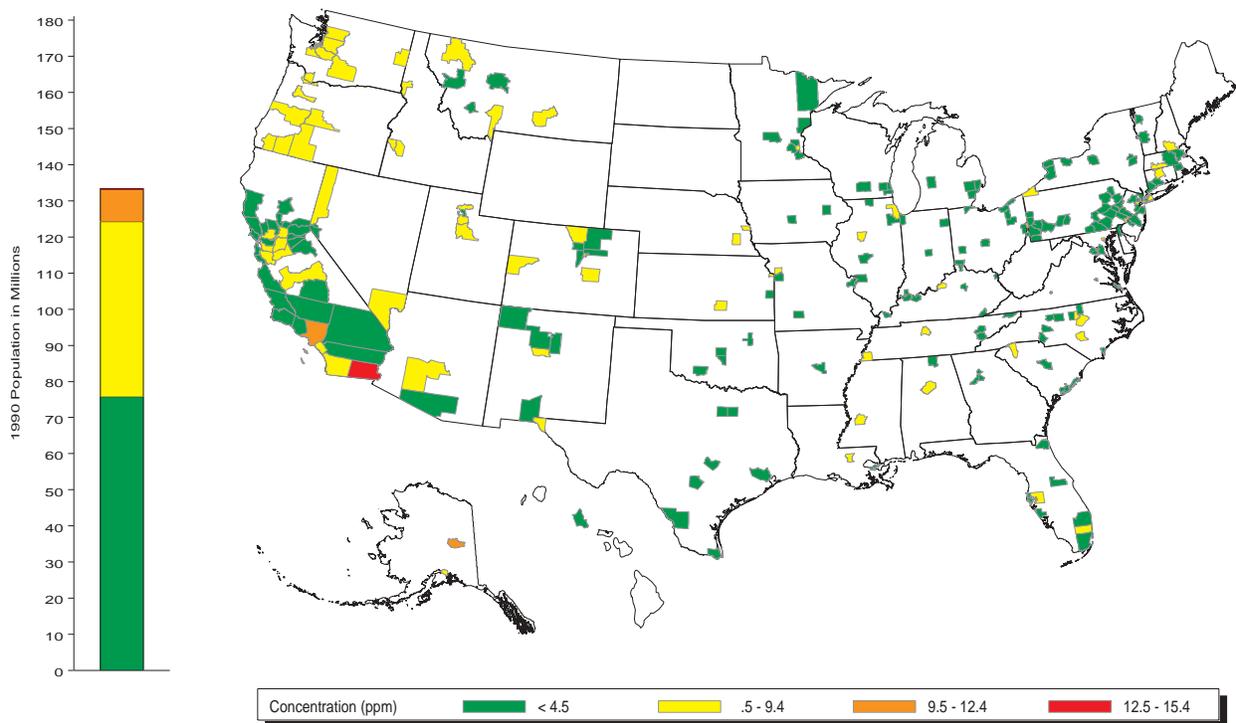
Emission estimation methods continue to evolve and improve over time. Methods have changed for many significant categories beginning with the years 1985, 1990, and 1996 and consequently are not consistent across all years in this trend period. See Appendix B Emissions Estimates Methodology for additional information.

**Table 2-2.** Milestones in Motor Vehicle Emissions Control

1970	New Clean Air Act sets auto emissions standards.	1990	CAAA set new tailpipe standards.
1971	Charcoal canisters appear to meet evaporative standards.	1992	Oxyfuel introduced in cities with high CO levels.
1973	EGR valves appear to meet NO <sub>x</sub> standards.	1993	Limits set on sulfur content of diesel fuel.
1974	Fuel economy standards are set.	1994	Phase-in begins of new vehicle standards and technologies.
1975	The first catalytic converters appear for hydrocarbon, CO. Unleaded gas appears for use in catalyst equipped cars.	1995	On-board diagnostic systems in 1996 model year cars.
1981	3-way catalysts with on-board computers and O <sub>2</sub> sensors appear.	1995	Phase I Federal Reformulated Gasoline sales begin in worst ozone nonattainment areas.
1983	I/M programs are established in 64 cities.	1998	Sales of 1999 model year California emissions equipped vehicles begin in the Northeast.
1989	Fuel volatility limits are set for RVP.		

ribbon panel of leading experts from the public health and scientific communities, automotive fuels industry, water utilities, and local and state governments to review the important issues posed by the use of MTBE and other oxygenates in gasoline. The Panel’s final report stated that “the

Wintertime Oxyfuel Program continues to provide a means for some areas of the country to come into, or maintain, compliance with the carbon monoxide standard. Los Angeles areas continue to use MTBE in this program. In most areas today, ethanol can, and is, meeting these winter-

**Figure 2-7.** Highest 2nd maximum non-overlapping 8-hour average CO concentration by county, 1999.

time needs for oxygen without raising fuel volatility concerns given the season of the year. The Panel recommends that the Wintertime Oxyfuel program be continued (a) for as long as it provides a useful compliance and/or maintenance tool for the affected states and metropolitan areas, and (b) assuming that the clarification of state and federal authority described above is enacted to enable states, where necessary, to regulate and/or eliminate the use of gasoline additives that threaten drinking supplies.<sup>6</sup> The Panel's Executive Summary and final report entitled *Achieving Clean Air and Clean Water: The Report of the Blue Ribbon Panel on Oxygenates in Gasoline* can be found on the Panel's homepage at: <http://www.epa.gov/otaq/consumer/fuels/oxypanel/blueribb.htm>.

Additionally, on March 20, 2000, the Clinton Administration, based on the recommendations of the Blue Ribbon Panel, announced a set of legislative principles to address concerns about the continued use of MTBE. The Administration recommended that Congress:

- Amend the CAA to provide the authority to significantly reduce or eliminate the use of MTBE.
- Ensure that air quality gains associated with the use of MTBE are not diminished.
- Replace the existing oxygen requirement contained in the CAA with a renewable fuel standard for all gasoline.

The Administration stated that it believed that the principles would provide an environmentally sound

and cost effective approach to addressing the risks posed by the current use of MTBE. Coincident with issuance of the legislative principles, EPA issued an Advance Notice of Proposed Rulemaking under Section 6 of the Toxic Substances Control Act (TSCA) to initiate a regulatory process to address MTBE risks using current authorities in the event that Congress did not act to amend the CAA.<sup>6</sup>

### 1999 Air Quality Status

The map in Figure 2-7 shows the variations in CO concentrations across the country in 1999. The air quality indicator is the largest annual second maximum 8-hour CO concentration measured at any site in each county. The bar chart to the left of the

map displays the number of people living in counties within each concentration range. The colors on the map and bar chart correspond to the colors of the concentration ranges displayed in the map legend. Only four of the 526 monitoring sites reporting ambient CO data to the Aerometric Information Retrieval System (AIRS) failed to meet the CO NAAQS in 1999. These four sites are located in

three counties—Los Angeles County, CA; Fairbanks Borough, AK; and Imperial County, CA (Calexico, CA). The site in this latter area is located just north of the border crossing with Mexicali, Mexico. There are 9 million people living in these three counties, compared to the 1998 count of six counties with a total population of 10 million people.

## Lead

### Air Quality Concentrations

1980–99	94% decrease
1990–99	60% decrease
1998–99	no change

### Emissions

1980–99	94% decrease
1990–99	16% decrease
1998–99	4% increase

### Worth Noting

- From 1980–1999, there has been a 94-percent decrease in lead emissions with a corresponding 94-percent decrease in maximum quarterly average lead concentrations at population-oriented monitors.
- Lead emissions are slightly increasing from 1998–1999 even though lead air quality continues its “no-change” status from previous years. Probable cause for the small emissions increase is increased use of aviation fuel, which can still contain large amounts of lead.
- In 1999, only two areas across the country were violating the lead NAAQS, but six are still nonattainment for lead. These areas tend to contain the lead point sources that had one or more source-oriented monitors that violated the NAAQS. These point sources are in Missouri (Doe Run/Herculeum plant) and Illinois (Chemetco facility).

### Nature and Sources

Twenty-five years ago, automotive sources were the major contributor of lead emissions to the atmosphere. As a result of EPA’s regulatory efforts to reduce the content of lead in gasoline, however, the contribution from the transportation sector, and particularly the automotive sector, has greatly declined. Though aviation fuels still

contain relatively large amounts of lead, industrial processes (primarily metals processing) are the major source of lead emissions to the atmosphere today. The highest ambient air concentrations of lead are found in the vicinity of ferrous and nonferrous smelters, battery manufacturers, and other stationary sources of lead emissions.

### Health and Environmental Effects

Exposure to lead occurs mainly through inhalation and through ingestion of lead in food, water, soil, or dust. It accumulates in the blood, bones, and soft tissues. Lead can also adversely affect the kidneys, liver, nervous system, and other organs. Excessive exposure to lead may cause neurological impairments such as seizures, mental retardation, and/or behavioral disorders. Lead may be a factor in high blood pressure and subsequent heart disease. Additionally, at low doses, fetuses and children may suffer from central nervous system damage. Neurobehavioral changes (i.e., low I.Q.) may result from lead exposure during the child’s first years of life.

Airborne lead can also have adverse impacts on the environment. Wild and domestic grazing animals may ingest lead that has deposited on plant or soil surfaces or that has been absorbed by plants through leaves or roots. At relatively low concentrations (2–10  $\mu\text{g}/\text{m}^3$ ), lead can inhibit plant growth and result in a shift to more tolerant plant species growing near roadsides and stationary source emissions. See also the Toxics chapter in this report for a discussion of the long-term impact of

lead on ecosystem function and stability.

### Primary and Secondary Standards

The primary as well as secondary NAAQS for lead is a quarterly average concentration not to exceed 1.5  $\mu\text{g}/\text{m}^3$ .

### National Air Quality Trends

The statistic used to track ambient lead air quality is the maximum quarterly mean concentration for each year. From 1980–1989, a total of 216 ambient lead monitors met the trends completeness criteria; and a total of 175 ambient lead monitors met the trends data completeness criteria for the 10-year period 1990–1999. Point-source oriented monitoring data were omitted from all ambient trends analysis presented in this section to avoid masking the underlying urban trends.

Figure 2-8 indicates that between 1990 and 1999, maximum quarterly average lead concentrations decreased 60 percent at population-oriented monitors. Between 1998 and 1999, national average lead concentrations (approaching the minimum detectable level) remained unchanged. The effect of the conversion to unleaded gasoline usage in vehicles on ambient lead concentrations is most evident when viewed over a longer period, such as illustrated in Figure 2-8. Between 1980 and 1999, ambient monitor data indicate that concentrations of lead declined 94 percent. This large decline tracks well with overall lead emissions, which also declined 94 percent between 1980 and 1999.

Figure 2-9 looks at urban, rural, and suburban 20-year trends sepa-

rately. The overall downward trend in lead concentrations can be noted for all locations from 1980–1999. The one slight oddity in Figure 2-9 is the slight upturn in Pb concentration seen at the rural sites in 1995. One of the rural sites in Louisiana (in St. John the Baptist parish) showed a concentration of 5.8  $\mu\text{g}/\text{m}^3$  in December 1995 causing the overall average to increase to 0.411 (up from normal levels of about 0.05  $\mu\text{g}/\text{m}^3$ ). Region 6 has been consulted regarding this issue and they, in turn, contacted the Louisiana Department of Environmental Quality (LDEQ) to confirm the high lead reading that occurred on December 17, 1995. LDEQ personnel have stated that this is a true reading and that the sampler must have been influenced by lead-rich plumes emitted by the industrial operations that took place at two nearby facilities: Bayou Steel and a recycling business.

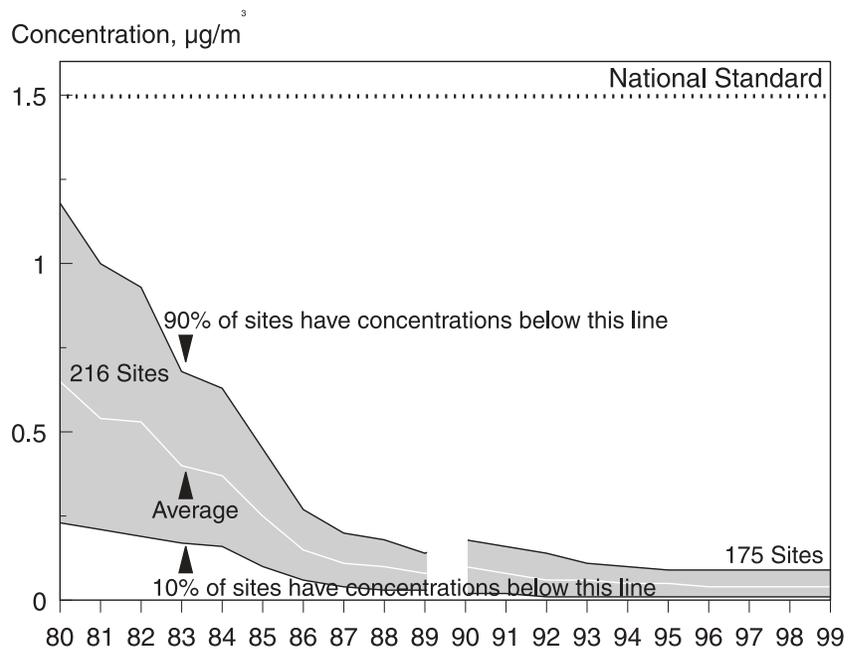
**Regional Air Quality Trends**

Figure 2-10 segregates the ambient trend analysis by EPA region. Although most regions showed large concentration reductions between 1980 and 1999, there were some intermittent upturns including a rather large upturn in the Region 1 trends plot. Most of these “bumps” in the trends graphs can be attributed to the inherent variability and noise associated with data reported near minimum detectable levels.

**National Emission Trends**

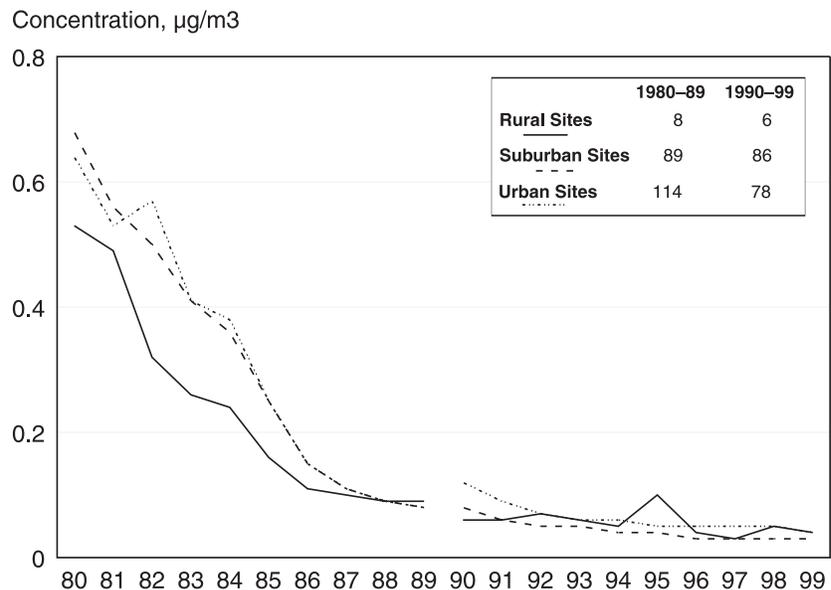
The lead emission estimates presented are a result of data developed for the National Emission Trends (NET) criteria database. Lead emissions for 1996 were also estimated in the National Toxics Inventory (NTI) and were used in the nationwide disper-

**Figure 2-8.** Trend in maximum quarterly average Pb concentrations (excluding point-source oriented sites), 1980–1999.

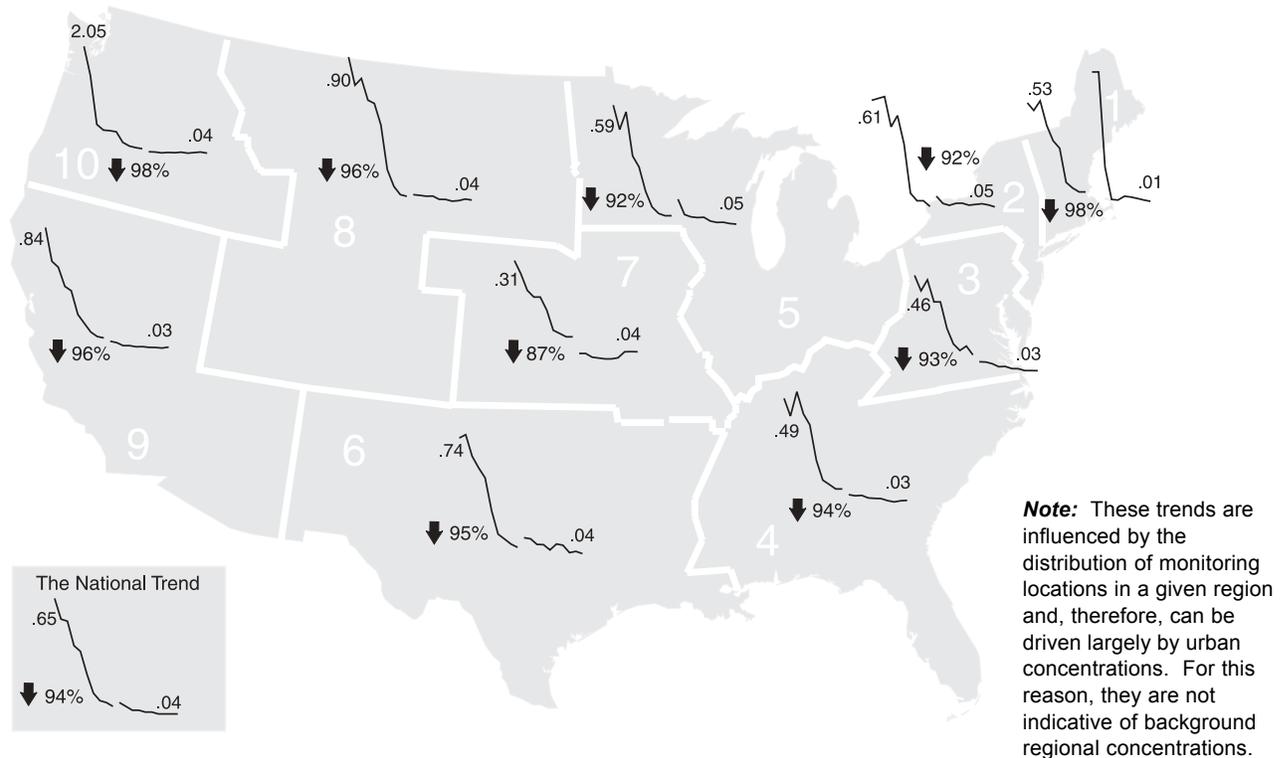


**Note:** When the total number of rural, suburban, and urban sites are summed for either the 1980–89 or 1990–99 time periods in Figure 2-9, this number may not equal the total number of sites shown in Figure 2-8 for the same time periods. This is due to a few monitoring sites falling outside the definitions of rural, suburban, or urban sites.

**Figure 2-9.** Pb maximum quarterly mean concentration trends by location (excluding point-source oriented sites), 1980–1999.



**Figure 2-10.** Trend in Pb maximum quarterly mean concentration by EPA Region, 1980–1999.



Alaska is in EPA Region 10; Hawaii, EPA Region 9; and Puerto Rico, EPA Region 2. Concentrations are µg/m³.

sion modeling as part of EPA’s National Air Toxics Assessment (NATA). For 1996, the NTI estimates would be the preferred source for data. In the future, the criteria emissions database (formerly the NET) will be combined with air toxics estimates (formerly in the NTI) in a single database called the National Emissions Inventory (NEI).

Because of the phase-out of leaded gasoline, lead emissions (and concentrations) decreased sharply during the 1980s and early 1990s. Figure 2-11 indicates that total lead emissions decreased 16 percent between 1990 and 1999. Figure 2-11 also shows that lead emissions decreased 94 percent between 1980 and 1999. The large ambient and emission reductions in lead going from 1980–

1990 can be largely attributed to the phasing out of leaded gasoline for automobiles. The magnitude of lead emission reductions after 1990 is a waning result of the phase-out of leaded gasoline use in automotive sources. The 4-percent increase in lead emissions from 1998–1999 is largely attributable to increased use of aviation gasoline. Aviation gasoline is not regulated for lead content and can use significant amounts of lead to comply with octane requirements for aviation fuel.

Figure 2-12 shows that industrial processes were the major source of lead emissions in 1999, accounting for 75 percent of the total. The transportation sector (which includes both onroad and nonroad sources) now accounts for only 13 percent of the

total 1999 lead emissions, with most of that coming from aircraft.

**1999 Air Quality Status**

The large reductions in long-term lead emissions from transportation sources have changed the nature of the ambient lead problem in the United States. Because industrial processes are now responsible for all violations of the lead standard, the lead monitoring strategy now focuses on emission from these point sources. The map in Figure 2-13 shows the lead monitors located in the vicinity of major sources of lead emissions. In 1999, two lead point sources had one or more source-oriented monitors that violated the NAAQS. These two sources are the Chemetco plant in Illinois and the Doe Run (Herculene-

um) plant in Missouri. It should be noted that the Franklin smelter in Pennsylvania, which in the past has emitted large amounts of lead, was shut down in 1997. These point sources are ranked in Figure 2-13 according to the site with the greatest maximum quarterly mean. Various enforcement and regulatory actions are being actively pursued by EPA and the states for cleaning up these sources.

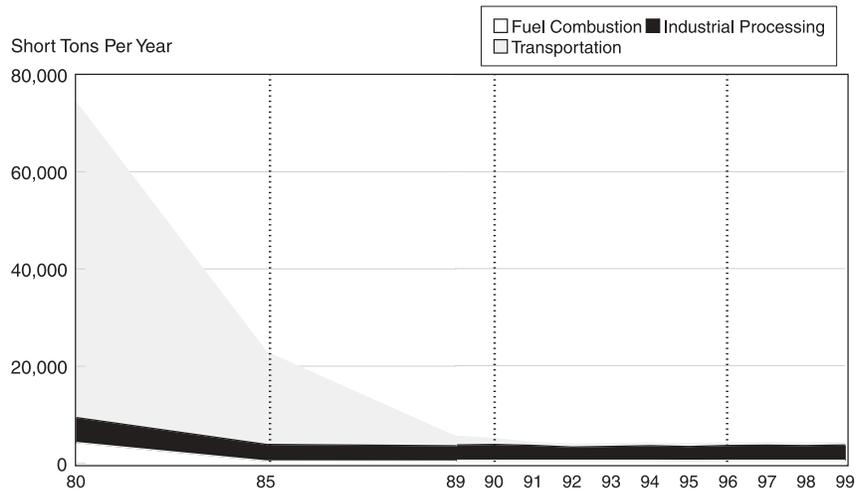
The map in Figure 2-14 shows the highest quarterly mean lead concentration by county in 1999. Two areas, with a total population of approximately 0.42 million, and containing the point sources identified in Figure 2-13, did not meet the lead NAAQS in 1999.

**Monitoring Status**

Due to the shift in ambient air monitoring focus from mobile-source emissions to stationary point sources of lead air pollution, EPA revised the lead air monitoring regulations by publishing a new rule on January 20, 1999. This action was taken at the direct request of numerous states and local agencies whose onroad mobile-source oriented lead monitors have been reporting peak lead air pollution values that are many times less than the quarterly lead NAAQS of 1.5 µg/m³ for a number of consecutive years.

The previous regulation required that each urbanized area with a population of 500,000 or more operate at least two lead National Air Monitoring Stations (NAMS). The new rule allows state and local agencies more flexibility. The rule substantially reduces the requirements for measuring lead air pollutant concentrations near major highways,

**Figure 2-11.** National total Pb emissions trend, 1980–1999.



**Notes:** Emissions data not available for consecutive years 1980–1989.

Emission estimation methods continue to evolve and improve over time. Methods have changed for many significant categories beginning with the years 1985, 1990, and 1996 and consequently are not consistent across all years in this trend period. See Appendix B Emissions Estimates Methodology for additional information.

**Figure 2-12.** Pb emissions by source category, 1999.

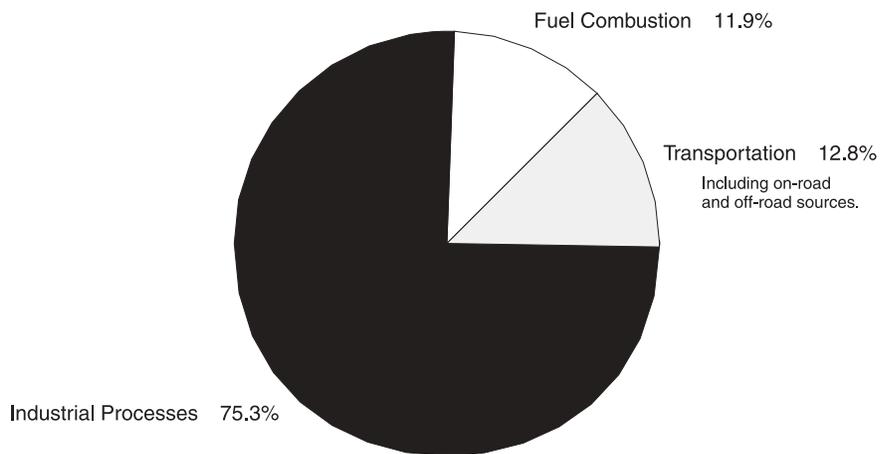


Figure 2-13. Pb maximum quarterly concentration in the vicinity of Pb point sources, 1999.

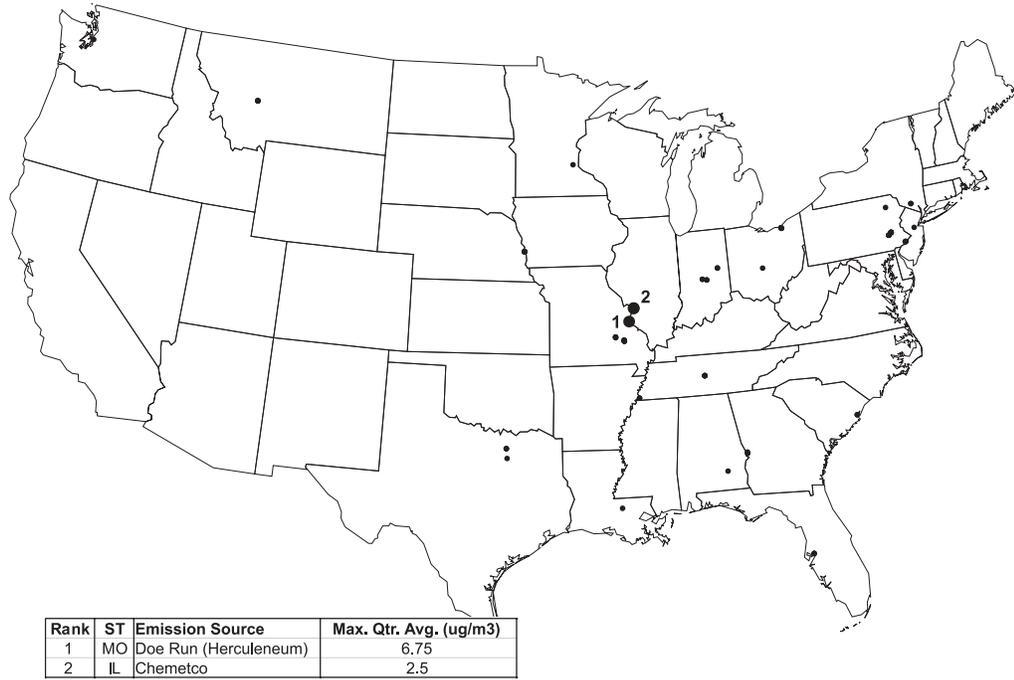
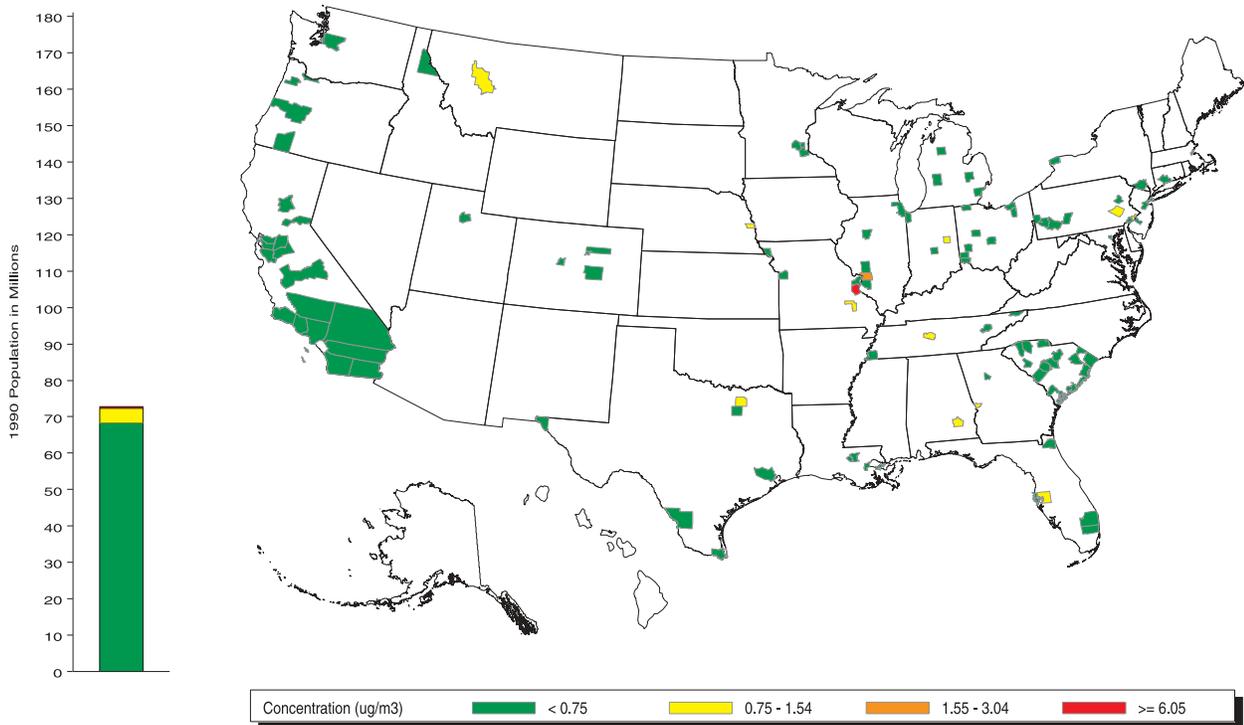


Figure 2-14. Highest Pb maximum quarterly mean by county, 1999.



thus shifting the focus to point sources and their impact on neighboring populations. The regulation also allows states to reduce the number of NAMS from approximately 85 to approximately 15. This reduction will still retain adequate monitoring to ensure attainment of the NAAQS, but it allows efficient refocusing of available monitoring.

## Nitrogen Dioxide

### Air Quality Concentrations

1980–99	25% decrease
1990–99	10% decrease
1998–99	no change

### Emissions

1980–99	4% increase
1990–99	5% increase
1998–99	2% decrease

### Worth Noting

- Over the past 20 years, nitrogen dioxide (NO<sub>2</sub>) concentrations across the country have decreased significantly.
- All areas of the country that once violated the national air quality standard for NO<sub>2</sub> now meet that standard.
- The last NO<sub>2</sub> nonattainment area, Los Angeles, was redesignated to attainment in July 1998.

### Nature and Sources

Nitrogen dioxide is a reddish brown, highly reactive gas that is formed in the ambient air through the oxidation of nitric oxide (NO). Nitrogen oxides (NO<sub>x</sub>), the term used to describe the sum of NO, NO<sub>2</sub> and other oxides of nitrogen, play a major role in the formation of ozone in the atmosphere through a complex series of reactions with volatile organic compounds (VOCs). A variety of NO<sub>x</sub> compounds and their transformation products occur both naturally and as a result of human activities. Anthropogenic (i.e., man-made) emissions of NO<sub>x</sub> account for a large majority of all nitrogen inputs to the environment. The major sources of anthropogenic NO<sub>x</sub> emissions are high-temperature combustion processes, such as those occurring in

automobiles and power plants. Most of NO<sub>x</sub> from combustion sources (about 95 percent) is emitted as NO; the remainder is largely NO<sub>2</sub>. Because NO is readily converted to NO<sub>2</sub> in the environment, the emissions estimates reported here assume nitrogen oxides are in the NO<sub>2</sub> form. Natural sources of NO<sub>x</sub> are lightning, biological and abiological processes in soil, and stratospheric intrusion. Ammonia and other nitrogen compounds produced naturally are important in the cycling of nitrogen through the ecosystem. Home heaters and gas stoves also produce substantial amounts of NO<sub>2</sub> in indoor settings.

### Health and Environmental Effects

Nitrogen dioxide is the most widespread and commonly found nitrogen oxide and is a matter of public health concern. The health effects of most concern associated with short-term exposures (i.e., less than three hours) to NO<sub>2</sub> at or near the ambient NO<sub>2</sub> concentrations seen in the United States, include cough and increased changes in airway responsiveness and pulmonary function in individuals with preexisting respiratory illnesses, as well as increases in respiratory illnesses in children 5–12 years old.<sup>7,8</sup> Evidence suggests that long-term exposures to NO<sub>2</sub> may lead to increased susceptibility to respiratory infection and may cause structural alterations in the lungs.

Atmospheric transformation of NO<sub>x</sub> can lead to the formation of ozone and nitrogen-bearing particles (e.g., nitrates and nitric acid). As discussed in the ozone and PM sections of this report, exposure to both PM and ozone is associated with adverse health effects.

Nitrogen oxides contribute to a wide range of effects on public welfare and the environment, including global warming and stratospheric ozone depletion. Deposition of nitrogen can lead to fertilization, eutrophication, or acidification of terrestrial, wetland and aquatic (e.g., fresh water bodies, estuaries, and coastal water) systems. These effects can alter competition between existing species, leading to changes in the number and type of species (composition) within a community. For example, eutrophic conditions in aquatic systems can produce explosive algae growth leading to a depletion of oxygen in the water and/or an increase in levels of toxins harmful to fish and other aquatic life.

### Primary and Secondary Standards

The level for both the primary and secondary NAAQS for NO<sub>2</sub> is 0.053 ppm annual arithmetic average (mean), not to be exceeded. In this report, the annual arithmetic average (mean) concentration is the metric used to evaluate and track ambient NO<sub>2</sub> air quality trends.

### National Air Quality Trends

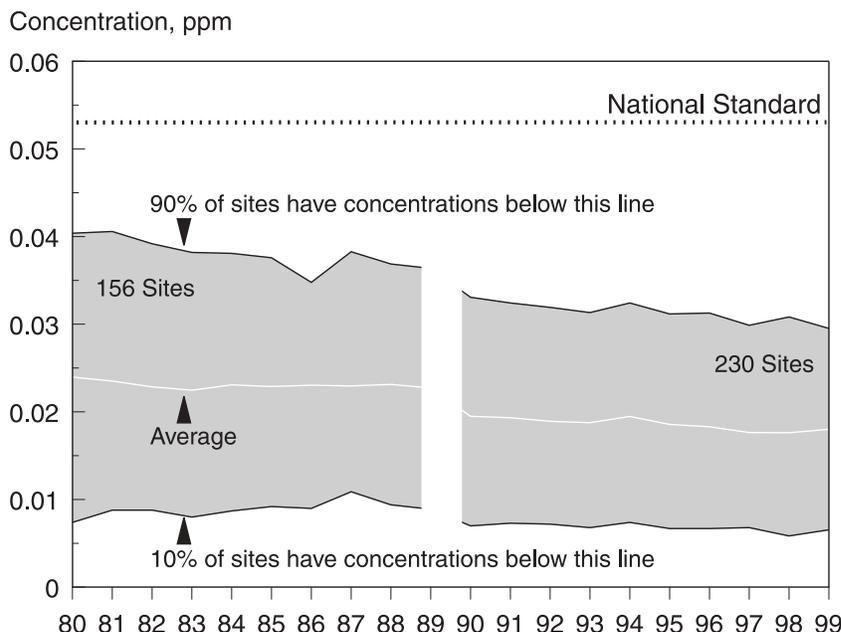
Nationally, annual mean NO<sub>2</sub> concentrations have decreased approximately 25 percent since 1980.<sup>9</sup> As discussed in previous sections of this report, long-term national ambient air quality trends are difficult to assess because few monitoring sites have operated continuously in the same location for 20 years. Figure 2-15 presents 20-year trends in ambient NO<sub>2</sub> concentrations by combining two separate 10-year trends databases, 1980–1989 (156 sites) and 1990–1999 (230 sites). Annual mean NO<sub>2</sub> concentrations declined in the early

1980s, were relatively unchanged during the mid-to-late 1980s, and resumed their decline in the 1990s. Figure 2-15 shows that the national composite annual mean NO<sub>2</sub> concentration in 1999 is 10 percent lower than that recorded in 1990, and is unchanged from the 1998 level. Except for 1994, NO<sub>2</sub> concentrations have decreased, or remained unchanged, each year since 1989.

Figure 2-16 reveals how the trends in annual mean NO<sub>2</sub> concentrations vary among rural, suburban and urban locations. The highest annual mean NO<sub>2</sub> concentrations are typically found in urban areas, with significantly lower annual mean concentrations recorded at rural sites. The 1999 composite mean at 137 urban sites is 24 percent lower than the 1980 level, compared to a 27-percent reduction at 180 suburban sites. At 66 rural sites, the composite mean NO<sub>2</sub> concentration in 1999 is the same as it was in 1980.

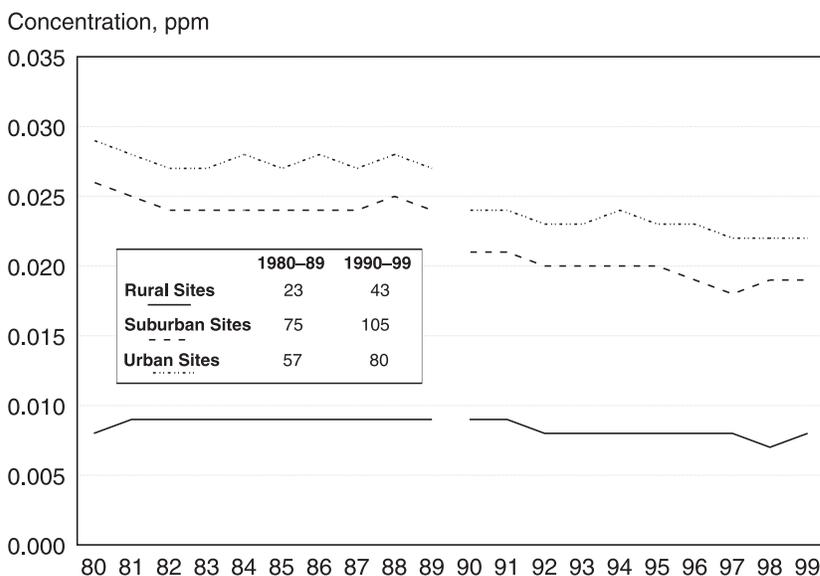
Interestingly, at the same time the nation has experienced these significant decreases in NO<sub>2</sub> air quality, nitrogen oxide emissions are increasing, as described in more detail later in this section of the chapter. One possible explanation involves the location of the majority of the nation's NO<sub>2</sub> monitors. Most NO<sub>2</sub> monitoring sites are mobile-source oriented sites in urban areas, and the 20-year decline in ambient NO<sub>2</sub> levels closely tracks the 19-percent reduction in emissions from gasoline powered vehicles over the same time period. However, nitrogen chemistry in the atmosphere is non-linear and, therefore, a change in NO<sub>x</sub> emissions may not have a proportional change in ambient concentrations of NO<sub>2</sub>. The relationship between emissions and ambient air quality levels is de-

**Figure 2-15.** Trend in annual NO<sub>2</sub> mean concentrations, 1980–1999.

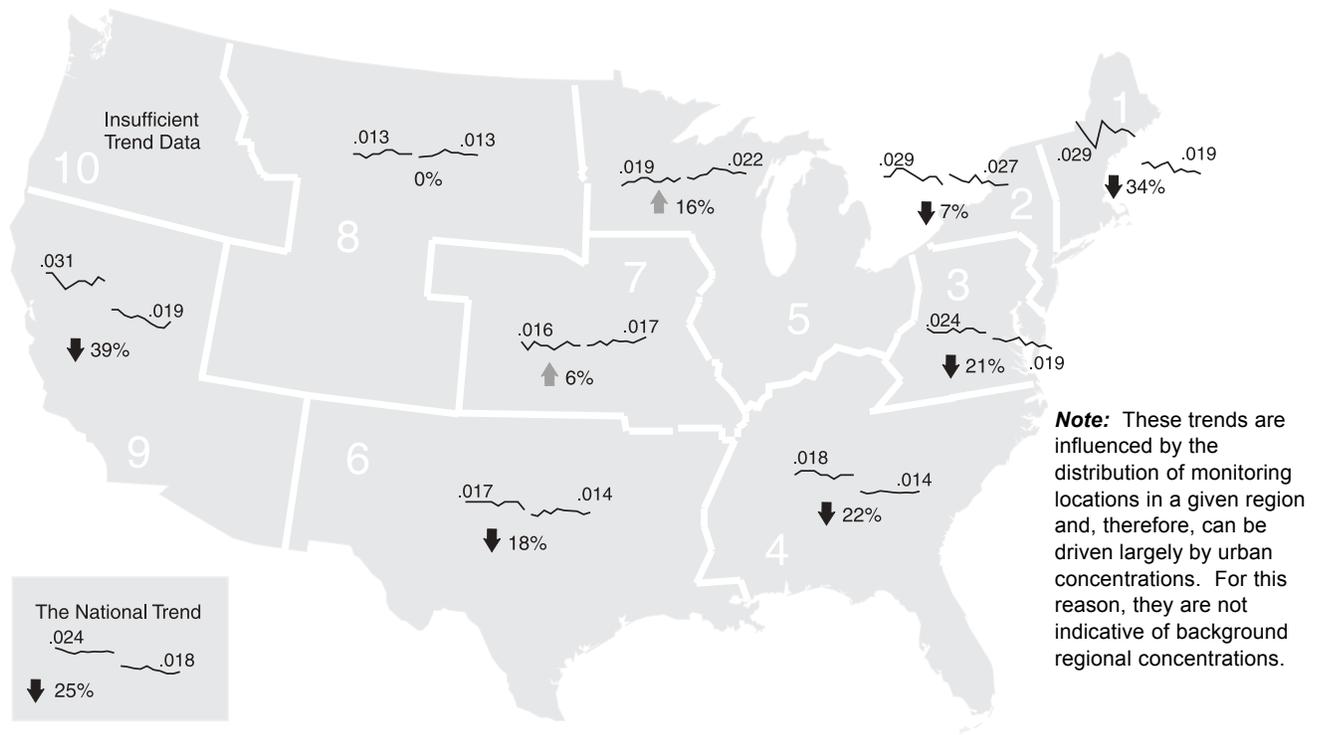


**Note:** When the total number of rural, suburban, and urban sites are summed for either the 1980–89 or 1990–99 time periods in Figure 2-16, this number may not equal the total number of sites shown in Figure 2-15 for the same time periods. This is due to a few monitoring sites falling outside the definitions of rural, suburban, or urban sites.

**Figure 2-16.** Trend in annual mean NO<sub>2</sub> concentrations by type of location, 1980–1999.



**Figure 2-17.** Trend in NO<sub>2</sub> maximum quarterly mean concentration by EPA Region, 1980–1999.



Alaska is in EPA Region 10; Hawaii, EPA Region 9; and Puerto Rico, EPA Region 2. Concentrations are ppm.

pendent on a number of factors such as concentrations of compounds which react with NO<sub>x</sub> emissions (e.g., free radicals and VOCs) as well as the form and concentration of various nitrogen compounds in the area being monitored. For example, an area could experience improving NO<sub>2</sub> air quality in conjunction with increased NO<sub>x</sub> emissions, if the emissions are rapidly converted to nitrates, a form of atmospheric nitrogen not detected by the NO<sub>2</sub> monitors. Alternatively, if levels of the compounds which react with NO<sub>x</sub> emissions to form ambient NO<sub>2</sub> are declining, increased NO<sub>x</sub> emissions may not translate into elevated levels of converted NO<sub>2</sub>.

**Regional Air Quality Trends**

The map in Figure 2-17 provides regional trends in NO<sub>2</sub> concentra-

tions during the past 20 years, 1980–1999 (except Region 10 which does not have any NO<sub>2</sub> trend sites). The trends statistic is the regional composite mean of the NO<sub>2</sub> annual mean concentrations across all sites with at least eight years of ambient measurements. The largest reductions in NO<sub>2</sub> concentrations occurred in the south coast of California and the New England states. Smaller reductions in mean NO<sub>2</sub> concentrations were recorded in the Mid-Atlantic, Southeast, and Southwest. Interestingly, NO<sub>2</sub> concentrations have actually increased in both the North Central and Midwest states. This increase in air quality levels coincides with increases in nitrogen oxide emissions from transportation (both onroad and nonroad) as well as power plants in

selected states with NO<sub>2</sub> monitors in these areas.

**National Emissions Trends**

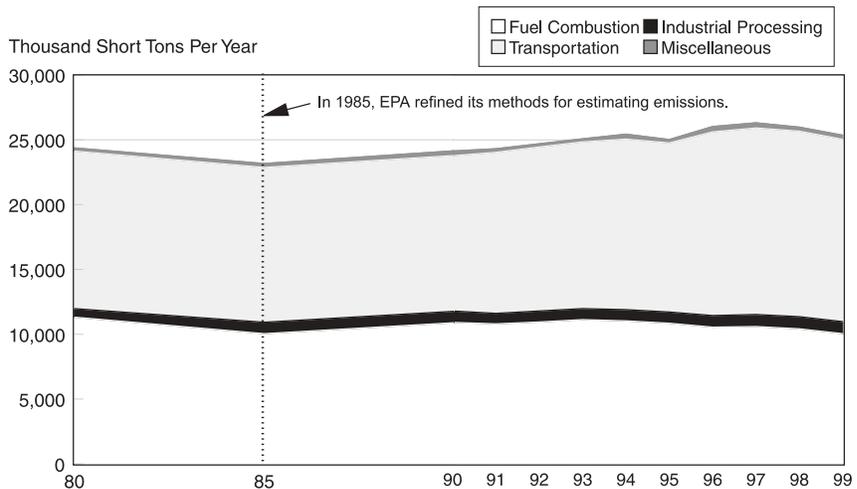
Nationally, emissions of nitrogen oxides have increased over the last 20 years by 4 percent and by 5 percent over the most recent 10-year period from 1990 to 1999. Figure 2-18 shows the temporal trend in NO<sub>x</sub> emissions nationwide. These increases are the result of a number of factors, the largest being an increase in nitrogen oxides emissions from transportation sources.

Figure 2-19 indicates that the two primary sources of NO<sub>x</sub> emissions are stationary source fuel combustion and transportation. Together, these two sources comprise 95 percent of 1999 total NO<sub>x</sub> emissions. Emissions from transportation sources have increased over the last 20 years (16

percent) and during the past 10 years (17 percent). For both light duty gasoline vehicles and light duty gasoline trucks, NO<sub>x</sub> emissions peaked in 1994, and then began a steady decrease through 1999. This decrease can be attributed primarily to the implementation of the Tier 1 emission standards which lowered NO<sub>x</sub> emissions from new cars and light duty trucks. In contrast, NO<sub>x</sub> emissions from heavy duty vehicles, both gasoline and diesel increased significantly over the 10-year period (50 percent for gasoline and 61 percent for diesel). A portion of this increase is due to the increase in VMT for these categories (104 percent for heavy duty gasoline vehicles and 99 percent for heavy duty diesel trucks). In addition, emissions from heavy duty diesel vehicles increased over this period due to the identification of “excess emissions” in many of these vehicles. New emission standards will lead to reductions in emissions from heavy duty vehicles in the future. Further, emissions from off-road vehicles particularly those diesel-fueled have steadily increased over the last 10 years.

Reductions in NO<sub>x</sub> emissions from fuel combustion have partially offset the impact of increases in the transportation sector. Emissions from electric utility fuel combustion sources have declined over the 20-year period 1980–1999 (11 percent) and over the 10-year period from 1990–1999 (8 percent). The Acid Deposition Control provisions of the CAA (Title IV) required EPA to establish NO<sub>x</sub> annual emission limits for coal-fired electric utility units in two phases resulting in NO<sub>x</sub> reductions of approximately 400,000 tons per year during Phase I (1996–1999) and two million

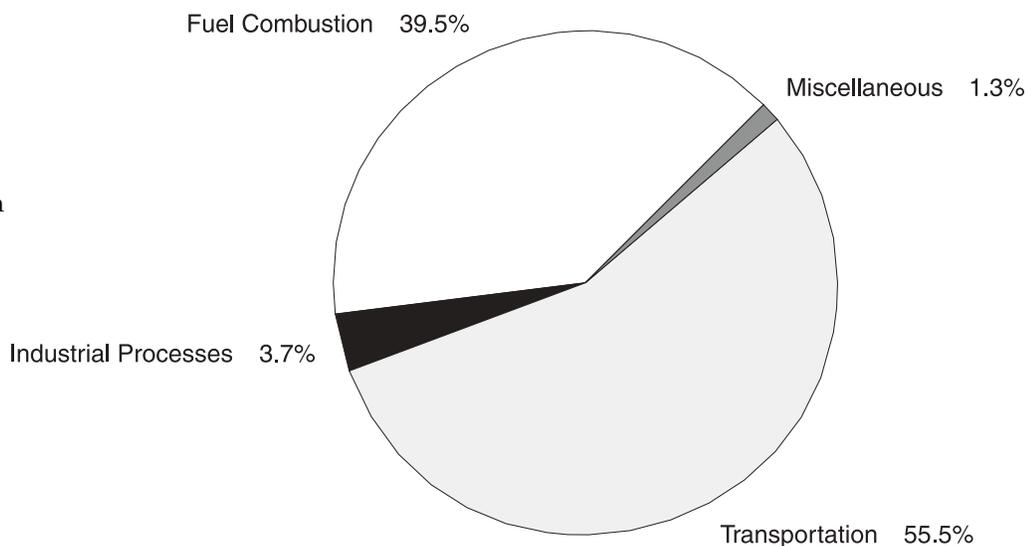
**Figure 2-18.** Trend in national total NO<sub>x</sub> emissions, 1980–1999.



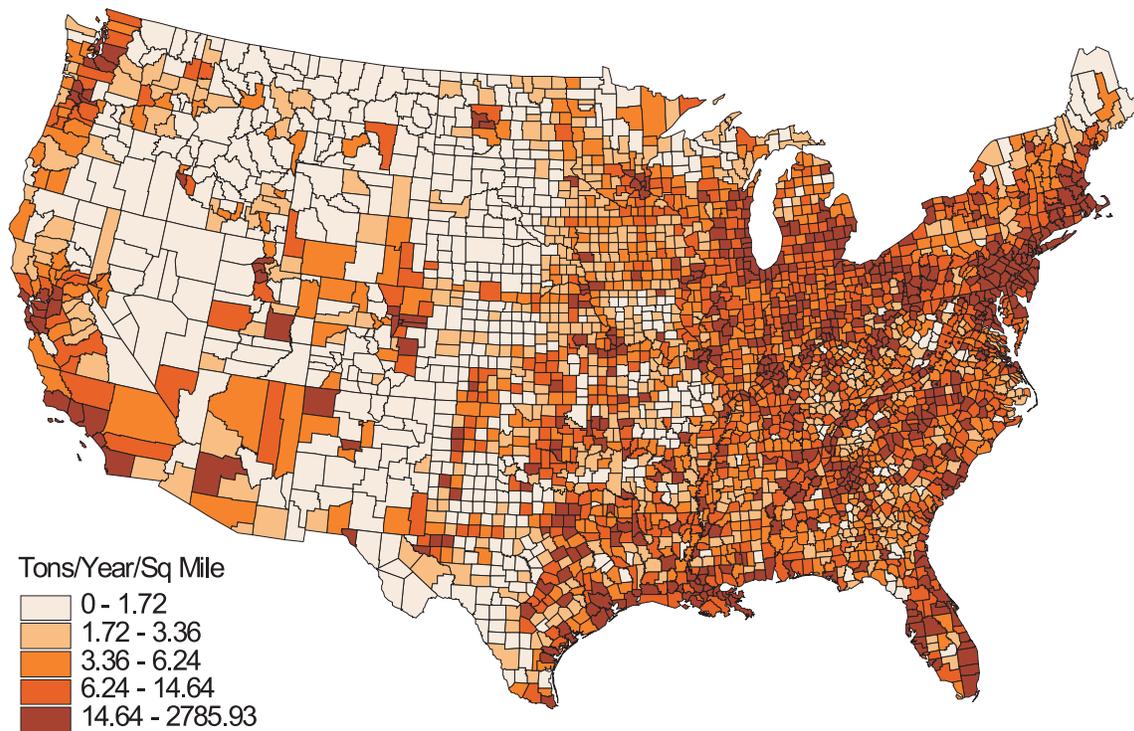
**Notes:** Emissions data not available for consecutive years 1980–1989.

Emission estimation methods continue to evolve and improve over time. Methods have changed for many significant categories beginning with the years 1985, 1990, and 1996 and consequently are not consistent across all years in this trend period. See Appendix B Emissions Estimates Methodology for additional information.

**Figure 2-19.** NO<sub>x</sub> emissions by source category, 1999.



**Figure 2-20.** Density map of 1999 nitrogen dioxide emissions, by county.



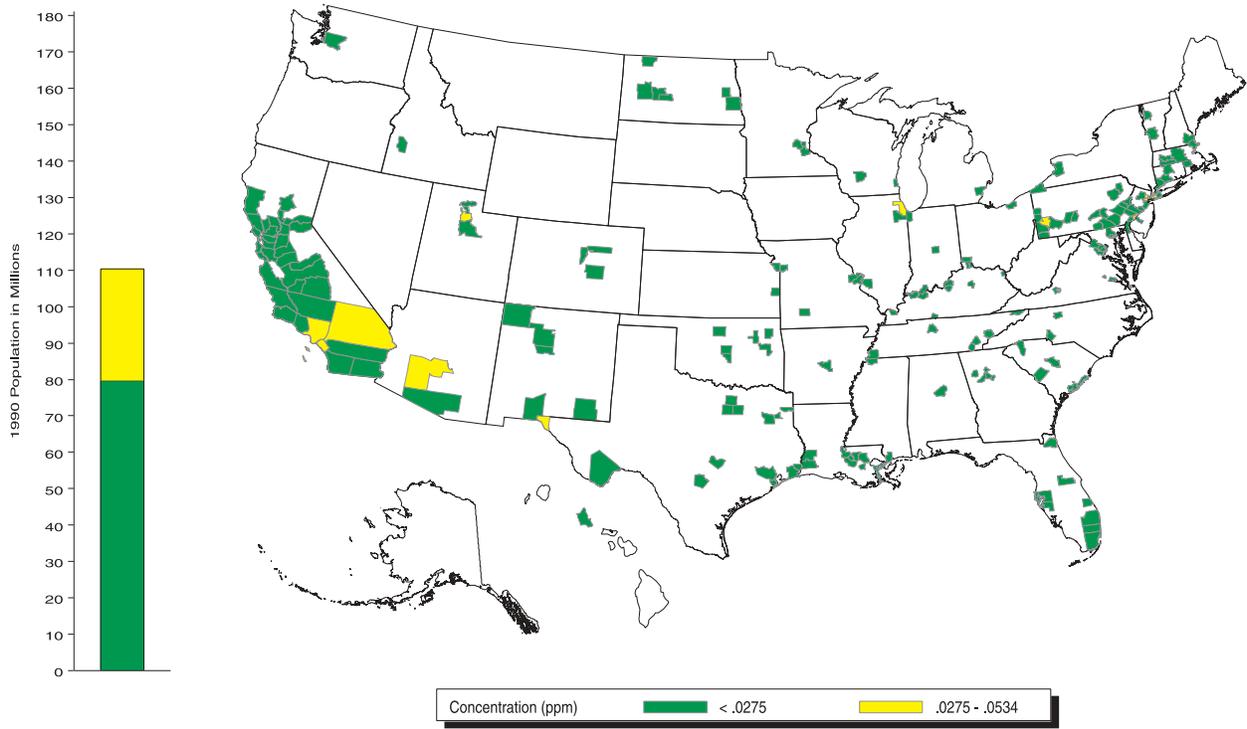
tons per year in Phase II (year 2000 and subsequent years).<sup>10</sup>

Figure 2-20 shows the geographic distribution of 1999  $\text{NO}_x$  emissions based on the tonnage per square mile for each county. This map illustrates that the eastern half of the country and the west coast emit more  $\text{NO}_x$  (on a density basis) than the western half of the continental United States.

#### **1999 Air Quality Status**

All monitoring locations across the nation, including Los Angeles, met the  $\text{NO}_2$  NAAQS in 1999. This is reflected on the map in Figure 2-21 that displays the highest annual mean  $\text{NO}_2$  concentration measured in each county.

Figure 2-21. Highest NO<sub>2</sub> annual mean concentration by county, 1999.



## Ozone

### Air Quality Concentrations

1980–99	20% decrease (1-hr)
	12% decrease (8-hr)
1990–99	4% decrease (1-hr)
	no change (8-hr)
1989–99	3% decrease (1-hr)
	1% decrease (8-hr)

### Emissions (Anthropogenic VOCs)

1980–99	31% decrease
1990–99	14% decrease
1998–99	3% decrease

### Worth Noting

- Over the last 20 years, ozone (O<sub>3</sub>) levels (1-hour and 8-hour) have improved considerably nationwide.
- Rate of improvement, however, appears to have slowed recently.
- Some parts of the country show increases in O<sub>3</sub> levels over the last 10 years, due largely to increased NO<sub>x</sub> emissions and weather conditions favorable to O<sub>3</sub> formation.
- Trends for selected urban areas after adjusting for meteorological conditions show slowing progress since the mid-1990s.
- O<sub>3</sub> levels in urban areas, however, where the O<sub>3</sub> problem has historically been the most severe, have shown marked improvement in response to stringent control programs.
- Rural O<sub>3</sub> levels appear to be increasing in the short term.
  - 1-hour levels are higher than those seen in urban areas for the second consecutive year.
  - 8-hour levels increasing nationally over the last 10 years.
  - Trends in 8-hour levels at CASTNet sites up since 1990.
  - 8-hour levels in a number of the nation's national parks are showing significant increases since 1990.

### Nature and Sources

Ground level O<sub>3</sub> remains a pervasive pollution problem in the United States. Ozone is readily formed in the atmosphere by the reaction of VOCs and NO<sub>x</sub> in the presence of heat and sunlight, which are most abundant in the summer. VOCs are emitted from a variety of sources including: motor vehicles, chemical plants, refineries, factories, consumer and commercial products, other industries, and natural (biogenic) sources. Nitrogen oxides are emitted from motor vehicles, power plants, and other sources of combustion, and natural sources including lightning and biological processes in soil. Changing weather patterns contribute to yearly differences in O<sub>3</sub> concentrations. Ozone and the precursor pollutants that cause O<sub>3</sub> also can be transported into an area from pollution sources located hundreds of miles upwind.

### Health and Environmental Effects

Ozone occurs naturally in the stratosphere and provides a protective layer high above the Earth. However, at ground level, it is the prime ingredient of smog. Short-term (1–3 hours) and prolonged (6–8 hours) exposures to ambient O<sub>3</sub> concentrations have been linked to a number of health effects of concern. For example, increased hospital admissions and emergency room visits for respiratory causes have been associated with ambient O<sub>3</sub> exposures.

Exposures to O<sub>3</sub> result in lung inflammation, aggravate preexisting respiratory diseases such as asthma, and may make people more susceptible to respiratory infection. Other health effects attributed to short-term and prolonged exposures to O<sub>3</sub>, generally while individuals are en-

gaged in moderate or heavy exertion, include significant decreases in lung function and increased respiratory symptoms such as chest pain and cough. Children active outdoors during the summer when O<sub>3</sub> levels are at their highest are most at risk of experiencing such effects. Other at-risk groups include adults who are active outdoors, such as outdoor workers, and individuals with preexisting respiratory disorders such as asthma and chronic obstructive lung disease. Within each of these groups are individuals who are unusually sensitive to O<sub>3</sub>. In addition, repeated long-term exposure to O<sub>3</sub> presents the possibility of irreversible changes in the lungs which could lead to premature aging of the lungs and/or chronic respiratory illnesses.

Ozone also affects sensitive vegetation and ecosystems. Specifically, O<sub>3</sub> can lead to reductions in agricultural and commercial forest yields, reduced survivability of sensitive tree seedlings, and increased plant susceptibility to disease, pests, and other environmental stresses such as harsh weather. In long-lived species, these effects may become evident only after several years or even decades. As these species are out-competed by others, long-term effects on forest ecosystems and habitat quality for wildlife and endangered species occurs. Furthermore, O<sub>3</sub> injury to the foliage of trees and other plants can decrease the aesthetic value of ornamental species as well as the natural beauty of our national parks and recreation areas.

### Primary and Secondary 1-hour Ozone Standards

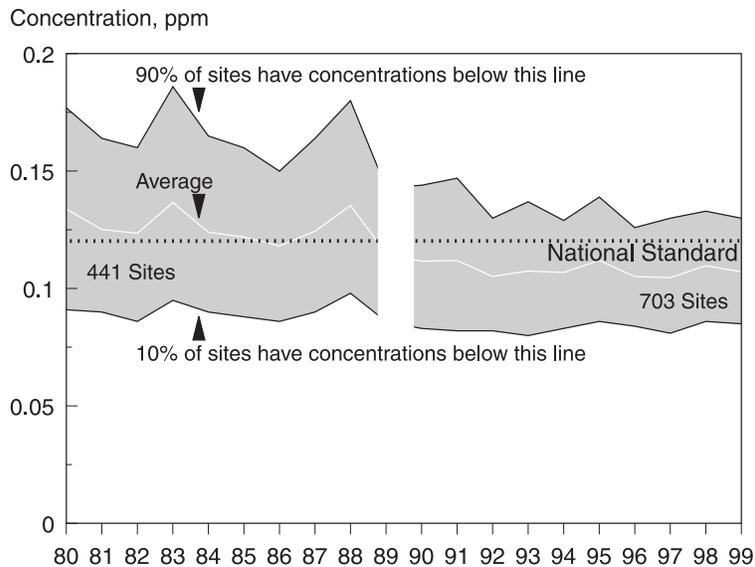
In 1979, EPA established 1-hour primary and secondary standards for O<sub>3</sub>. The level of the 1-hour primary

and secondary O<sub>3</sub> NAAQS is 0.12 ppm daily maximum 1-hour concentration that is not to be exceeded more than once per year on average. To encourage an orderly transition to the revised O<sub>3</sub> standards (promulgated in 1997; see following section for more information), EPA initiated a policy in which the 1-hour standards would no longer apply once an area experienced air quality data meeting the 1-hour standards. In 1998 and early 1999, EPA revoked the 1-hour O<sub>3</sub> NAAQS in 2,942 counties in the United States, leaving 201 counties where the 1-hour standard still applies.<sup>11, 12, 13</sup> However, due to unresolved legal challenges, the Agency is unable to enforce and effectively implement the 8-hour standard. As a result, many areas were without applicable air quality standards adequate to ensure public health and welfare. Therefore, in July 2000, EPA reinstated the 1-hour standard nationwide to alleviate this unanticipated policy outcome and provide protection of public health and welfare.<sup>14</sup>

**Primary and Secondary 8-hour Ozone Standards**

On July 18, 1997, EPA strengthened the O<sub>3</sub> NAAQS based on the latest scientific information showing adverse effects from exposures allowed by the then existing standards. The standard was set in terms of an 8-hour averaging time.<sup>15</sup> Numerous industry and environmental petitioners, including the American Trucking Associations (ATA), challenged the O<sub>3</sub> and the new PM<sub>2.5</sub> standards in the United States Court of Appeals for the District of Columbia Circuit. On May 14, 1999, a three-judge panel of that court concluded that EPA's interpretation of the Clean Air Act unconstitutionally delegated legisla-

**Figure 2-22.** Trend in annual 2nd-highest daily maximum 1-hour, and 4th-highest daily 8-hour O<sub>3</sub> concentrations, 1980–1999.



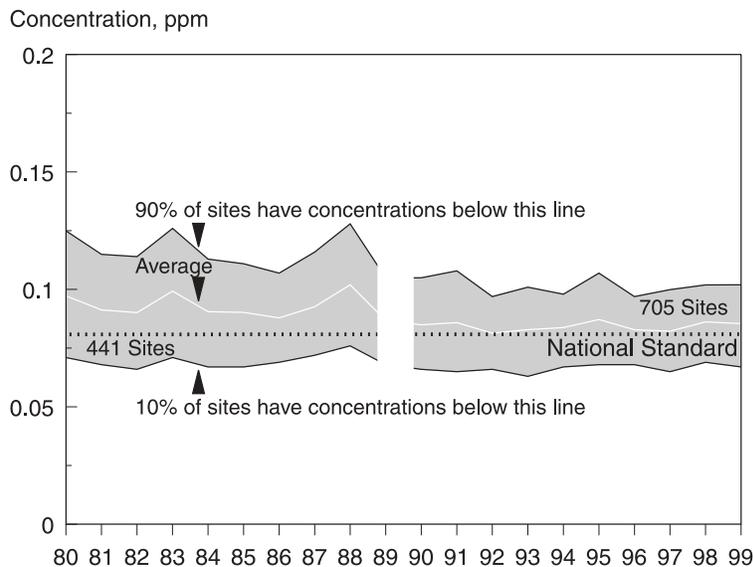
tive power to EPA and remanded the standards to EPA. EPA appealed that ruling, and on February 27, 2001, the Supreme Court unanimously upheld the constitutionality of Clean Air Act section 109 and affirmed EPA's ability to set NAAQS based solely on public health and welfare factors, without consideration of costs, which are considered in the implementation of the standards. The court rejected the D.C. Circuit's conclusion that EPA's interpretation of the implementation provisions violated the statute's clear terms, but nevertheless remanded the implementation policy to EPA on the basis that EPA's policy was not a reasonable interpretation of ambiguous statutory language. Because the D.C. Circuit originally remanded, but did not vacate the O<sub>3</sub> and PM<sub>2.5</sub> standards, they have remained legally effective throughout the ongoing litigation. The case has now been returned to the Court of Appeals,

where the remaining issues are to be considered in accordance with the decision of the Supreme Court.

For a variety of reasons, EPA has not yet taken actions to implement either standard. EPA is currently reviewing the results of the litigation and will be conferring with states and other interested parties to determine the approach and schedule for moving forward with implementing the O<sub>3</sub> NAAQS. Refer to <http://www.epa.gov/airlinks> for up-to-date information concerning actions surrounding the revised standards.

**Air Quality Trends**

Because the 1-hour and 8-hour NAAQS have different averaging times and forms, two different statistics are used in this report to track ambient O<sub>3</sub> air quality trends. For the 1-hour O<sub>3</sub> NAAQS, this report uses the composite mean of the annual second-highest daily maximum

**Figure 2-23.** Trend in 4<sup>th</sup>-highest daily 8-hour O<sub>3</sub> concentrations, 1980–1999.

1-hour O<sub>3</sub> concentration as the statistic to evaluate trends. For the 8-hour O<sub>3</sub> NAAQS, the report relies on the annual fourth-highest 8-hour daily maximum O<sub>3</sub> concentration as the statistic of interest to assess trends.

### National Air Quality Trends

Figure 2-22 clearly shows that, over the past 20 years, peak 1-hour O<sub>3</sub> concentrations have declined considerably at monitoring sites across the country. From 1980 to 1999, national 1-hour O<sub>3</sub> levels improved 20 percent with 1980, 1983, 1988 and 1995 representing peak years for this pollutant. Because only a few sites have monitored continuously for two decades, the 20-year trends line in Figure 2-22 is composed of two segments—441 sites with complete data during the first 10 years (1980–1989) and 705 sites meeting the data completeness criteria in the most recent 10 years (1990–1999). It is important to inter-

pret such long-term, quantitative ambient O<sub>3</sub> trends carefully given changes in network design, siting criteria, spatial coverage and monitoring instrument calibration procedures during the past two decades. More recently, national 1-hour O<sub>3</sub> levels have continued to improve but the progress has been less rapid evidenced by the 4-percent decrease from 1990–1999.

Figure 2-23 shows the national trend in 8-hour O<sub>3</sub> concentrations across the same sites used to estimate the national 1-hour O<sub>3</sub> trends. As was the case with the 1-hour graphic, the 20-year trends line in Figure 2-23 is composed of two segments—441 sites with complete data during the first 10 years (1980–1989) and 705 sites meeting the data completeness criteria in the most recent 10 years (1990–1999). Nationally, 8-hour levels have decreased 12 percent over the last 20 years with even more

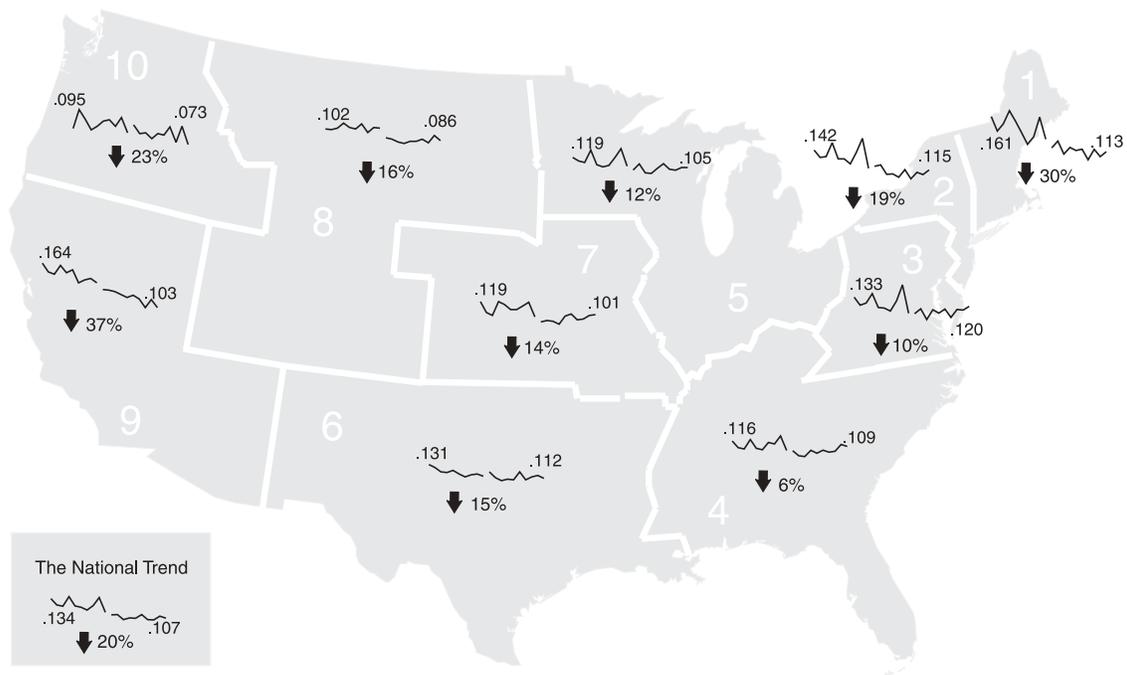
substantial improvement (18 percent) at higher concentration sites (as shown by the 90th percentile). However, just as is true for the 1-hour levels, the progress in 8-hour O<sub>3</sub> levels over last 10 years has dampened with no change in national levels between 1990 and 1999. The trend in the 8-hour O<sub>3</sub> statistic is similar to the trend in the 1-hour values, although the concentration range is smaller.

### Regional Air Quality Trends

The maps in Figures 2-24 and 2-25 examine the trend in 1-hour and 8-hour O<sub>3</sub> concentrations during the past 20 years by geographic region of the country. The O<sub>3</sub> levels (both 1-hour and 8-hour) in all areas have generally followed the pattern of declining trends since 1980 similar to that of the national observations. However, the magnitude of improvement has not been consistent across all Regions. The most pronounced declines in O<sub>3</sub> levels have occurred in the Northeast and West, while the Southeast has evidenced the least improvement. Further, over the last 10 years, O<sub>3</sub> concentrations (both 1-hour and 8-hour) in the Mid-Atlantic, Southeast, Midwest and North Central regions of the country have actually increased. These increases appear to be explained by weather conditions more conducive to O<sub>3</sub> formation (i.e., higher summer temperatures and drier conditions) in 1999 relative to 1990 paired with increased NO<sub>x</sub> emissions in many of the affected states (except the Mid-Atlantic region which seems to have been most affected by more conducive meteorological conditions).

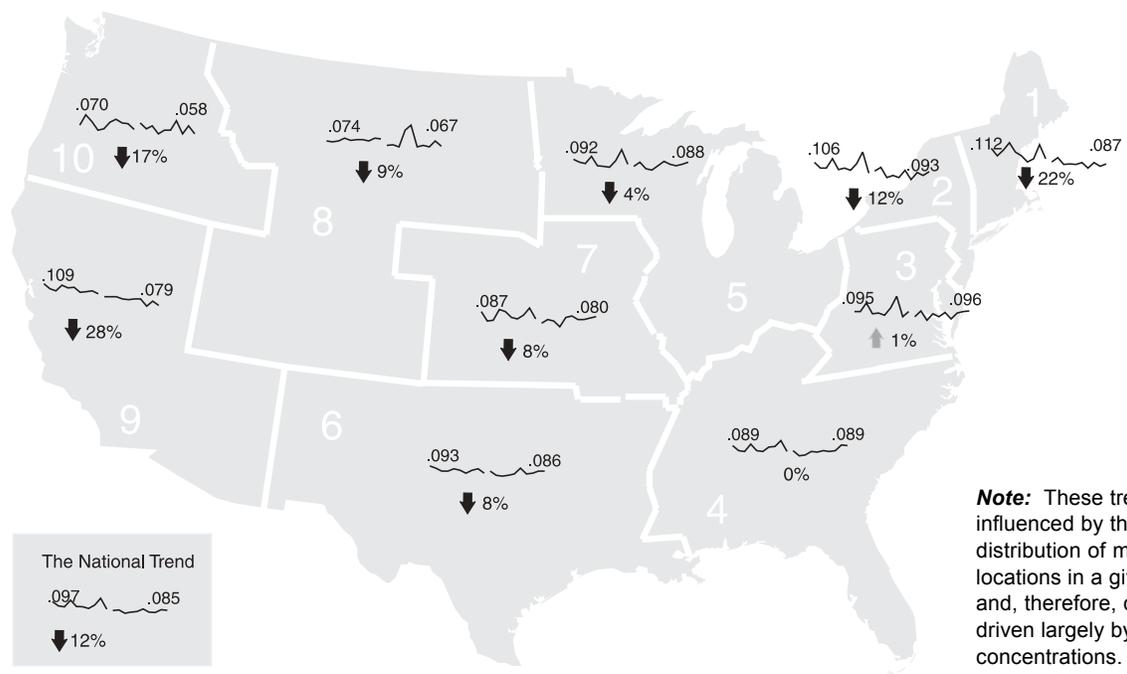
In Figure 2-26, the national 1-hour O<sub>3</sub> trend is disaggregated to show the 20-year change in ambient O<sub>3</sub> concentrations among rural, suburban, and

**Figure 2-24.** Trend in 2nd highest daily 1-hour O<sub>3</sub> concentration by EPA Region, 1980–1999.



Alaska is in EPA Region 10; Hawaii, EPA Region 9; and Puerto Rico, EPA Region 2. Concentrations are ppm.

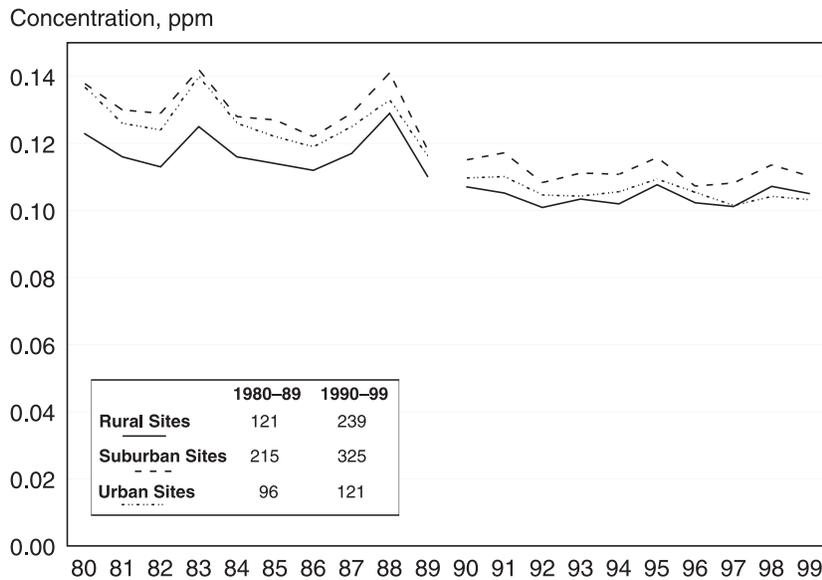
**Figure 2-25.** Trend in 4th highest daily 8-hour O<sub>3</sub> concentration by EPA Region, 1980–1999.



**Note:** These trends are influenced by the distribution of monitoring locations in a given region and, therefore, can be driven largely by urban concentrations. For this reason, they are not indicative of background regional concentrations.

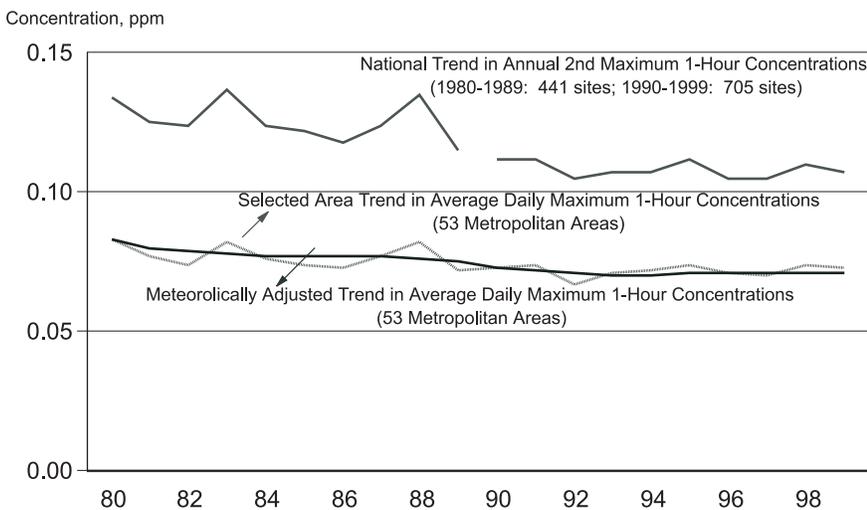
Alaska is in EPA Region 10; Hawaii, EPA Region 9; and Puerto Rico, EPA Region 2. Concentrations are ppm.

**Figure 2-26.** Trend in annual 2nd-highest daily maximum 1-hour O<sub>3</sub> concentrations by location, 1980–1999.



**Note:** When the total number of rural, suburban, and urban sites are summed for either the 1980–89 or 1990–99 time periods in Figure 2-26, this number may not equal the total number of sites shown in Figure 2-22 for the same time periods. This is due to a few monitoring sites falling outside the definitions of rural, suburban, or urban sites.

**Figure 2-27.** Comparison of actual and meteorologically adjusted 1-hour O<sub>3</sub> trends, 1980–1999.



urban monitoring sites. The highest ambient O<sub>3</sub> concentrations are typically found at suburban sites, consistent with the downwind transport of emissions from the urban center. During the past 20 years, O<sub>3</sub> concentrations decreased by 20 percent at 540 suburban sites, and 25 percent at 217 urban sites. However, at 360 rural sites, 1-hour O<sub>3</sub> levels for 1999 are only 14 percent lower than the 1980 level and, for the second consecutive year, are greater than the level observed for urban sites.

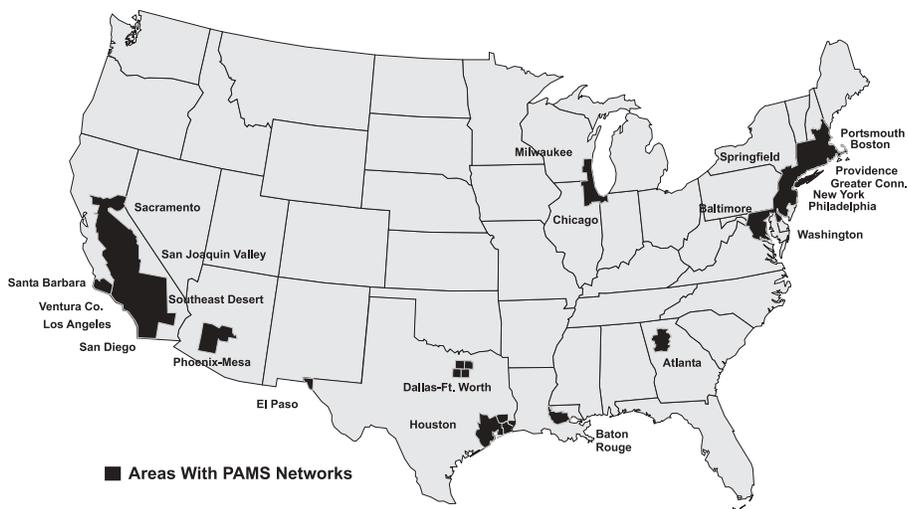
**Urban Area Air Quality Trends**

Figure 2-27 presents the meteorologically-adjusted trend in 1-hour O<sub>3</sub> concentrations for 53 metropolitan areas between 1980 and 1999. Ambient O<sub>3</sub> trends are influenced by year-to-year changes in meteorological conditions, population growth, changes in emissions levels from ongoing control measures as well as the relative levels of O<sub>3</sub> precursors VOCs and NO<sub>x</sub>. As discussed in previous *Trends Reports*, EPA uses a statistical model to adjust data on the annual rate of change in O<sub>3</sub> from individual metropolitan areas to account for meteorological impacts, including surface temperature and wind speed.<sup>16</sup> As seen in this figure, after adjusting for meteorological conditions, 1-hour O<sub>3</sub> levels in these selected areas show steady improvement from 1980 through the mid-1990s. The adjusted O<sub>3</sub> levels decreased an average of 1 percent annually through 1994. However, beginning in 1994, the improvement appears to slow. Since the mid-1990s, national 1-hour O<sub>3</sub> levels adjusted to account for variable weather conditions are nearly unchanged.

However, urban areas with the most severe and persistent O<sub>3</sub> prob-

lems (i.e., those classified as extreme, severe, and serious O<sub>3</sub> nonattainment areas) show decreases in 1-hour O<sub>3</sub> concentrations between 1990 and 1999 (12 percent) and between 1995 and 1999 (10 percent). These declines, based on data from sites in the areas required to operate the Photochemical Assessment Monitoring Stations (PAMS) network, are consistent with, but more pronounced than, the 4-percent improvement seen nationwide (at the 705 trend sites).<sup>17</sup> Areas with PAMS networks are shown in Figure 2-28. In addition to

**Figure 2-28.** Areas with PAMS networks.



**Table 2-3.** Summary of Changes in Summer 6-9 a.m. Mean Concentrations of NO<sub>x</sub> and TNMOC at PAMS Sites

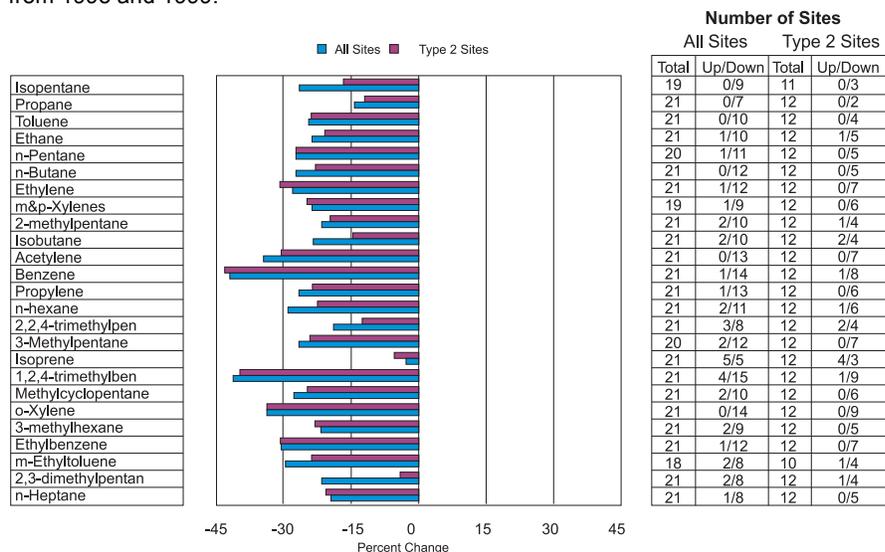
	# of			Median Change
	Total	Up	Down	
<b>1998-99 (all sites)</b>				
NO <sub>x</sub>	58	10	11	2%
TNMOC	42	2	14	-8%
<b>1995-99 (all sites)</b>				
NO <sub>x</sub>	34	9	9	-6%
TNMOC	17	0	10	-24%
<b>1995-99 (type 2 sites)</b>				
NO <sub>x</sub>	17	3	5	-4%
TNMOC	11	0	6	-24%

**Note:** 1. The numbers shown in the “Up” and “Down” columns refer to the number of sites in which the change in summer 6-9 a.m. mean concentrations between 1995 and 1999 is statistically significant. The total number of sites (“Total”) may not equal the sum of the corresponding “Up” and “Down” categories.

2. PAMS type 2 sites are monitoring sites located to detect the maximum downwind ozone precursor emissions impacts.

measuring O<sub>3</sub> levels, PAMS sites include measurements of NO<sub>x</sub>, total non-methane organic compounds (TNMOC), a target list of VOC species including several carbonyls, plus surface and upper air meteorology during summer months when weather conditions are most conducive to O<sub>3</sub> formation. Table 2-3 shows

**Figure 2-29.** A comparison of the median change in summer morning concentrations of the most abundant VOC species measured at all PAMS sites and PAMS type 2 sites from 1995 and 1999.

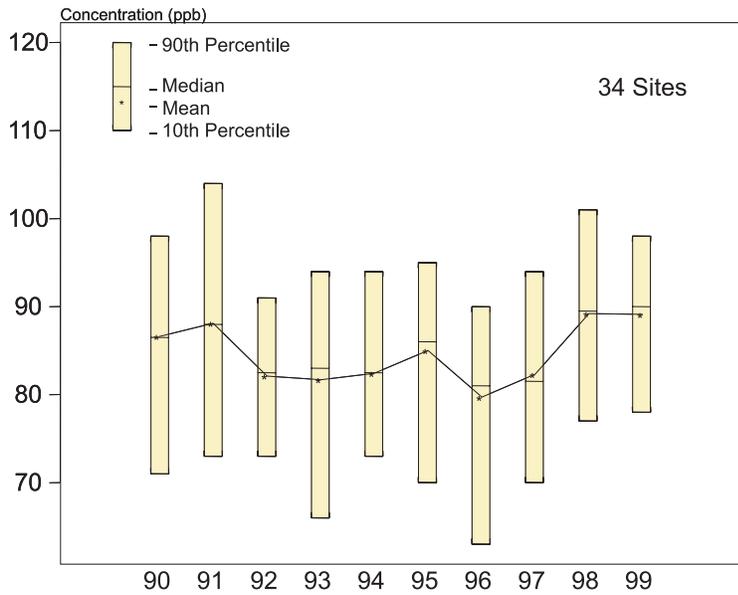


**Notes:** 1. The numbers shown in the “Up” and “Down” columns refer to the number of sites in which the change in summer 6-9 a.m. mean concentrations between 1995 and 1999 is statistically significant. The total number of sites “Total” may not equal the sum of the corresponding “Up” and “Down” categories.

2. Results for formaldehyde and acetaldehyde (both carbonyl compounds) were not included in this analysis because of sampling issues with carbonyl compounds in the PAMS network. EPA is continuing to assess the issues for further comparison of the measurements.

3. Results for acetone and isoprene were not included due to lack of consistency in analytic results.

**Figure 2-30.** Trend in 4<sup>th</sup>-highest daily 8-hour O<sub>3</sub> based on 34 CASTNet sites in the rural eastern United States, 1980–1999.

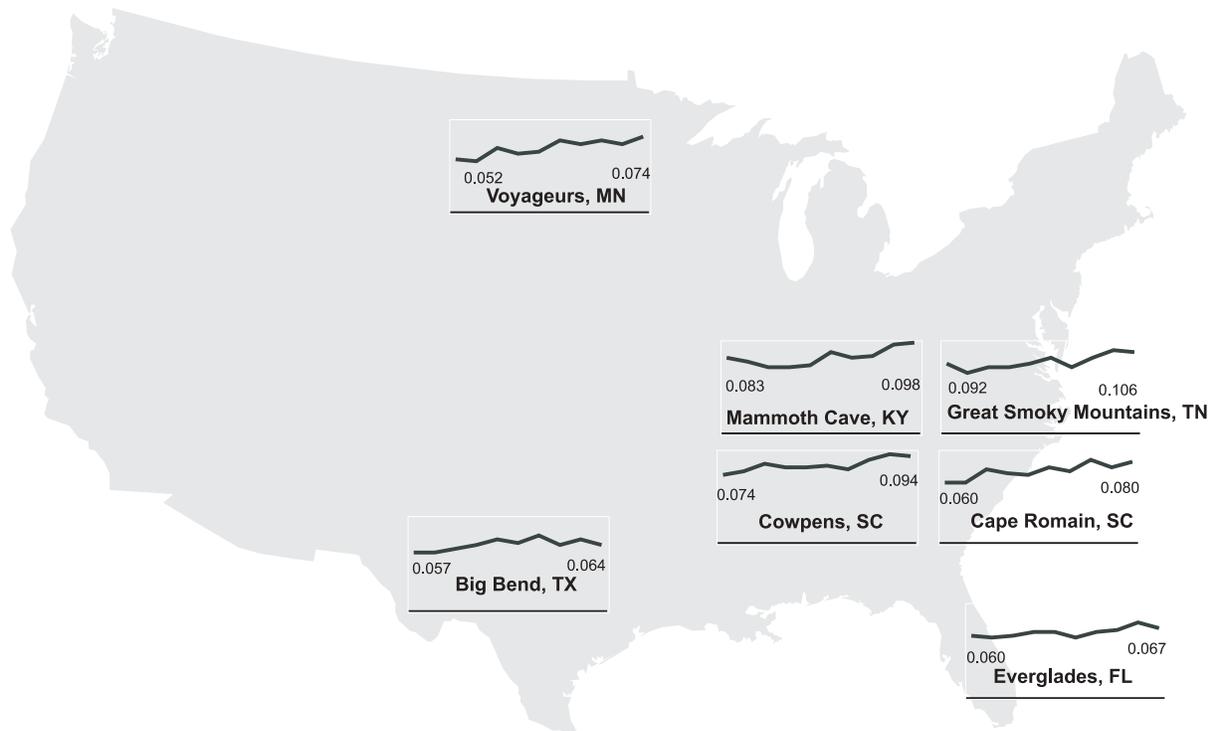


changes in summer 6:00–9:00 a.m. TNMOC and NO<sub>x</sub> concentrations for selected PAMS sites.<sup>18</sup> Morning NO<sub>x</sub> concentrations showed a median decline of 6 percent between 1995 and 1999 across 34 PAMS sites, while summer morning TNMOC concentrations registered a median decline of 24 percent across 17 PAMS sites. Figure 2-29 presents the median changes in summer morning concentrations of the most abundant VOC species measured at PAMS sites.<sup>19</sup> All 24 compounds included in this analysis showed declines in median values between 1995 and 1999.

**Rural Area Air Quality Trends**

Figure 2-30 presents the trend in 8-hour O<sub>3</sub> concentrations for 34 rural sites from the Clean Air Status and Trends Network (CASTNet) for the

**Figure 2-31.** Trend in annual 4th-highest daily maximum 8-hour O<sub>3</sub> concentrations in National Parks, 1980–1999.

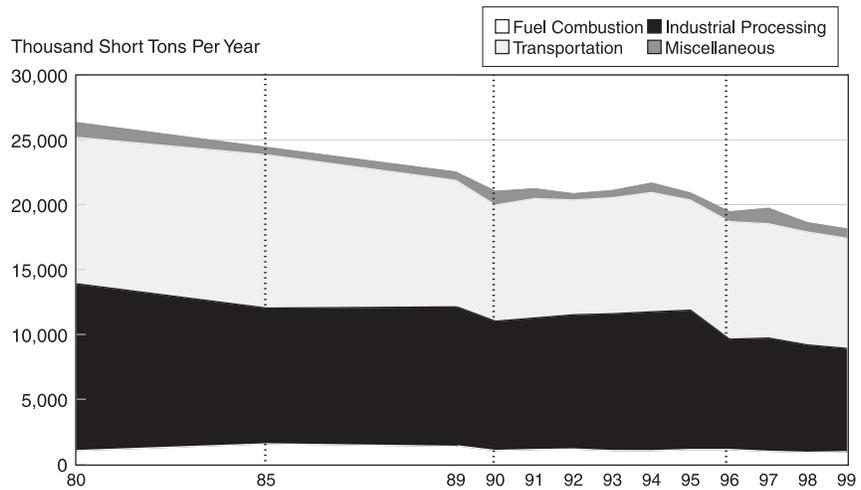


↑ Indicates a statistically significant upward trend. Otherwise the trend was not statistically significant. Concentrations are ppm.

most recent 10-year period, 1990–1999.<sup>20</sup> The 8-hour O<sub>3</sub> concentrations at these eastern sites, which were the highest during the hot and dry summers of 1991 and 1998, have increased 2 percent over the last 10 years and register no significant change from 1997–1998. This trend in 8-hour O<sub>3</sub> levels at 34 selected sites is mirrored at other rural sites nationwide. Across the nation, rural 8-hour O<sub>3</sub> levels improved 9 percent from 1980–1999, but increased by 2 percent over the last 10 years.<sup>21</sup>

Figure 2-31 further examines patterns in rural O<sub>3</sub> levels by presenting the 10-year trends in the 8-hour O<sub>3</sub> concentrations at seven selected National Park Service (NPS) sites.<sup>22</sup> These sites are located in Class I areas, a special subset of rural environments (all national parks and wilderness areas exceeding 5,000 acres) accorded a higher degree of protection under the CAA provisions for the prevention of significant deterioration. There are more than 26 NPS sites nationally; however, this analysis focuses on the specific sites with sufficient data to evaluate 10-year trends. Over the last 10 years, 8-hour O<sub>3</sub> concentrations in 25 of our national parks increased nearly 8 percent. Nine monitoring sites in eight of these parks experienced statistically significant upward trends in 8-hour O<sub>3</sub> levels: Great Smoky Mountain (TN), Big Bend (TX), Cape Romain (SC), Cowpens (SC), Denali (AK), Everglades (FL), Mammoth Cave (KY), and Voyageurs (MN). For the remaining 17 parks, 8-hour O<sub>3</sub> levels at eight increased only slightly between 1990 and 1999, while seven showed decreasing levels and two were unchanged.

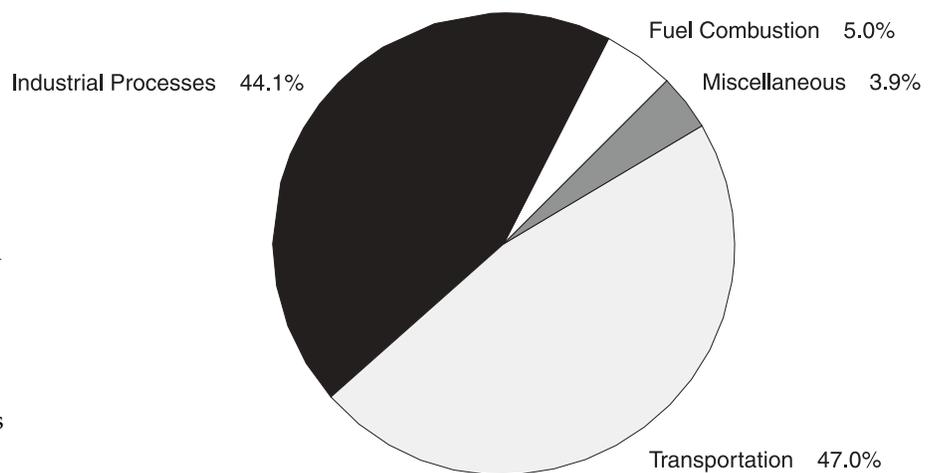
**Figure 2-32.** Trend in national total anthropogenic VOC emissions, 1980–1999.



**Notes:** Emissions data not available for consecutive years 1980–1989.

Emission estimation methods continue to evolve and improve over time. Methods have changed for many significant categories beginning with the years 1985, 1990, and 1996 and consequently are not consistent across all years in this trend period. See Appendix B Emissions Estimates Methodology for additional information.

**Figure 2-33.** Anthropogenic VOC emissions by source category, 1999.



**Table 2-4.** Biogenic Sources of VOC Emissions By Region

Region	VOC	Source
Southwestern United States	Isoprene	Oak (mostly), citrus, eucalyptus
	Monoterpenes	Pine, citrus, eucalyptus
Northeastern United States	Isoprene	Oak (mostly), spruce
	Monoterpenes	Maple, hickory, pine, spruce, fir, cottonwood

**National Emissions Trends**

Figure 2-32 shows that national total VOC emissions (which contribute to O<sub>3</sub> formation) from anthropogenic (man-made) sources decreased 31 percent between 1980 and 1999, and 14 percent over the last 10 years. National total NO<sub>x</sub> emissions (the other major precursor to O<sub>3</sub> formation) increased 4 percent and 5 percent respectively over the same two periods.

Nationally, the two major sources of VOC emissions are industrial processes (44 percent) and transportation sources (47 percent) as shown in Figure 2-33. Solvent use comprises 60 percent of the industrial process emissions category and 26 percent of total VOC emissions. Industrial VOC emissions have decreased 21 percent since 1990, in part due to the implementation of MACT controls that affect specific chemical and solvent industries. The VOC emissions totals by source category and year are presented in Table A-5 in Appendix A. Recent control measures to reduce transportation sector emissions include regulations to lower fuel volatility and to reduce NO<sub>x</sub> and VOC emissions from tailpipes.<sup>23</sup> The effectiveness of these control measures is reflected in a decrease in VOC emis-

sions from highway vehicles. VOC emissions from highway vehicles have declined 18 percent since 1990, while highway vehicle NO<sub>x</sub> emissions have increased 19 percent over the same period.

The nonroad methodology for estimating emissions was changed this year with the use of an improved nonroad model for the years 1996 and later. However, this model was not used for the earlier years resulting in a “discontinuity” of about 40 percent for VOC emissions going from 1995–1996.

As required by the CAA, the Federal Reformulated Gasoline Program (RFG) implemented in 1995 has resulted in emissions reductions that exceed those required by law.<sup>24, 25</sup> However, the discovery of MTBE (one of two fuel oxygenates used in reformulated gasoline to help improve air quality) in the water supplies around the country has required examination of the approach used in this program. As previously described in the CO section of this report, in November 1998, EPA announced the creation of a blue ribbon panel of leading experts from the public health and scientific communities, automotive fuels industry, water utilities, and local and state government to review the important

issues posed by the use of MTBE and other oxygenates in gasoline. The Panel concluded that RFG provides considerable air quality improvements and benefits for millions of U.S. citizens. However, due to MTBE’s persistence and mobility in water, and its likelihood to contaminate ground and surface water, the Panel recommended that its use in gasoline be substantially reduced.<sup>26</sup> Additionally, on March 20, 2000, the Clinton Administration, based on the recommendations of the Blue Ribbon Panel, announced a set of legislative principles to address concerns about the continued use of MTBE. The Administration recommended that Congress:

- Amend the CAA to provide the authority to significantly reduce or eliminate the use of MTBE.
- Ensure that air quality gains associated with the use of MTBE are not diminished.
- Replace the existing oxygen requirement contained in the CAA with a renewable fuel standard for all gasoline.

In addition to anthropogenic sources of VOC and NO<sub>x</sub>, there are natural or biogenic sources of these compounds as well. Table 2-4 shows the different predominant plant species responsible for VOC emissions in different parts of the country for two major biogenic species of concern, isoprene and monoterpenes. Though it is not possible to control the level of these natural emissions, when developing O<sub>3</sub> control strategies, their presence is an important factor to consider. Biogenic NO<sub>x</sub> emissions are associated with lightning and biological processes in soil. On a regional basis, biogenic VOC emissions can be greater than anthropogenic VOC emissions. Biogenic NO<sub>x</sub> emissions,

Figure 2-34. Density map of 1999 anthropogenic VOC emissions, by county.

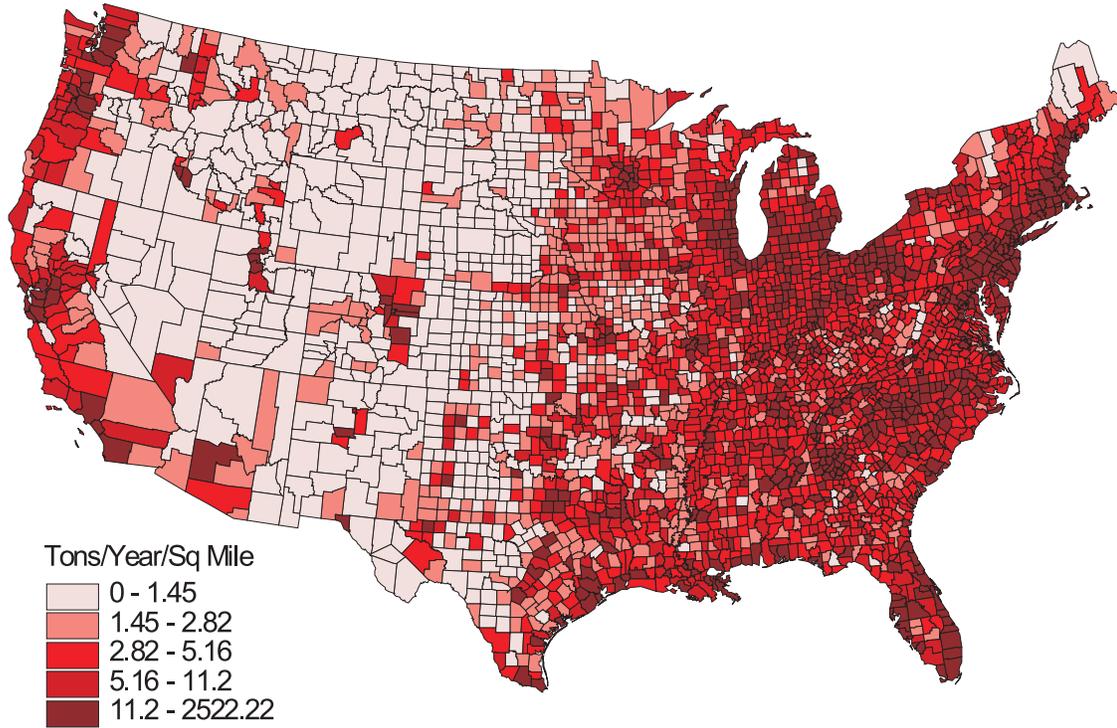
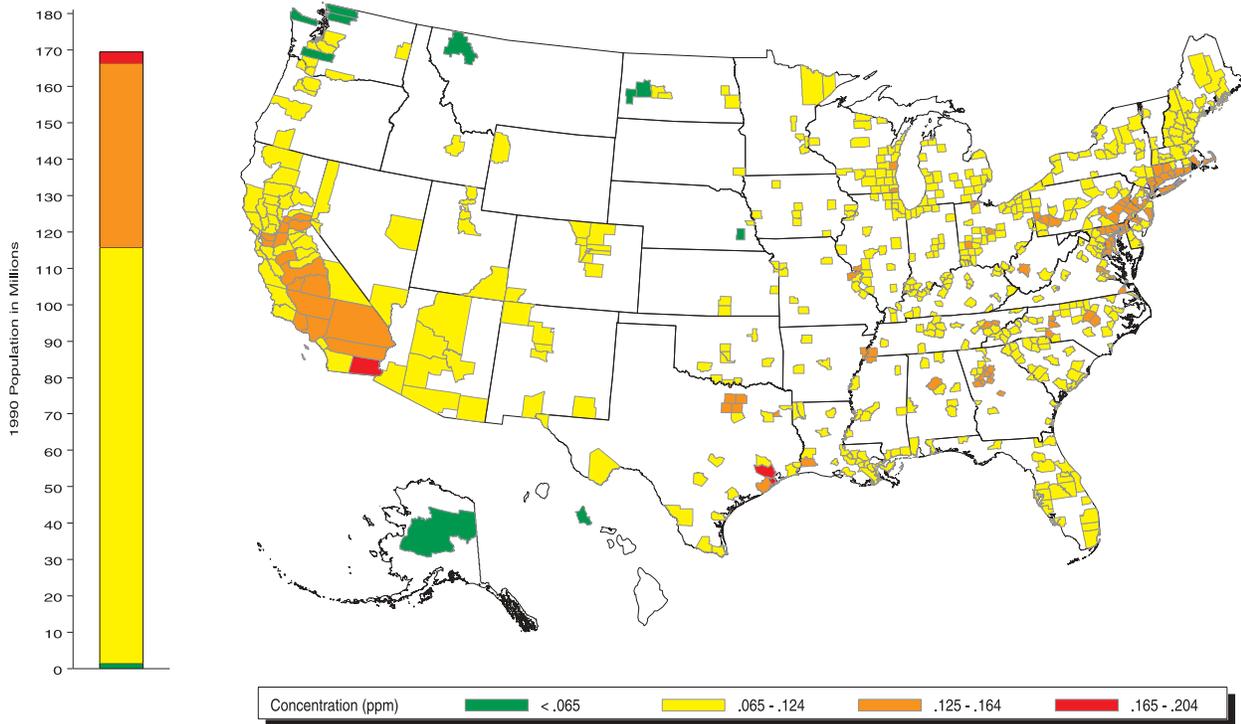
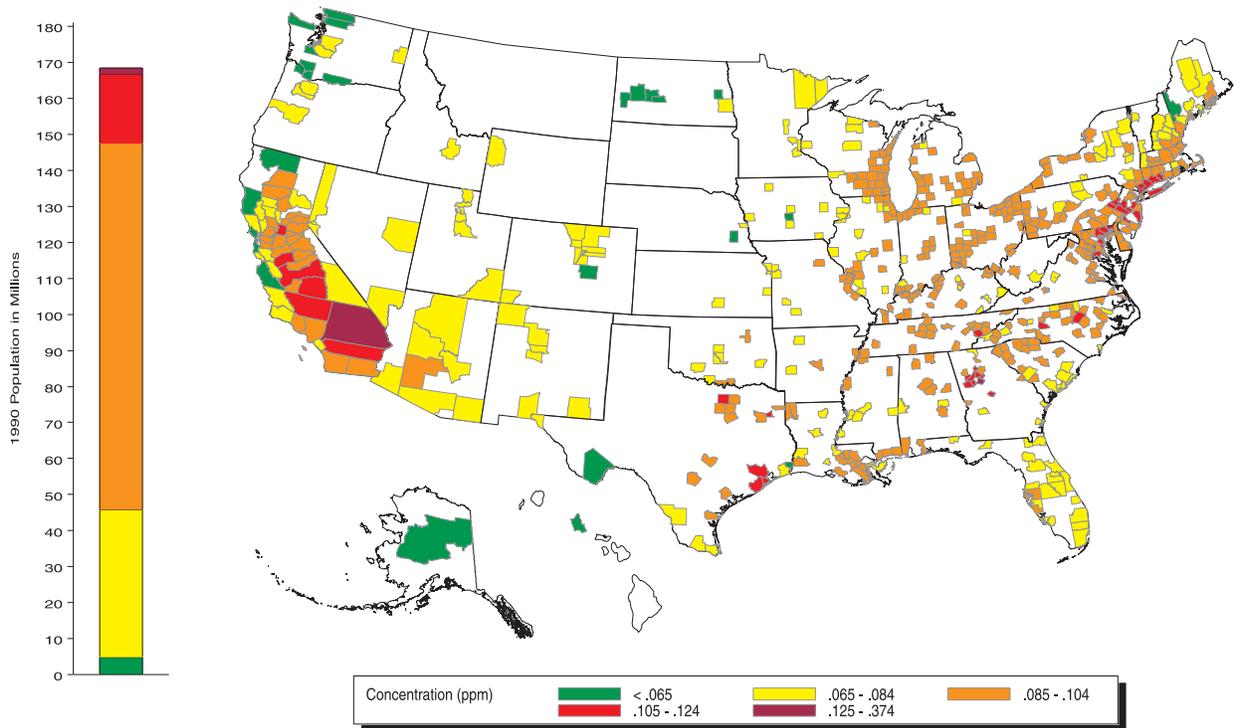


Figure 2-35. Highest second daily maximum 1-hour O<sub>3</sub> concentration by county, 1999.



**Figure 2-36.** Highest fourth daily maximum 8-hour O<sub>3</sub> concentration by county, 1999.



on the other hand, are less than 10 percent of total NO<sub>x</sub> emissions.<sup>27</sup>

Figure 2-34 shows the geographic distribution of 1999 VOC emissions based on the tonnage per square mile for each county. This map illustrates that the eastern half of the country and the west coast emit more VOC (on a density basis) than the western half of the continental United States.

**Air Quality Status**

The map in Figure 2-35 presents second highest daily maximum 1-hour O<sub>3</sub> concentrations by county in 1999. The accompanying bar chart to the left of the map reveals that in 1999 approximately 54 million people lived in 101 counties where O<sub>3</sub> concentrations were above the level of the 1-hour O<sub>3</sub> NAAQS. These numbers represent a slight increase from the totals reported last year (51 mil-

lion people living in 92 counties) with O<sub>3</sub> concentrations above the level of the O<sub>3</sub> NAAQS in 1998. The map in Figure 2-35 shows large spatial differences, with higher O<sub>3</sub> concentrations typically found in Southern California, the Gulf Coast, and the Northeast and North Central states. Historically, the highest 1-hour concentrations have been found in Los Angeles; however, in 1999, Harris County, TX has the highest second daily maximum value.

Figure 2-36 presents a map of fourth highest daily maximum 8-hour O<sub>3</sub> values by county in 1999 and an accompanying bar chart of the number of people in counties corresponding to various air quality ranges. The map reveals widespread areas with high 8-hour O<sub>3</sub> concentrations (i.e., greater than 0.084 ppm) in much of the eastern half of the coun-

try and in California as well as isolated counties in the West. The corresponding bar chart indicates that roughly 123 million people live in counties where fourth highest daily maximum 8-hour O<sub>3</sub> concentrations were greater than 0.084 ppm.