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Latest Findings on National Air Quality

2002 STATUS AND TRENDS

Cover Photo of Denali National Park, Alaska, by Kim Ferguson, Waynesville, North Carolina

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2002 STATUS AND TRENDS

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More detailed information on air pollution trends is available at **www.epa.gov/airtrends**.

National Air Quality

A summary report highlighting our nation's air quality status and trends.

Highlights

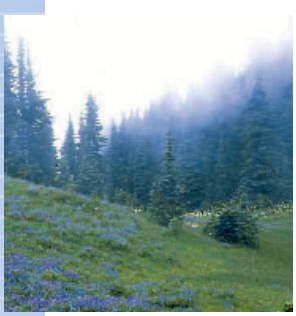
- National air quality levels measured at thousands of monitoring stations across the country have shown improvements over the past 20 years for all six principal pollutants.
- Since 1970, aggregate emissions of the six principal pollutants have been cut 48 percent. During that same time, U.S. gross domestic product increased 164 percent, energy consumption increased 42 percent, and vehicle miles traveled increased 155 percent.
- Despite this progress, about 160 million tons of pollution are emitted into the air each year in the United States. Approximately 146 million people live in counties where monitored air in 2002 was unhealthy at times because of high levels of at least one of the six principal air pollutants.
- The vast majority of areas that experienced unhealthy air did so because of one or both of two pollutants—ozone and particulate matter (PM). Important efforts to control these pollutants include implementing more protective National Ambient Air Quality Standards (NAAQS) for ozone and PM and issuing rules to reduce emissions from onroad transportation and stationary combustion sources. These rules will bring reductions in emissions over the next several years.
- Additional reductions will be needed to provide clean air in the future. For example, the Clear Skies legislation currently being considered in Congress, would, if enacted, mandate reductions of particle- and ozone-forming compounds from power generators by 70 percent from current levels through a nationwide cap and trade program. This will also reduce acid rain and improve visibility. Also, in May 2003, EPA proposed nonroad diesel engine regulations that would help improve PM and ozone air quality. By 2030, this program would reduce annual emissions of PM by 95 percent, NO_x by 90 percent, and sulfur levels by 99 percent from these engines.
- Of the six tracked pollutants, progress has been slowest for ground-level ozone. Over the past 20 years, almost all geographic areas experienced some progress in lowering ozone concentrations. The Northeast and Pacific Southwest exhibited the greatest improvement. In particular, substantial progress seen in Los Angeles has continued through 2002. However, the national average ozone (8-hour) levels have been fairly constant in other metropolitan areas. An analysis to adjust 8-hour ozone levels in metropolitan areas to account for the influence of meteorological conditions shows the 10-year trend to be relatively unchanged. At the same time, for many national parks, the 8-hour ozone levels have increased somewhat.
- Ground-level ozone is not emitted directly into the air, but is formed in the atmosphere by the reaction of volatile organic compounds (VOCs) and nitrogen oxides (NO_x) in the presence of heat and sunlight. Emissions of VOCs have decreased about 40 percent over the past 20 years. However, regional-scale NO_x reductions over the same period are only 15 percent. More NO_x reductions will be necessary before more substantial ozone air quality improvements are realized. Some of these additional reductions will result from existing and recently enacted NO_x emission reduction programs and also, potentially, from the Clear Skies legislation, if enacted.
- The improvement in overall emissions since 1970 included in this year's findings reflect more accurate estimates of VOC, NO_x, PM, and carbon monoxide (CO) releases from highway vehicles and nonroad engines. Previous years' findings underreported emissions for cars and trucks in the 1970s and 1980s. This year's findings incorporate improvements in EPA's mobile source emission models, which are based on actual emissions measurements from thousands of motor vehicles and have been peer-reviewed. The new mobile model better represents average U.S.

EPA tracks air pollution in two ways:

- Air quality measured from over 3,000 locations (over 5,200 monitors) across the nation operated primarily by state, local, and tribal agencies
- Emissions going back more than 30 years.

Six Principal Air Pollutants Tracked Nationally

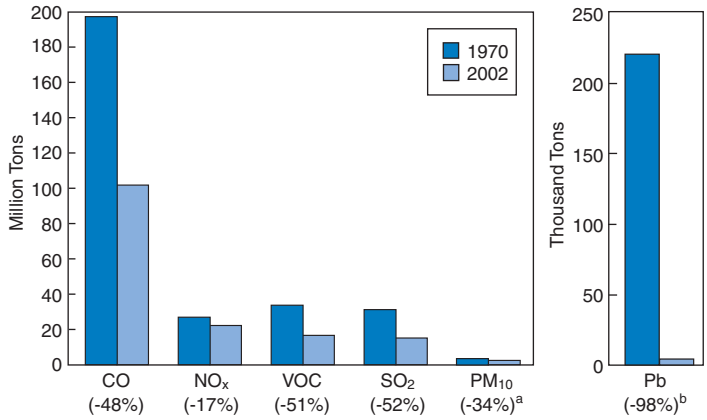
- Nitrogen Dioxide (NO_2)
- Ozone (O_3) – formed by volatile organic compounds (VOCs) and nitrogen oxides (NO_x)
- Sulfur Dioxide (SO_2)
- Particulate Matter (PM) – formed by SO_2, NO_x, ammonia, VOCs, and direct particle emissions
- Carbon Monoxide (CO)
- Lead (Pb)



driving habits, such as more rapid accelerations and faster highway speeds.

- Sulfates formed primarily from SO_2 emissions from coal-fired power plants are a major component of fine particles (known as $PM_{2.5}$) in the eastern United States. SO_2 emissions decreased approximately 33 percent from 1983 to 2002. Nationally, average SO_2 ambient concentrations have been cut approximately 54 percent over the same period. Reductions in SO_2 concentrations and emissions since 1990 are primarily due to controls implemented under EPA's Acid Rain Program. Sulfate reductions since 1999 are partly responsible for some improvement in ambient fine particle concentrations, particularly in the southeastern United States.
- In many locations, EPA now has 4 years of air quality monitoring data for fine particles (known as $PM_{2.5}$). Areas across the Southeast, Mid-Atlantic, Midwest regions, and California have air quality that is unhealthy due to particle pollution. Region-wide emissions from power plants and motor vehicles are among the largest contributors to the high $PM_{2.5}$ concentrations.
- Since 1990, many actions have been taken that will significantly reduce air toxics across the country. Specifically, regulations for facilities such as chemical plants, dry cleaners, coke ovens, and incinerators will reduce emissions of toxic air pollution by 1.5 million tons from 1990 levels. In addition, recent actions to address emissions of toxic air pollutants from motor vehicles as well as stringent standards for heavy-duty trucks, buses, and diesel fuel will eliminate 95 percent of emissions of diesel particulate matter.
- Measurements have shown that atmospheric concentrations of methyl chloroform are falling, indicating that emissions have been greatly reduced. Concentrations of other ozone-depleting substances in the upper layers of the atmosphere, like chlorofluorocarbons (CFCs), are also beginning to decrease.

Comparison of 1970 and 2002 Emissions



[a] Based on 1985 emission estimates. Emission estimates prior to 1985 are uncertain.
[b] Values for lead are based on 2001 data; 2002 data for lead are not yet available.

Air Pollution

The Concern

Exposure to air pollution is associated with numerous effects on human health, including respiratory problems, hospitalization for heart or lung diseases, and even premature death. Children are at greater risk because they are generally more active outdoors and their lungs are still developing. The elderly and people with heart or lung diseases are also more sensitive to some types of air pollution.

Air pollution can also significantly affect ecosystems. For example, ground-level ozone has been associated with reductions of agricultural and commercial forest yields, and airborne releases of NO_x are one of the largest sources of nitrogen pollution in certain waterbodies, such as the Chesapeake Bay.

The Causes

Air pollution comes from many different sources. These include large stationary sources such as factories, power plants, and smelters; smaller sources such as dry cleaners and degreasing operations; mobile sources such as cars, buses, planes, trucks, and trains; and natural sources such as windblown dust and wildfires.

Six Principal Pollutants

Under the Clean Air Act, EPA establishes air quality standards to protect public health, including the health of "sensitive" populations such as people with asthma, children, and older adults. EPA also sets limits to protect public welfare. This includes protecting ecosystems, including plants and animals, from harm, as well as protecting against decreased visibility and damage to crops, vegetation, and buildings.

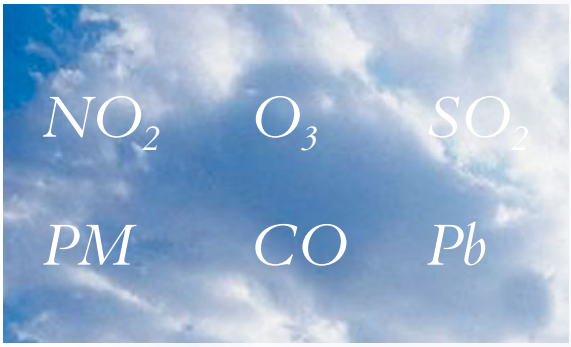
	Percent Change in Air Quality 1983-2002	1993-2002
NO_2	-21	-11
O_3 1-h	-22	-2[a]
8-h	-14	+4[a]
SO_2	-54	-39
PM_{10}	—	-13
$PM_{2.5}$	—	-8[b]
CO	-65	-42
Pb	-94	-57

	Percent Change in Emissions 1983-2002	1993-2002
NO_x	-15	-12
VOC	-40	-25
SO_2	-33	-31
PM_{10}[c]	-34[d]	-22
$PM_{2.5}$[c]	—	-17
CO	-41	-21
Pb[e]	-93	-5

—Trend data not available.
[a] Not statistically significant.
[b] Based on percentage change from 1999.
[c] Includes only directly emitted particles.
[d] Based on percentage change from 1985. Emission estimates prior to 1985 are uncertain.
[e] Lead emissions are included in the toxic air pollutant emissions inventory and are presented for 1982-2001.

Negative numbers indicate improvements in air quality or reductions in emissions. Positive numbers show where emissions have increased or air quality has gotten worse.

Changes in air quality concentrations do not always match changes in nationwide emissions. There are several reasons for this. First, most monitors are located in urban areas so air quality is most likely to track changes in urban air emissions rather than in total emissions. Second, not all of the principal pollutants are emitted directly to the air. Ozone and many particles are formed after directly emitted gases react chemically to form them. Third, the amount of some pollutants measured at monitoring locations depends on the chemical reactions that occur in the atmosphere during the time it takes the pollutant to travel from its source to the monitoring station. Fourth, emissions from some sources are estimated rather than measured. Finally, weather conditions often contribute to the formation and buildup of pollutants in the ambient air. For example, peak ozone concentrations typically occur during hot, dry, stagnant summertime conditions.



EPA has set national air quality standards for six principal air pollutants (also called the criteria pollutants): nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), particulate matter (PM), carbon monoxide (CO), and lead (Pb). Four of these pollutants (CO, Pb, NO_2, and SO_2) are emitted directly from a variety of sources. Ozone is not directly emitted, but is formed when NO_x and volatile organic compounds (VOCs) react in the presence of sunlight. PM can be directly emitted, or it can be formed when emissions of nitrogen oxides (NO_x), sulfur oxides (SO_x), ammonia, organic compounds, and other gases react in the atmosphere.

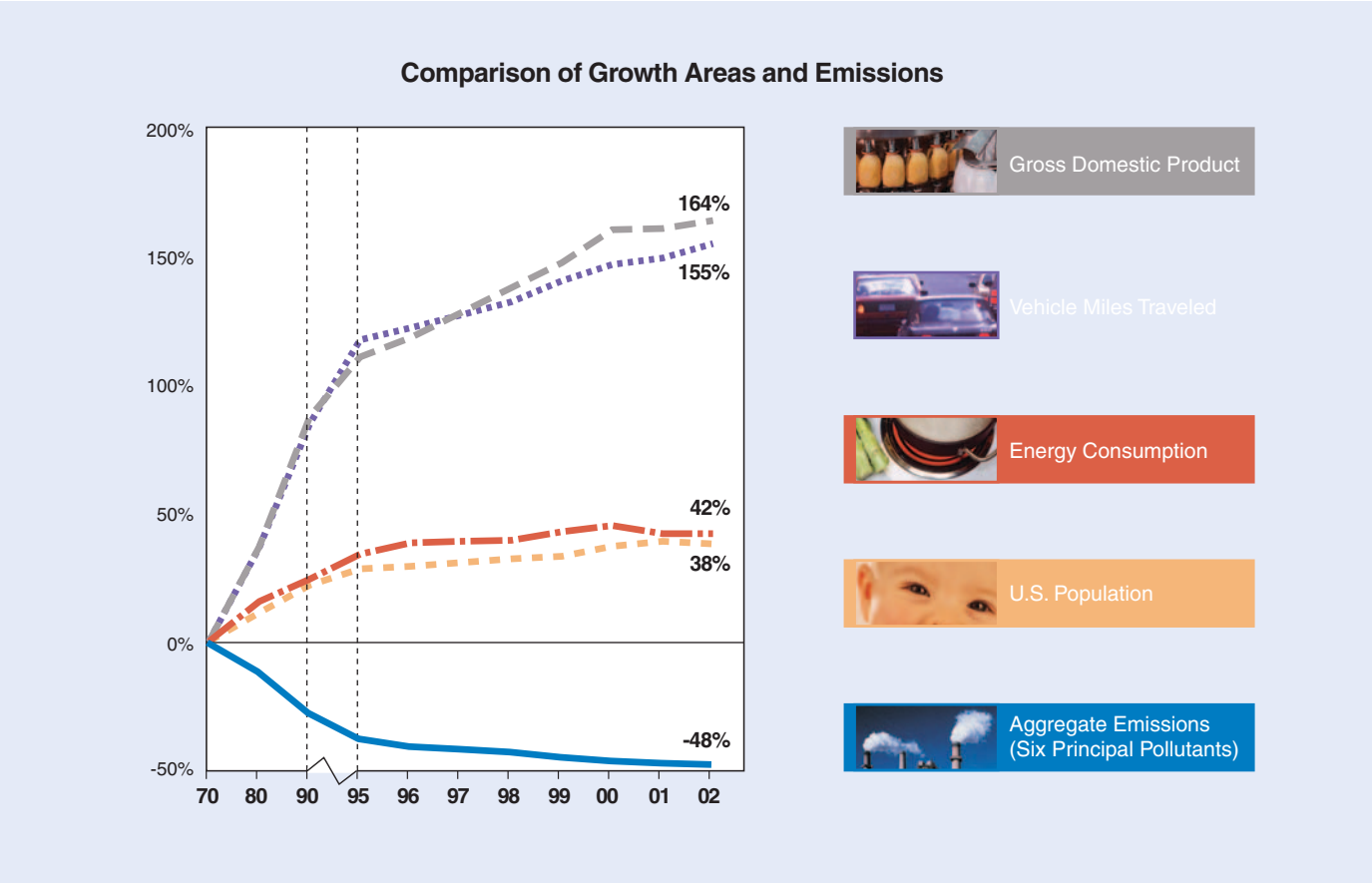
Each year EPA looks at the levels of these pollutants in the air and the amounts of emissions from various sources to see how both have changed over time and to summarize the current status of air quality.

Reporting Air Quality and Emissions Trends

Each year, air quality trends are created using measurements from monitors located across the country. The table to the left shows that the air quality based on concentrations of the principal pollutants has improved nationally over the past 20 years (1983–2002).

EPA estimates nationwide emissions of ambient air pollutants and the pollutants they are formed from (their precursors). These estimates are based on actual monitored readings or engineering calculations of the amounts and types of pollutants emitted by vehicles, factories, and other sources. Emission estimates are based on many factors, including levels of industrial activity, technological developments, fuel consumption, vehicle miles traveled, and other activities that cause air pollution.

Methods for estimating emissions continue to improve. Today's estimates are different from last year's estimates. One reason is because this year



Between 1970 and 2002, gross domestic product increased 164 percent, vehicle miles traveled increased 155 percent, energy consumption increased 42 percent, and U.S. population increased 38 percent. At the same time, total emissions of the six principal air pollutants decreased 48 percent.

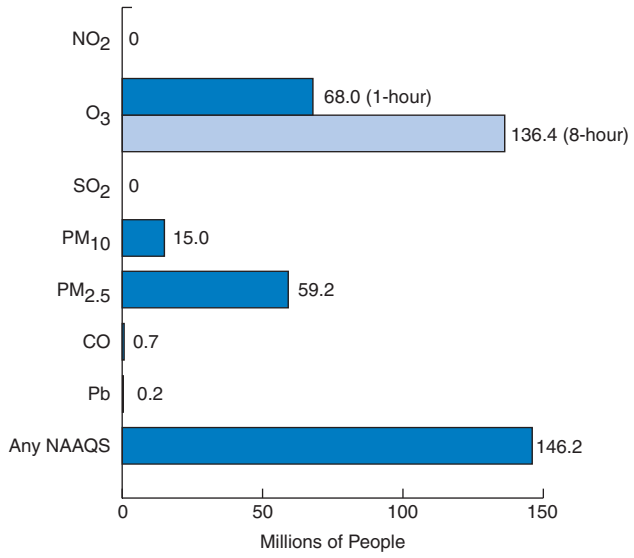
EPA used updated, peer-reviewed models that estimate VOC, NO_x, CO, and PM emissions from highway vehicles and nonroad engines and and better represent real-world conditions, such as more rapid accelerations and faster highway speeds. The emissions estimates generated by the new highway vehicle model are derived from actual tailpipe measurements from thousands of vehicles. Another change in the reporting of emissions trends is that emissions from wildfires and prescribed burning are not considered in the estimates of emission change. This is due to the large variability in the year-to-year levels of these emissions and the relatively small impact these distant emissions have on most monitoring locations. Because of the high degree of uncertainty in predicting emissions for these fires, their emissions have not been projected for 2002 for PM, CO, and VOCs. These emissions will be estimated when 2002 acres-burned data become available. However, fire

emissions are included in the emission graphics through 2001. As a result of these reporting changes, some emissions trends have changed significantly. For example, rather than describing no change in the 20-year emission trend for CO, EPA now estimates a 41 percent decrease in CO emissions from 1983 to 2002. This estimated change in emissions is supported by the trend in CO air quality.

Emissions of air pollutants continue to play an important role in a number of air quality issues. About 160 million tons of pollution are emitted into the atmosphere each year in the United States. These emissions mostly contribute to the formation of ozone and particles, the deposition of acids, and visibility impairment.

Despite great progress in air quality improvement, approximately 146 million people nationwide lived in counties with pollution levels above the NAAQS in 2002. Out of the 230 nonattainment areas identified during the 1990 Clean Air Act Amendments designation process, 124 areas remain. In these nonattainment areas, however, the severity of air pollution episodes has decreased.

Number of People Living in Counties with Air Quality Concentrations above the Level of the NAAQS in 2002



Multiple years of data are generally used to determine if an area attains the NAAQS.

The Clean Air Act

The Clean Air Act provides the principal framework for national, state, tribal, and local efforts to protect air quality. Improvements in air quality are the result of effective implementation of clean air laws and regulations, as well as efficient industrial technologies. Under the Clean Air Act, EPA has a number of responsibilities, including

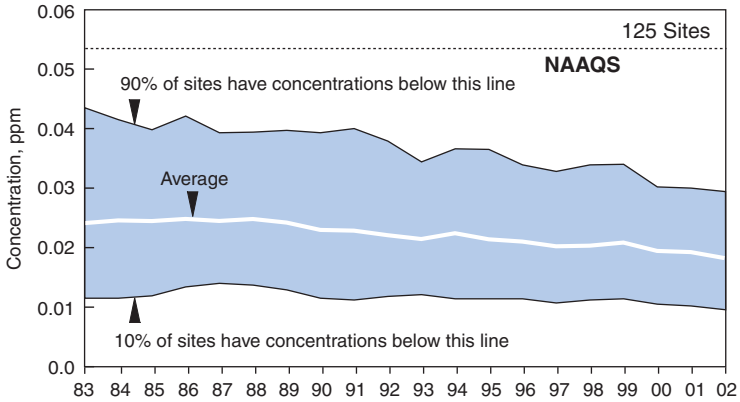
- Conducting periodic reviews of the NAAQS for the six principal pollutants that are considered harmful to public health and the environment.
- Ensuring that these air quality standards are met (in cooperation with the state, tribal, and local governments) through national standards and strategies to control air pollutant emissions from vehicles, factories, and other sources.
- Reducing emissions of SO_2 and NO_x that cause acid rain.
- Reducing air pollutants such as PM, SO_x, and NO_x, which can reduce visibility across large regional areas, including many of the nation's most treasured parks and wilderness areas.
- Ensuring that sources of toxic air pollutants that may cause cancer and other adverse human health and environmental effects are well controlled and that the risks to public health and the environment are substantially reduced.
- Limiting the use of chemicals that damage the stratospheric ozone layer in order to prevent increased levels of harmful ultraviolet radiation.

NITROGEN DIOXIDE (NO_2)

Nature and Sources of Nitrogen Oxides

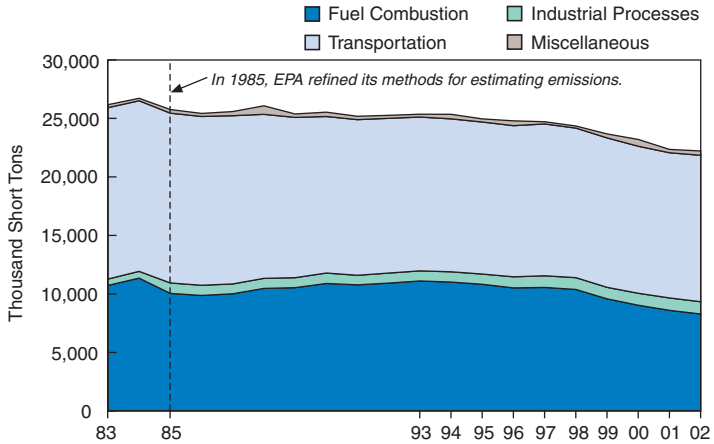
Nitrogen dioxide is a reddish brown, highly reactive gas that is formed in the ambient air through the oxidation of nitric oxide (NO). Nitrogen oxides (NO_x), the generic term for a group of highly reactive gases that contain nitrogen and oxygen in varying amounts, play a major role in the formation of ozone, PM, haze, and acid rain. While EPA tracks national emissions of NO_x, the national monitoring network measures ambient concentrations of NO_2 for comparison to national air quality standards. The major sources of man-made NO_x emissions are high-temperature combustion processes such as those that occur in automobiles and power plants. Home heaters and gas stoves can also produce substantial amounts of NO_2 in indoor settings.

NO_2 Air Quality, 1983–2002
Based on Annual Arithmetic Average



1983–02: 21% decrease
1993–02: 11% decrease

NO_x Emissions, 1983–2002



1983–02: 15% decrease
1993–02: 12% decrease

Health and Environmental Effects

Short-term exposures (e.g., less than 3 hours) to low levels of NO_2 may lead to changes in airway responsiveness and lung function in individuals with preexisting respiratory illnesses. These exposures may also increase respiratory illnesses in children. Long-term exposures to NO_2 may lead to increased susceptibility to respiratory infection and may cause irreversible alterations in lung structure. NO_x react in the air to form ground-level ozone and fine particle pollution, which are associated with adverse health effects.

NO_x contribute to a wide range of environmental effects directly and when combined with other precursors in acid rain and ozone. Increased nitrogen inputs to terrestrial and wetland systems can lead to changes in plant species composition and diversity. Similarly, direct nitrogen inputs to aquatic ecosystems such as those found in estuarine and coastal waters (e.g., Chesapeake Bay) can lead to eutrophication (a condition that promotes excessive algae growth, which can lead to a severe depletion of dissolved oxygen and increased levels of toxins harmful to aquatic life). Nitrogen, alone or in acid rain, also can acidify soils and surface waters. Acidification of soils causes the loss of essential plant nutrients and increased levels of soluble aluminum that are toxic to plants. Acidification of surface waters creates conditions of low pH and levels of aluminum that are toxic to fish and other aquatic organisms. NO_x also contribute to visibility impairment.

Trends in NO_2 Levels and NO_x Emissions

Since 1983, monitored levels of NO_2 have decreased 21 percent. These downward trends in national NO_2 levels are reflected in all regions of the country. Nationally, average NO_2 concentrations are well below the NAAQS and are currently at the lowest levels recorded in the past 20 years. All areas of the country that once violated the NAAQS for NO_2 now meet that standard. Over the past 20 years, national emissions of NO_x have declined by almost 15 percent. The reduction in emissions for NO_x presented here differs from the increase in NO_x emissions reported in previous editions of this report. In particular, this report's higher estimate of NO_x emissions in the 1980s and early 1990s reflects an improved understanding of emissions from real-world driving. While overall NO_x emissions are declining, emissions from some sources such as nonroad engines have actually increased since 1983. These increases are of concern given the significant role NO_x emissions play in the formation of ground-level ozone (smog) as well as other environmental problems like acid rain and nitrogen loadings to waterbodies described above. In response, EPA has proposed regulations that will significantly control NO_x emissions from nonroad diesel engines.

GROUND-LEVEL OZONE (O_3)

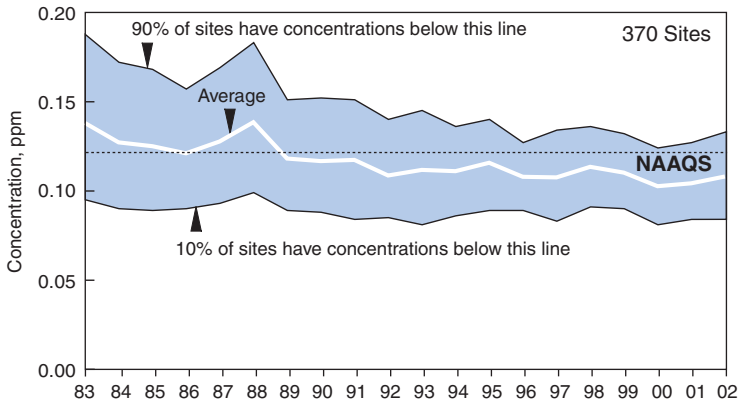
Nature and Sources of Ozone

Ground-level ozone (the primary constituent of smog) continues to be a pollution problem throughout many areas of the United States.

Ozone is not emitted directly into the air but is formed by the reaction of VOCs and NO_x in the presence of heat and sunlight. Ground-level ozone forms readily in the atmosphere, usually during hot summer weather. VOCs are emitted from a variety of sources, including motor vehicles, chemical plants, refineries, factories, consumer and commercial products, and other industrial sources. NO_x is emitted from motor vehicles, power plants, and other sources of combustion. Changing weather patterns contribute to yearly differences in ozone concentrations from region to region. Ozone and the pollutants that form ozone also can be transported into an area from pollution sources found hundreds of miles upwind.

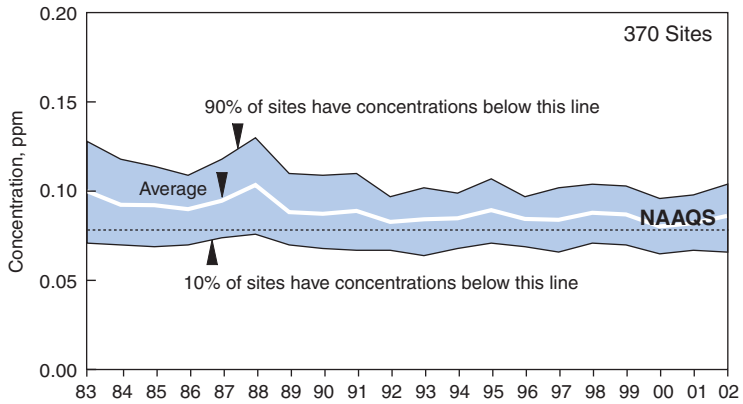
Ozone occurs naturally in the stratosphere and provides a protective layer high above the Earth. See page 26 for more information on the stratospheric ozone layer.

Ozone Air Quality, 1983–2002
Based on Annual 2nd Maximum 1-Hour Average



1983–02: 22% decrease
1993–02: 2% decrease

Ozone Air Quality, 1983–2002
Based on Annual 4th Maximum 8-Hour Average



1983–02: 14% decrease
1993–02: 4% increase

Health and Environmental Effects

Short-term (1- to 3-hour) and prolonged (6- to 8-hour) exposures to ambient ozone have been linked to a number of health effects of concern. For example, health effects attributed to ozone exposure include significant decreases in lung function and increased respiratory symptoms such as chest pain and cough. Exposures to ozone can make people more susceptible to respiratory infection, result in lung inflammation, and aggravate preexisting respiratory diseases such as asthma. Also, increased hospital admissions and emergency room visits for respiratory problems have been associated with ambient ozone exposures. These effects generally occur while individuals are actively exercising, working, or playing outdoors. Children, active outdoors during the summer when ozone levels are at their highest, are most at risk of experiencing such effects. Other at-risk groups include adults who are active outdoors (e.g., some outdoor workers) and individuals with preexisting respiratory disease such as asthma and chronic obstructive pulmonary disease. In addition, longer-term exposures to moderate levels of ozone present the possibility of irreversible changes in the lung structure, which could lead to premature aging of the lungs and worsening of chronic respiratory illnesses.

Ozone also affects vegetation and ecosystems, leading to reductions in agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased plant susceptibility to disease, pests, and other environmental stresses (e.g., harsh weather). In long-lived species, these effects may become evident only after several years or even decades, thus having the potential for long-term effects on forest ecosystems. Ground-level ozone damage to the foliage of trees and other plants can also decrease the aesthetic value of ornamental species as well as the natural beauty of our national parks and recreation areas.

Trends in Ozone Levels, Related Emissions

In 1997, EPA revised the NAAQS for ozone by setting an 8-hour standard at 0.08 ppm. Currently, EPA is tracking trends based on 1-hour and 8-hour data. Over the past 20 years, national ambient ozone levels decreased 22 percent based on 1-hour data and 14 percent based on 8-hour data. Between 1983 and 2002, emissions of VOCs (excluding wildfires and prescribed burning) decreased 40 percent. During that same time, emissions of NO_x decreased 15 percent. Additional NO_x reductions will be necessary before more substantial ozone air quality improvements are realized. For example, future emission reductions from existing and recently enacted NO_x control programs such as the NO_x SIP Call, Tier 2, Heavy Duty Diesel, Non-road Proposal, and, potentially, Clear Skies legislation will result in millions of fewer tons of NO_x emissions.

For the period 1983 to 2002, a downward national trend in 1-hour and 8-hour ozone levels occurred in most geographic areas in the country. The Northeast and Pacific Southwest exhibited the most substantial improvement for 1-hour and 8-hour ozone levels. The Mid-Atlantic and North Central regions experienced minimal decreases in 8-hour ozone levels. In contrast, the Pacific Northwest region showed a slight increase in the 8-hour ozone over the period 1983 to 2002.

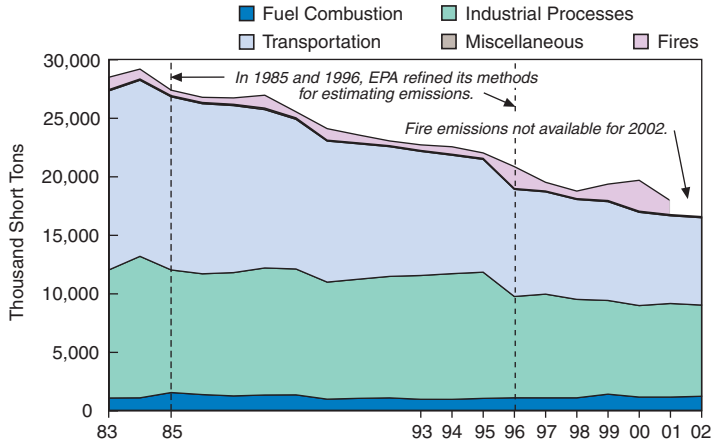
For the 10-year period 1993-2002, the national trend in 8-hour ozone shows a 4 percent increase and the national trend in 1-hour ozone shows a

2 percent decrease. However, standard statistical tests show that these trends are not statistically significant. Ozone concentrations varied over this 10-year period from year to year but did not change overall.

Regional trends can provide additional information to understand progress on ozone levels. For example, the trend in 8-hour ozone for the Pacific Southwest shows the 20-year trend (1983-2002) as a 29 percent decrease. When considering the Los Angeles area separately, the trend for Los Angeles shows a 49 percent decrease for the 20-year period and a 15 percent decrease for the other locations in the Pacific Southwest. For the 10-year period 1993-2002, the Pacific Southwest has an overall 13 percent decrease in 8-hour ozone. However, when considering Los Angeles separately, the Los Angeles area has a 28 percent decrease for the 10-year period while the Pacific Southwest without Los Angeles has a 5 percent decrease. This illustrates that national assessments for ozone do not describe trends completely, particularly where control measures such as those implemented in Los Angeles have had a significant effect in reducing ozone concentrations.

It is important to note that year-to-year changes in ambient ozone trends are influenced by meteorological conditions, population growth, and changes in emission levels of ozone precursors (i.e., VOCs and NO_x) resulting from ongoing control measures. For example, to further evaluate the 10-year

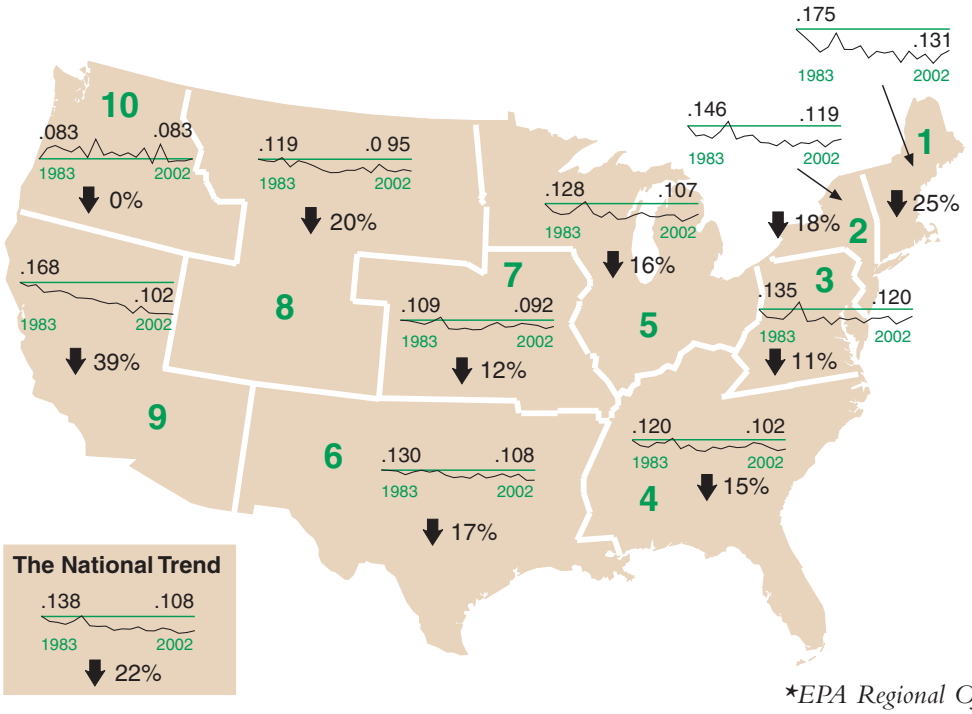
VOC Emissions, 1983–2002



1983–02: 40% decrease
1993–02: 25% decrease

Trend in 1-Hour Ozone Levels, 1983–2002, Averaged across EPA Regional Office Boundaries*

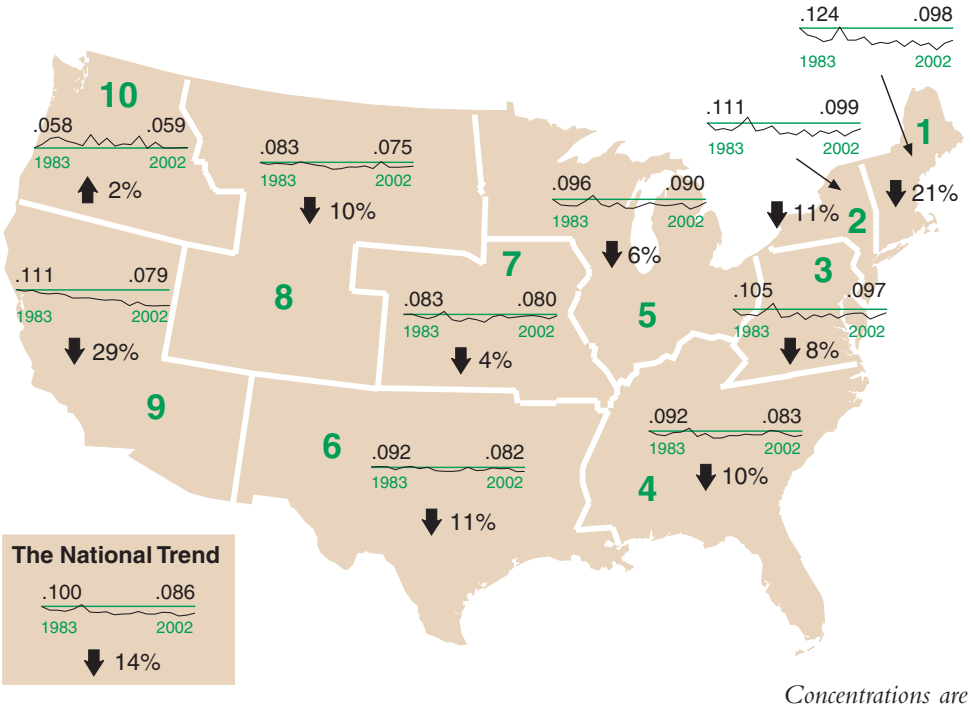
Based on Annual 2nd Highest Daily Maximum



EPA Regional Office contacts can be found at www.epa.gov/epahome/locate2.htm.

Trend in 8-Hour Ozone Levels, 1983–2002, Averaged across EPA Regional Office Boundaries

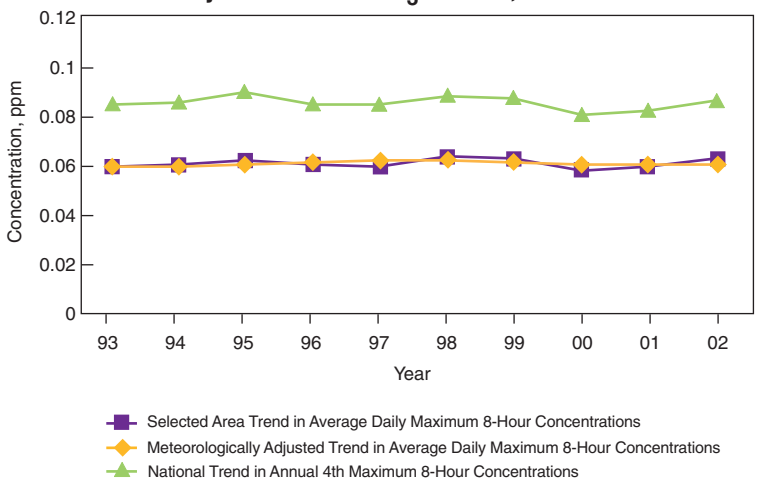
Based on Annual 4th Maximum 8-Hour Average



Concentrations are in parts per million (ppm).

8-hour ozone trends, EPA applied a model to the annual rate of change in ozone based on measurements in 53 metropolitan areas. This model adjusted the ozone data in these areas to account for the influence of local meteorological conditions, including surface temperature and windspeed. The figure below shows the aggregated trend in 8-hour ozone for these 53 areas adjusted for meteorological conditions for the 10-year period 1993-2002. The figure also shows the aggregated trend for these areas unadjusted for meteorology and the national average in 8-hour ozone. From this figure, the meteorologically adjusted trend for this 10-year period can be seen as relatively flat.

Comparison of Actual and Meteorological Adjusted 8-Hour O_3 Trends, 1993–2002



In 2002, meteorological conditions were favorable for relatively high ozone concentrations primarily in the eastern half of the nation as evidenced by the higher observed 8-hour ozone compared to meteorologically adjusted levels. On average, the June through August period in 2002 was the third warmest year on record. A preliminary review of these meteorological conditions indicates that they were similar to conditions experienced in 1988 in the eastern United States—another high-ozone year and the fourth warmest summer period on record. By way of comparison, the average daily maximum 4th-highest 8-hour ozone concentrations throughout the Eastern United States showed decreases of approximately 15 to 20 percent between 1988 and 2002. This indicates regional improvements in 8-hour ozone concentrations.

Furthermore, preliminary examination of meteorologically adjusted 8-hour ozone on a subregional basis in the Eastern United States reveals a pattern of increasing ozone through 1998 followed by a period of generally improving ozone air quality. This reversal appears to correspond to the implementation of regional NO_x reductions from power plants (see Acid Rain section).

Twenty-eight of our national parks had ozone trend data for the 10-year period 1993-2002. Seven monitoring sites in five of these parks experienced statistically significant upward trends in 8-hour ozone levels: Great Smoky Mountains (Tennessee), Craters of the Moon (Idaho), Mesa Verde (Colorado), Denali (Alaska), and Acadia (Maine). Monitoring data for one park showed statistically significant improvements over the same time period: Saguaro (Arizona). For the remaining 22 parks with ozone trends data, the 8-hour ozone levels at 13 increased only slightly between 1993 and 2002, while 5 showed decreasing levels and 4 were unchanged.

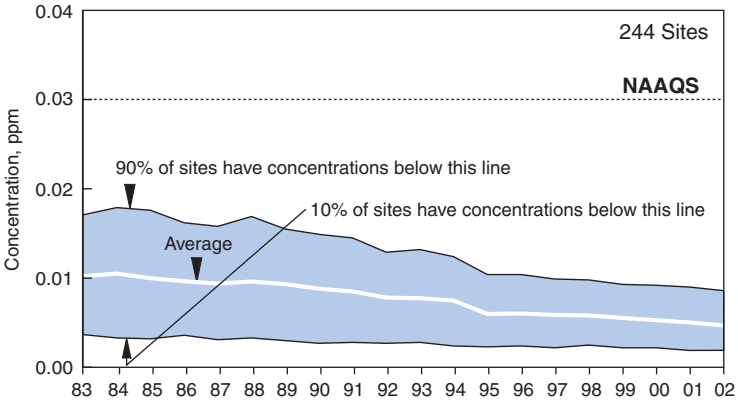
Although the recent national trends in 1-hour and 8-hour ozone are relatively unchanged, important regional decreases have occurred. EPA is continuing to investigate these regional assessments to further evaluate the trends in 1-hour and 8-hour ozone.

SULFUR DIOXIDE (SO_2)

Nature and Sources of Sulfur Dioxide

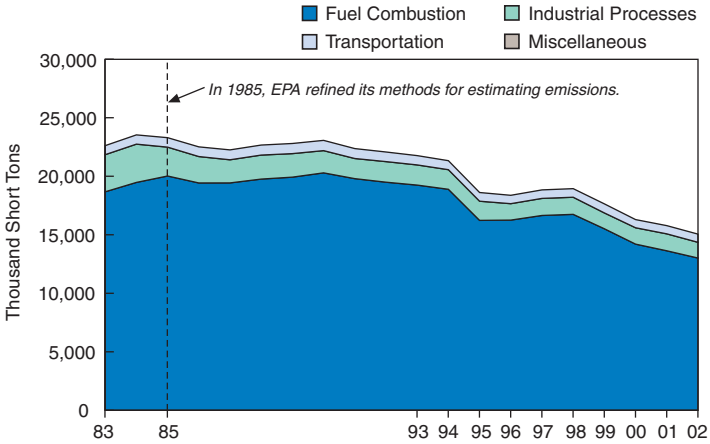
Sulfur dioxide belongs to the family of SO_x gases. These gases are formed when fuel containing sulfur (mainly coal and oil) is burned at power plants and during metal smelting and other industrial processes. Most SO_2 monitoring stations are located in urban areas. The highest monitored concentrations of SO_2 are recorded near large industrial facilities. Fuel combustion, largely from electricity generation, accounts for most of the total SO_2 emissions.

SO_2 Air Quality, 1983–2002
Based on Annual Arithmetic Average



1983–02: 54% decrease
1993–02: 39% decrease

SO_2 Emissions, 1983–2002



1983–02: 33% decrease
1993–02: 31% decrease

Health and Environmental Effects

High concentrations of SO_2 can result in temporary breathing impairment for asthmatic children and adults who are active outdoors. Short-term exposures of asthmatic individuals to elevated SO_2 levels during moderate activity may result in breathing difficulties that can be accompanied by symptoms such as wheezing, chest tightness, or shortness of breath. Other effects that have been associated with longer-term exposures to high concentrations of SO_2, in conjunction with high levels of PM, include aggravation of existing cardiovascular disease, respiratory illness, and alterations in the lungs' defenses. The subgroups of the population that may be affected under these conditions include individuals with heart or lung disease, as well as the elderly and children.

Together, SO_2 and NO_x are the major precursors to acidic deposition (acid rain), which is associated with the acidification of soils, lakes, and streams and accelerated corrosion of buildings and monuments. SO_2 also is a major precursor to $PM_{2.5}$, which is a significant health concern, and a main contributor to poor visibility. (See Acid Rain section, page 16, for a more detailed discussion.)

Trends in SO_2 Levels and Emissions

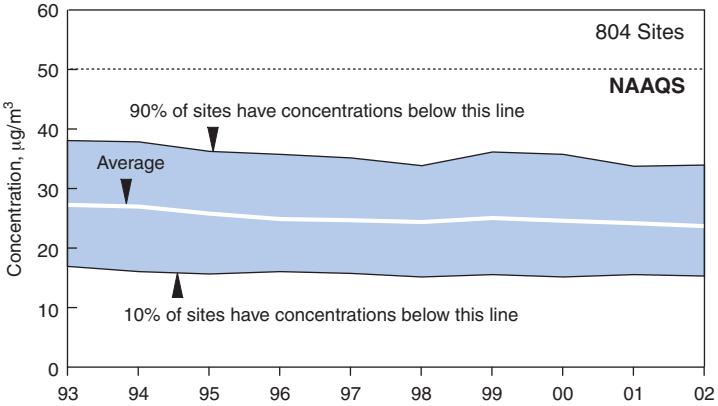
Nationally, average SO_2 ambient concentrations have decreased 54 percent from 1983 to 2002 and 39 percent over the more recent 10-year period 1993 to 2002. SO_2 emissions decreased 33 percent from 1983 to 2002 and 31 percent from 1993 to 2002. Reductions in SO_2 concentrations and emissions since 1990 are due, in large part, to controls implemented under EPA's Acid Rain Program, which began in 1995. In addition, in 2001 and 2002, energy consumption for electricity generation and industrial power leveled off; therefore, SO_2 and NO_x emissions from this sector did not increase as much as expected.

Nature and Sources of Particulate Matter

Particulate matter is the general term used for a mixture of solid particles and liquid droplets found in the air. Some particles are large enough to be seen as dust or dirt. Others are so small they can be detected only with an electron microscope. $PM_{2.5}$ describes the "fine" particles that are less than or equal to 2.5 µm in diameter. "Coarse fraction" particles are greater than 2.5 µm, but less than or equal to 10 µm in diameter. PM_{10} refers to all particles less than or equal to 10 µm in diameter (about one-seventh the diameter of a human hair). PM can be emitted directly or formed in the atmosphere. "Primary" particles, such as dust from roads or black carbon (soot) from combustion sources, are emitted directly into the atmosphere.

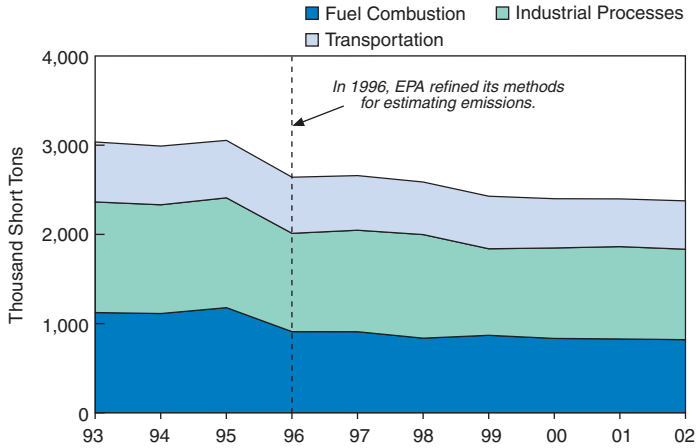
"Secondary" particles are formed in the atmosphere from primary gaseous emissions. Examples include sulfates formed from SO_2 emissions from power plants and industrial facilities; nitrates formed from NO_x emissions from power plants, automobiles, and other combustion sources; and carbon formed from organic gas emissions from automobiles and industrial facilities. The chemical composition of particles depends on location, time of year, and weather. Generally, coarse PM is composed largely of primary particles and fine PM contains many more secondary particles.

PM_{10} Air Quality, 1993–2002
Based on Seasonally Weighted Annual Average



1993–02: 13% decrease

PM_{10} Emissions, 1993–2002



1993–02: 22% decrease

Health and Environmental Effects

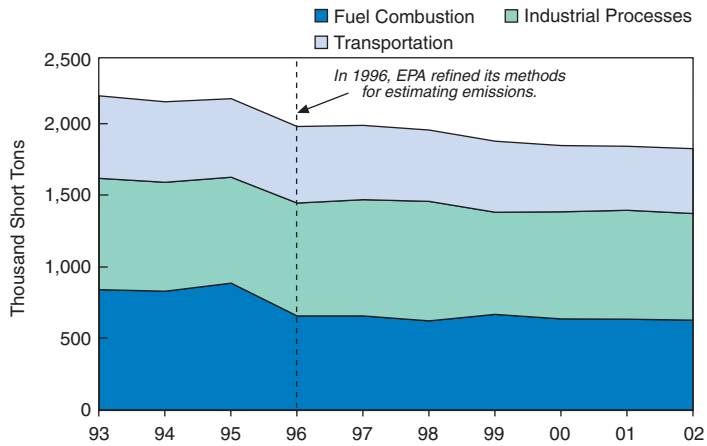
Particles that are small enough to get into the lungs (those less than or equal to 10 µm in diameter) can cause numerous health problems and have been linked with illness and death from heart and lung disease. Various health problems have been associated with long-term (e.g., multi-year) exposures as well as daily and, potentially, peak (e.g., 1-hour) exposures to particles. Particles can aggravate respiratory conditions such as asthma and bronchitis and have been associated with cardiac arrhythmias (heartbeat irregularities) and heart attacks. Particles of concern can include both fine and coarse-fraction particles, although fine particles have been more clearly linked to the most serious health effects. People with heart or lung disease, the elderly, and children are at highest risk from exposure to particles.

In addition to health problems, PM is the major cause of reduced visibility in many parts of the United States. Airborne particles also can impact vegetation and ecosystems and can cause damage to paints and building materials. (See sections on Acid Rain, NO_2, and SO_2.)

Trends in PM_{10} Levels and Direct Emissions

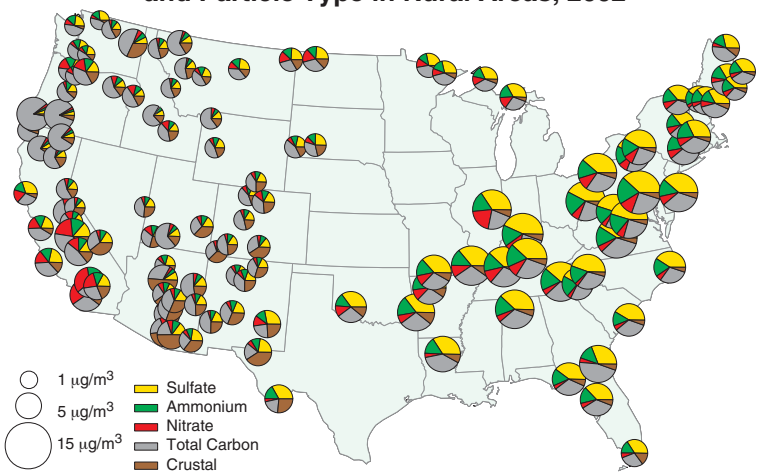
Between 1993 and 2002, average PM_{10} concentrations decreased 13 percent, while direct PM_{10} emissions decreased 22 percent.

$PM_{2.5}$ Emissions, 1993–2002



1993–02: 17% decrease

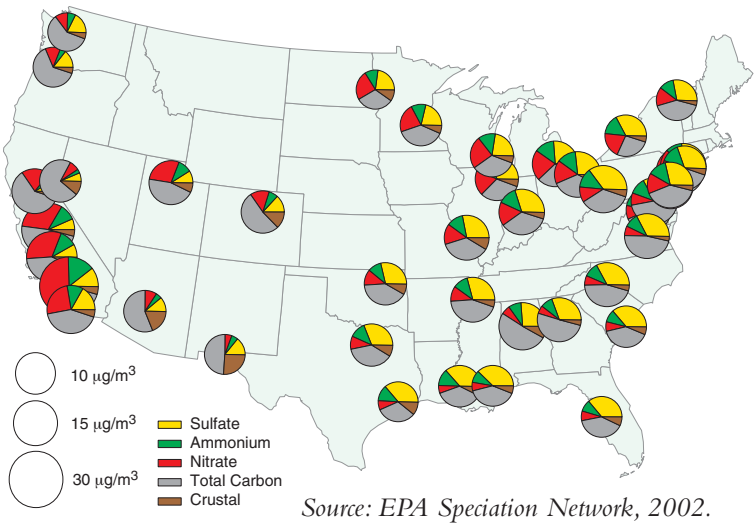
Annual Average $PM_{2.5}$ Concentrations ($\mu g/m^3$) and Particle Type in Rural Areas, 2002



Source: Interagency Monitoring of Protected Visual Environments Network, 2002.

Note: Direct comparisons of the information in these two maps should take into consideration the fact that one is a rural network and the other is an urban network and that there are differences in instruments and measurement methods.

Annual Average $PM_{2.5}$ Concentrations ($\mu g/m^3$) and Particle Type in Urban Areas, 2002



Source: EPA Speciation Network, 2002.

If enacted, President Bush's Clear Skies Initiative would decrease PM concentrations by dramatically reducing emissions of SO_2 and NO_x. This initiative would also reduce mercury emissions (www.epa.gov/clearskies).

Trends in $PM_{2.5}$ Levels and Direct Emissions

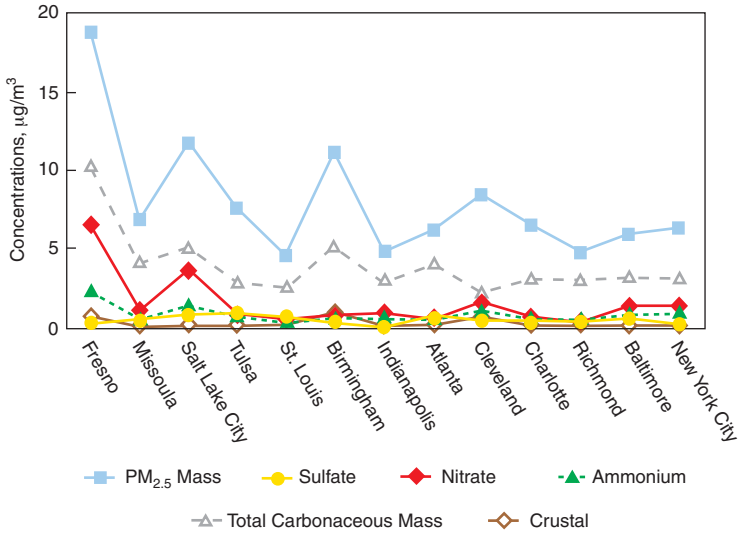
The chart at lidf shows that direct $PM_{2.5}$ emissions from man-made sources decreased 17 percent nationally between 1993 and 2002. This chart tracks only directly emitted particles and does not account for secondary particles, which typically account for a large percentage of $PM_{2.5}$. As discussed previously, the principal secondary particles are sulfates, nitrates, and organic carbon.

The maps at left show how sulfates, nitrates, and total carbon (black carbon and organic carbon) along with other components, contribute to $PM_{2.5}$ concentrations. The first map represents the most recent year of data (September 2001–August 2002) available from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network, which was established in 1987 to track trends in pollutants, such as $PM_{2.5}$, that contribute to visibility impairment. Because the monitoring sites are located in rural areas throughout the country, the network is a good source for assessing regional differences in $PM_{2.5}$. The second map represents the most recent year of data (September 2001–August 2002) from EPA's urban speciation network, which was established in 1999. All of these sites are located in urban areas.

The IMPROVE data show that $PM_{2.5}$ levels in rural areas are highest in the eastern United States and southern California, as shown by the larger circles. Sulfates and associated ammonium dominate the East, with carbon as the next most prevalent component. Sulfate concentrations in the East largely result from SO_2 emissions from coal-fired power plants. In California and other areas of the West, carbon and nitrates make up most of the $PM_{2.5}$ measured.

The urban speciation data show that sites in urban areas, as shown in the circles in the map at right, generally have higher annual average $PM_{2.5}$ concentrations than nearby rural areas. Urban sites in the East include a large percentage of carbon and sulfates (and ammonium). Urban sites in the Midwest and far West (and especially in California) include a large percentage of carbon and nitrates.

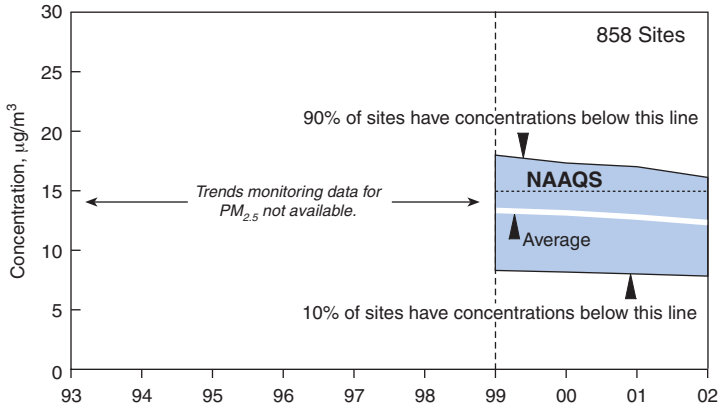
Urban Increments of $PM_{2.5}$ Mass and Major Chemical Species, 2002



Source: Interagency Monitoring of Protected Visual Environments Network and EPA Speciation Network, 2002.

The lines in the figure above display West-to-East urban increments of $PM_{2.5}$ levels and the major chemical constituents. EPA compared the annual average $PM_{2.5}$ concentration at each of these 13 sites with measurements from a nearby rural site. The urban excess shown above illustrates the difference in concentrations from these paired sites. In general, the single largest component of urban excess is total carbonaceous material. There is little or no excess of sulfates (confirming the regional nature of this pollutant) and only moderate urban excess of nitrate at some locations. The components of $PM_{2.5}$ showing urban excesses come from sources local to the urban area. This illustrates the importance of local, metropolitan area controls in addition to regional control programs.

$PM_{2.5}$ Air Quality, 1993–2002
Based on Seasonally Weighted Annual Average



1999–02: 8% decrease

In 1999, EPA and its state, tribal, and local air pollution control partners deployed a monitoring network to begin measuring $PM_{2.5}$ concentrations nationwide. Now that there are several years of monitoring data available, EPA has begun to examine trends at the national level. Annual average $PM_{2.5}$ concentrations decreased 8 percent nationally from 1999 to 2002. Much of that reduction occurred in the Southeast where the monitored levels of $PM_{2.5}$ decreased 18 percent from 1999 to 2002. Lower annual average concentrations in the Southeast can be attributed, in part, to decreases in sulfates, which largely result from power plant emissions of SO_2.

$PM_{2.5}$ concentrations vary regionally. Based on the monitoring data, parts of California and many areas in the eastern United States have annual average $PM_{2.5}$ concentrations above the level of the annual $PM_{2.5}$ standard. With few exceptions, the rest of the country generally has annual average concentrations below the level of the annual $PM_{2.5}$ health standard.

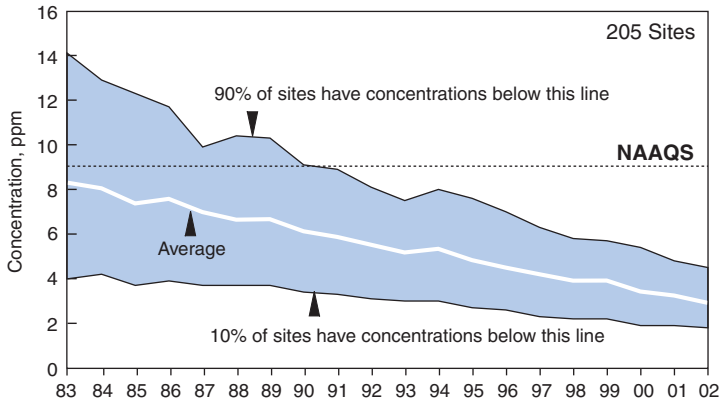
Because of health effects associated with short-term exposure to $PM_{2.5}$, daily levels are also of concern. Actual and forecasted daily air quality is assessed and reported using EPA's Air Quality Index (AQI). The forecasted AQI is typically featured in *USA Today* and on *The Weather Channel*, as well as in local media. In the summertime, ozone is usually the pollutant of concern on days when the air is unhealthy. But $PM_{2.5}$ also plays a role in unhealthy air quality in the summertime in some regions, even on days when the ozone levels are not high. $PM_{2.5}$ is also responsible for days with unhealthy air in cooler months. Because of its complex chemical makeup, $PM_{2.5}$ levels can be in the unhealthy range any time during the year (sulfates are usually higher in the summer; carbon and nitrates, in the winter). Many major metropolitan areas are beginning year-round reporting and forecasting of AQI values through the incorporation of daily $PM_{2.5}$ information.

CARBON MONOXIDE (CO)

Nature and Sources of Carbon Monoxide

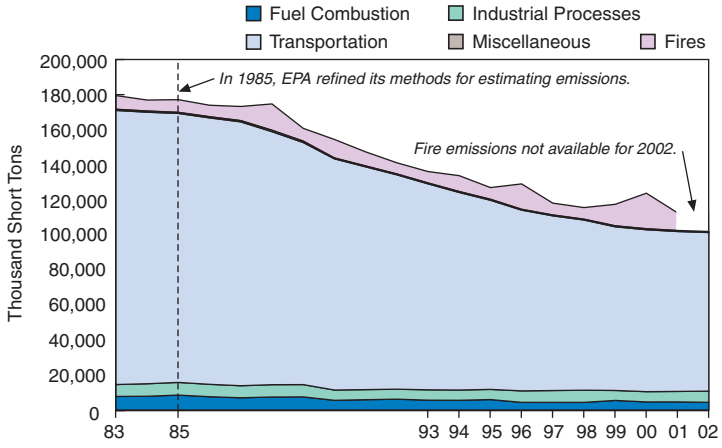
Carbon monoxide is a colorless and odorless gas, formed when carbon in fuel is not burned completely. It is a component of motor vehicle exhaust, which contributes about 60 percent of all CO emissions nationwide. Nonroad vehicles account for the remaining CO emissions from transportation sources. High concentrations of CO generally occur in areas with heavy traffic congestion. In cities, as much as 95 percent of all CO emissions may come from automobile exhaust. Other sources of CO emissions include industrial processes, nontransportation fuel combustion, and natural sources such as wildfires. Peak CO concentrations typically occur during the colder months of the year when CO automotive emissions are greater and nighttime inversion conditions (where air pollutants are trapped near the ground beneath a layer of warm air) are more frequent.

CO Air Quality, 1983–2002
Based on Annual 2nd Maximum 8-hour Average



1983–02: 65% decrease
1993–02: 42% decrease

CO Emissions, 1983–2002



1983–02: 41% decrease
1993–02: 21% decrease

Health Effects

CO enters the bloodstream through the lungs and reduces oxygen delivery to the body's organs and tissues. The health threat from levels of CO sometimes found in the ambient air is most serious for those who suffer from cardiovascular disease such as angina pectoris. At much higher levels of exposure not commonly found in ambient air, CO can be poisonous, and even healthy individuals may be affected. Visual impairment, reduced work capacity, reduced manual dexterity, poor learning ability, and difficulty in performing complex tasks are all associated with exposure to elevated CO levels.

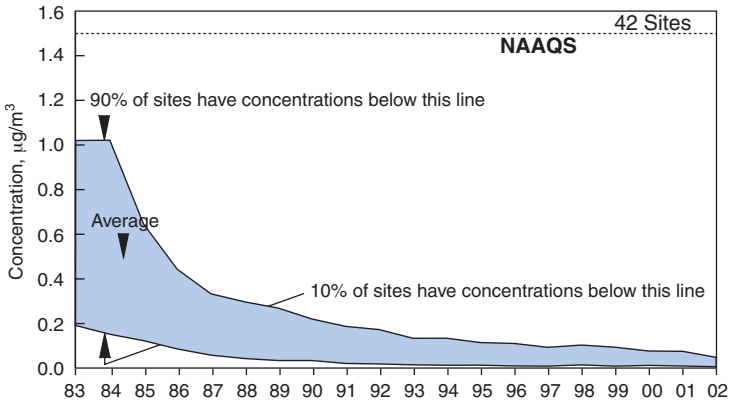
Trends in CO Levels and Emissions

Nationally, the 2002 ambient average CO concentration is almost 65 percent lower than that for 1983 and is the lowest level recorded during the past 20 years. CO emissions from transportation sources, the major contributor to ambient CO concentration, decreased dramatically during this period as indicated by EPA's improved new model of highway vehicle emissions. In particular, this report's higher estimate of CO emissions in the 1980s and early 1990s reflects an improved understanding of emissions from real-world driving. Between 1993 and 2002, ambient CO concentrations decreased 42 percent. Total CO emissions decreased 21 percent (excluding wildfires and prescribed burning) for the same period. This improvement in air quality occurred despite a 23 percent increase in vehicle miles traveled during the 10-year period.

Nature and Sources of Lead

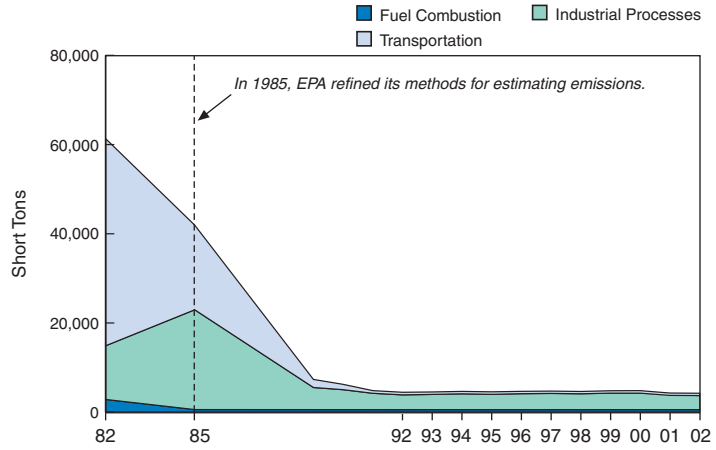
In the past, automotive sources were the major contributor of lead emissions to the atmosphere. As a result of EPA's regulatory efforts to reduce the content of lead in gasoline, however, the contribution of air emissions of lead from the transportation sector, and particularly the automotive sector, has greatly declined over the past two decades. Today, industrial processes, primarily metals processing, are the major source of lead emissions to the atmosphere. The highest air concentrations of lead are usually found in the vicinity of smelters and battery manufacturers.

Lead Air Quality, 1983–2002
Based on Annual Maximum Quarterly Average



1983–02: 94% decrease
1993–02: 57% decrease

Lead Emissions, 1982–2002[a]



1982–02: 93% decrease
1993–02: 5% decrease

[a] As of 2002, lead emissions are included in the Toxic National Emissions Inventory.

Health and Environmental Effects

Exposure to lead occurs mainly through inhalation of air and ingestion of lead in food, water, soil, or dust. It accumulates in the blood, bones, and soft tissues and can adversely affect the kidneys, liver, nervous system, and other organs. Excessive exposure to lead may cause neurological impairments such as seizures, mental retardation, and behavioral disorders. Even at low doses, lead exposure is associated with damage to the nervous systems of fetuses and young children, resulting in learning deficits and lowered IQ. Recent studies also show that lead may be a factor in high blood pressure and subsequent heart disease. Lead can also be deposited on the leaves of plants, presenting a hazard to grazing animals and humans through ingestion.

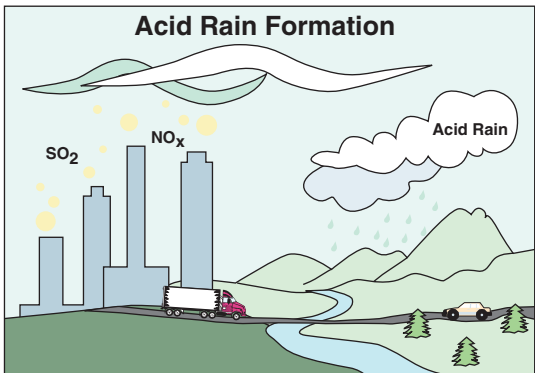
Trends in Lead Levels and Emissions

Because of the phaseout of leaded gasoline, lead emissions and concentrations decreased sharply during the 1980s and early 1990s. The 2002 average air quality concentration for lead is 94 percent lower than in 1983. Emissions of lead decreased 93 percent over the 21-year period 1982–2002. These 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 NAAQS, the lead monitoring strategy currently focuses on emissions from these point sources. Today, the only violations of the lead NAAQS occur near large industrial sources such as lead smelters and battery manufacturers. Various enforcement and regulatory actions are being actively pursued by EPA and the states for cleaning up these sources.

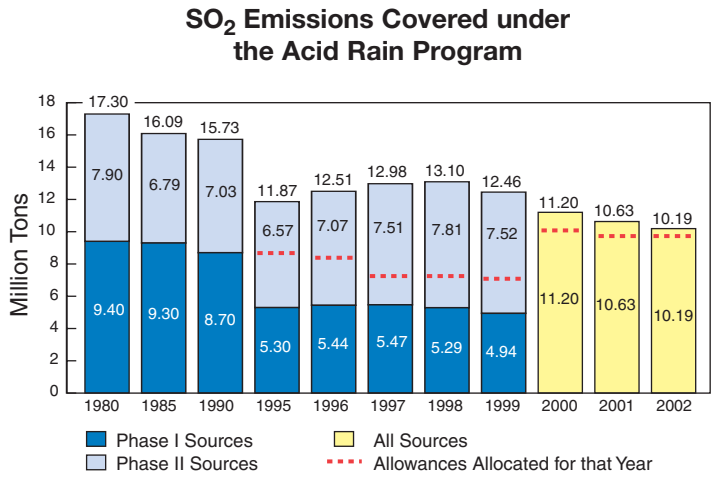
Acid Rain

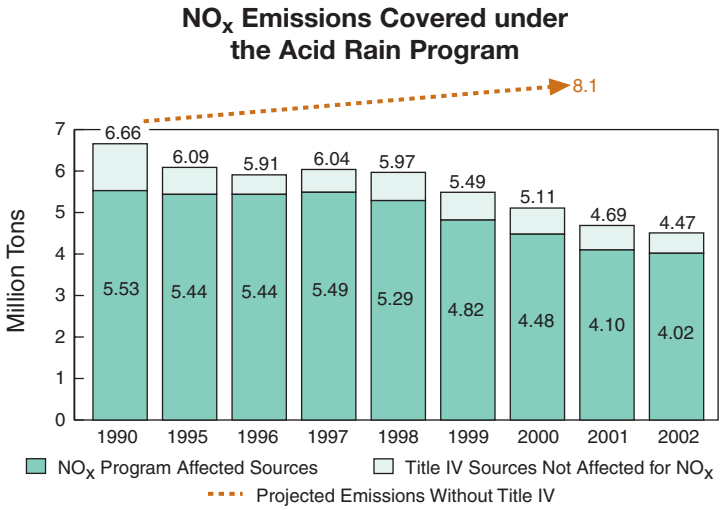
Nature and Sources of the Problem

Acidic deposition or "acid rain" occurs when emissions of sulfur dioxide and nitrogen oxides in the atmosphere react with water, oxygen, and oxidants to form acidic compounds. These compounds fall to the Earth in either dry form (gas and particles) or wet form (rain, snow, and fog). Some are carried by the wind, sometimes hundreds of miles, across state and national borders. In the United States, about 63 percent of annual SO_2 emissions and 22 percent of NO_x emissions are produced by burning fossil fuels for electricity generation.



Coal-fired electric utilities and other sources that burn fossil fuels emit SO_2 and NO_x.





Health and Environmental Effects

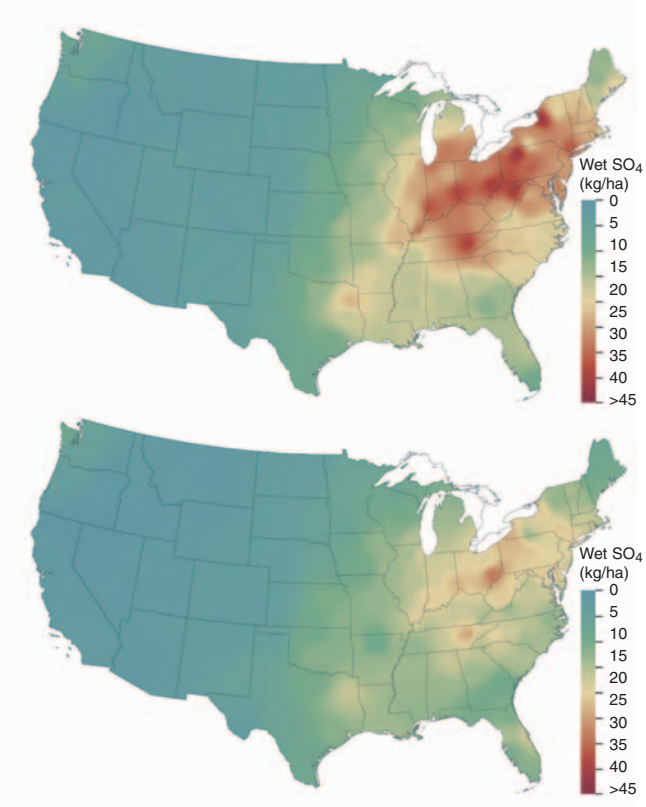
In the environment, acid deposition causes soils and waterbodies to acidify (making the water unsuitable for some fish and other wildlife) and damages some trees, particularly at high elevations. It also speeds the decay of buildings, statues, and sculptures that are part of our national heritage. The nitrogen portion of acid deposition contributes to eutrophication in coastal ecosystems, the symptoms of which include algal blooms (some of which may be toxic), fish kills, and loss of plant and animal diversity. Finally, acidification of lakes and streams can increase the amount of methyl mercury available in aquatic systems. Most exposure to mercury comes from eating contaminated fish. Reductions in SO_2 and NO_x have begun to reduce some of these negative environmental effects and are leading to significant improvements in public health.

Program Structure

The goal of EPA's Acid Rain Program is to improve public health and the environment by reducing emissions of SO_2 and NO_x. The program was implemented in two phases: Phase I for SO_2 began in 1995 and targeted the largest and highest-emitting coal-fired power plants. Phase I for NO_x began in 1996. Phase II for both pollutants began in 2000 and sets restrictions on Phase I plants as well as smaller coal-, gas-, and oil-fired plants. Approximately 3,000 units are now affected by the Acid Rain Program.

By 2010, the Acid Rain Program will reduce annual SO_2 emissions by half from 1980 levels. The program sets a permanent cap of 8.95 million tons on the total amount of SO_2 that may be emitted by power plants nationwide. It employs an emissions trading program to achieve emission reductions more efficiently and cost-effectively. Sources are allocated allowances each year (one allowance equals 1 ton of SO_2 emissions), which can be bought or sold or banked for future use. This approach gives sources the flexibility and incentive to reduce emissions at the lowest cost

Change in Sulfate Deposition from Precipitation



Source: U.S. EPA analysis of National Atmospheric Deposition Program data.

and the cap ensures that emission reductions are maintained over time.

The NO_x component of the Acid Rain Program limits the emission rate for all affected utilities, resulting in a 2 million ton NO_x reduction from 1990 levels by 2001. There is no cap on total NO_x emissions, but under this program a source can choose to overcontrol at units where it is technically easier to control emissions, average these emissions with those at their other units, and thereby achieve overall emissions reductions at lower cost.

Emissions and Atmospheric Trends

SO_2 emissions reductions were significant in the first 6 years of EPA's Acid Rain Program. In 2002, sources in the Acid Rain Program emitted 10.2 million tons, down from 15.7 million tons in 1990. Emissions of SO_2 in 2002 were 400,000 tons less than in 2001. As in 2001, sources again drew down the bank of unused allowances in 2002, resulting in emission levels greater than the allowances allocated in 2002 but still lower than emissions during any previous year.

NO_x emissions from all Acid Rain Program sources have also declined since 1990. NO_x emissions have decreased steadily from 6 million tons in 1997 to 4.5 million tons in 2002. The more than 1,000 sources affected by the Acid Rain NO_x Program emitted 4.1 million tons in 2000, approximately 1.5 million tons (25 percent) less than they did in 1990. NO_x emissions from these sources in 2001 were 3.6 million tons (over 40 percent) below what emissions were projected to have been in 2000 without the Acid Rain Program.

For all years from 1995 through 2001, wet sulfate deposition exhibited dramatic and unprecedented reductions over a large area of the eastern United States. Average sulfate deposition in 1999-2001 has decreased more than 8 kg/ha from 30-40 kg/ha in 1989-1991 in much of the mid-Appalachian and the northeastern United States. Similarly, sulfate air concentrations, which contribute to human health and visibility problems, were reduced significantly in the East. Wet nitrogen deposition decreased slightly in some places between 1989-1991 and 1999-2001, but increased in others up to 3 kg/ha in areas with significant agricultural activity and areas where vehicles are the predominant source of NO_x emissions.

These reductions in acid deposition and improvements in air quality are directly related to the large regional decreases in SO_2 and NO_x emissions resulting from the Acid Rain Program. The largest reductions in wet sulfate deposition occurred across the Ohio River Valley and in the Northeast. The largest reductions in sulfate concentrations also occurred along the Ohio River Valley and in states downwind. Reductions in the East in hydrogen ion concentrations, the primary indicator of precipitation acidity, were similar to those of sulfate concentrations, both in magnitude and location. The largest reductions in wet nitrate deposition were in the northeastern United States, Michigan, and Texas. The states immediately west of the Mississippi River and in the eastern Plains, parts of the Southeast, and California showed the highest increases in nitrogen deposition even though emissions from acid rain sources have not increased substantially there. Acid rain sources account for only 22 percent of nationwide nitrogen emissions, so emissions trends in other source categories, especially agriculture and mobile sources, also affect air concentrations and deposition of nitrogen.

Visibility

Nature and Sources of the Problem

Visibility impairment is one of the most obvious effects of air pollution and occurs at many of the best known and most treasured natural parks and wilderness areas, such as the Grand Canyon, Yosemite, Yellowstone, Mount Rainier, Shenandoah, and the Great Smoky Mountains National Park, as well as in urban areas.

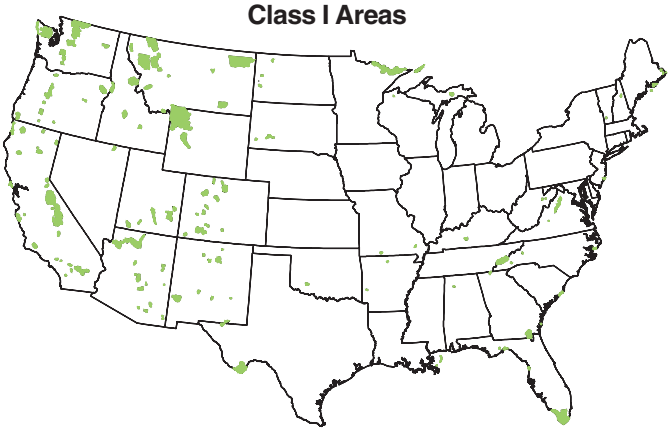
Visibility impairment results from the scattering and absorption of light by air pollution, including particles and gases. The scattering and absorption by air pollution limits the distance we can see and can also degrade the color, clarity, and contrast of scenes. The same fine particles that are linked to serious health effects and premature death can also significantly affect our ability to see.

Some particles that contribute to visibility impairment are emitted directly into the atmosphere from their sources, such as dust from roads or elemental carbon (soot) from wood combustion. In other cases, particles are formed in the atmosphere from primary gaseous emissions such as sulfates formed from SO_2 emissions from power plants and other industrial facilities and nitrates formed from NO_x emissions from power plants, automobiles, and other types of combustion sources. These types of particles are referred to as secondarily formed particles. In the eastern United States, reduced visibility is mainly attributable to secondarily formed sulfates. Although these secondarily formed particles still account for a major portion of particulate loading in the West, primary emissions from sources like wood smoke contribute a larger percentage of the total particulate loading than in the East.

	East	West
Sulfates	60%–86%	25%–50%
Organic Carbon	10%–18%	25%–40%
Nitrates	7%–16%	5%–45%
Elemental Carbon (soot)	5%–8%	5%–15%
Crustal Material (soil dust)	5%–15%	5%–25%

This table shows pollutants that contribute to visibility impairment in the eastern and western parts of the United States. Sulfates are generally the largest contributor in both the East and the West.

Class I Areas



The Clean Air Act provides for the protection of visibility in our national parks and wilderness areas, also known as Class I areas. There are 156 Class I areas across the United States as shown. (See ***http://www2.nature.nps.gov/ard/parks/ClassIAreas.jpg****)*

Also, humidity can significantly increase the effect of pollution on visibility, causing some particles to become more efficient at scattering light and causing visibility impairment. Annual average relative humidity levels are 70 to 80 percent in the East as compared with 50 to 60 percent in the West. Poor summer visibility in the eastern United States is primarily the result of high sulfate concentrations combined with high humidity levels.

Program Structure

The Clean Air Act provides for the protection of visibility in national parks and wilderness areas, also known as Class I areas. The Clean Air Act's national goal calls for remedying existing visibility impairment and preventing future impairment in these 156 Class I areas across the country.

In 1987, the IMPROVE network was established as a cooperative effort among EPA, states, National Park Service, U.S. Forest Service, Bureau of Land Management, and U.S. Fish and Wildlife Service. Data are collected and analyzed from this network to determine the type of pollutants primarily responsible for reduced visibility and to track progress toward the Clean Air Act's national goal.

In April 1999, EPA initiated a new regional haze program. The program addresses visibility impairment in national parks and wilderness areas caused by numerous sources located over broad regions. The program sets a framework for states to develop goals for improving visibility on the worst visibility days each year and to adopt emission strategies to meet these goals. Because fine particles are frequently transported hundreds of miles, pollution that occurs in one state may contribute

to the visibility impairment in another state. For this reason, EPA encourages states to coordinate through regional planning organizations to develop regional strategies to improve visibility and to reduce pollutants that contribute to fine particles and ground-level ozone. States are also required to review progress every 5 years and revise any strategies as necessary.

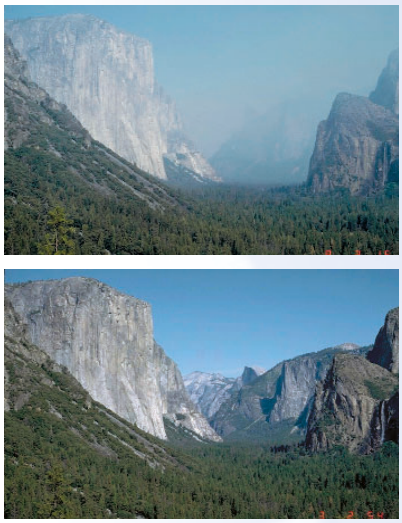
In 2000, the IMPROVE Monitoring Network started an expansion from 30 to 110 monitoring sites. The expansion work was completed in the fall of 2001. States, tribes, and federal land management agencies support more than 50 additional sites. Collectively, these will be used to track future progress in accordance with the regional haze program.

Shenandoah National Park under bad and good visibility conditions. The visual range in the top photo is 25 km while the visual range in the bottom photo is 180 km.

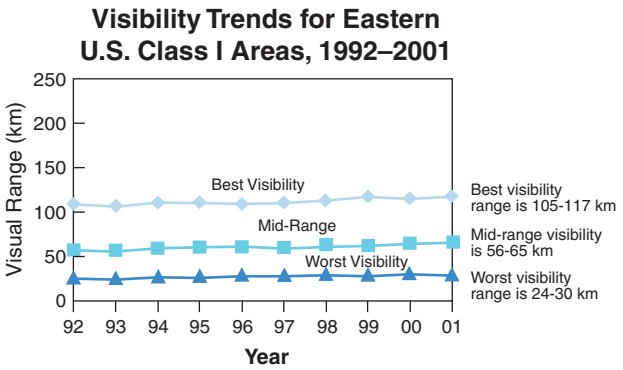
Visibility Trends

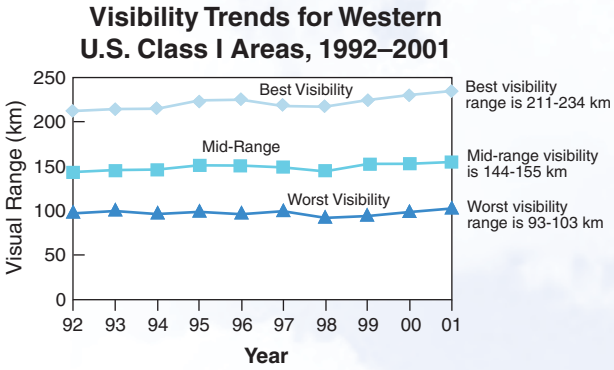
Without the effects of pollution, a natural visual range in the United States is approximately 75 to 150 km (45 to 90 miles) in the East and 200 to 300 km (120 to 180 miles) in the West.

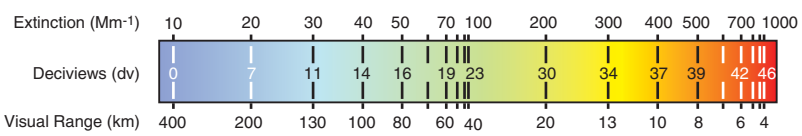
Data collected by the IMPROVE network show that visibility impairment for the worst visibility in the West is similar to days with the best visibility in the East. In 2001, mean visual range for the worst days in the East was only 29 km (48.3 miles) compared to 117 km (195 miles) for the best visibility. In the West, visibility impairment for the worst days remained relatively unchanged over the 10-year period, with the mean visual range for 2001 (103 km) nearly the same as the 1992 level (98 km).



Yosemite National Park under bad and good visibility conditions. The visual range in the top photo is 111 km while the visual range in the bottom photo is greater than 208 km.







***Visibility Metrics**. Comparisons of extinction (Mm^{-1}), deciviews (dv), and visual range (km). Notice the difference in the three scales: 10 Mm^{-1} corresponds to about 400 km visual range and 0.0 dv, while 1,000 Mm^{-1} is about 4 km visual range and 46 dv.*

Toxic Air Pollutants

Nature and Sources of the Problem

Toxic air pollutants, or air toxics, are those pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects. Air toxics may also cause adverse environmental and ecological effects. Examples of toxic air pollutants include benzene, found in gasoline; perchloroethylene, emitted from some dry cleaning facilities; and methylene chloride, used as a solvent by a number of industries. Most air toxics originate from man-made sources, including mobile sources (e.g., cars, trucks, construction equipment) and stationary sources (e.g., factories, refineries, power plants), as well as indoor sources (e.g., some building materials and cleaning solvents). Some air toxics are also released from natural sources such as volcanic eruptions and forest fires. The Clean Air Act identifies 188 air toxics from industrial sources. EPA has identified 21 pollutants as mobile source air toxics, including diesel particulate matter and diesel exhaust organic gases. In addition, EPA has listed 33 urban hazardous air pollutants that pose the greatest threats to public health in urban areas.

Health and Environmental Effects

People exposed to toxic air pollutants at sufficient concentrations may experience various health effects, including cancer and damage to the immune system, as well as neurological, reproductive (e.g., reduced fertility), developmental, respiratory, and other health problems.

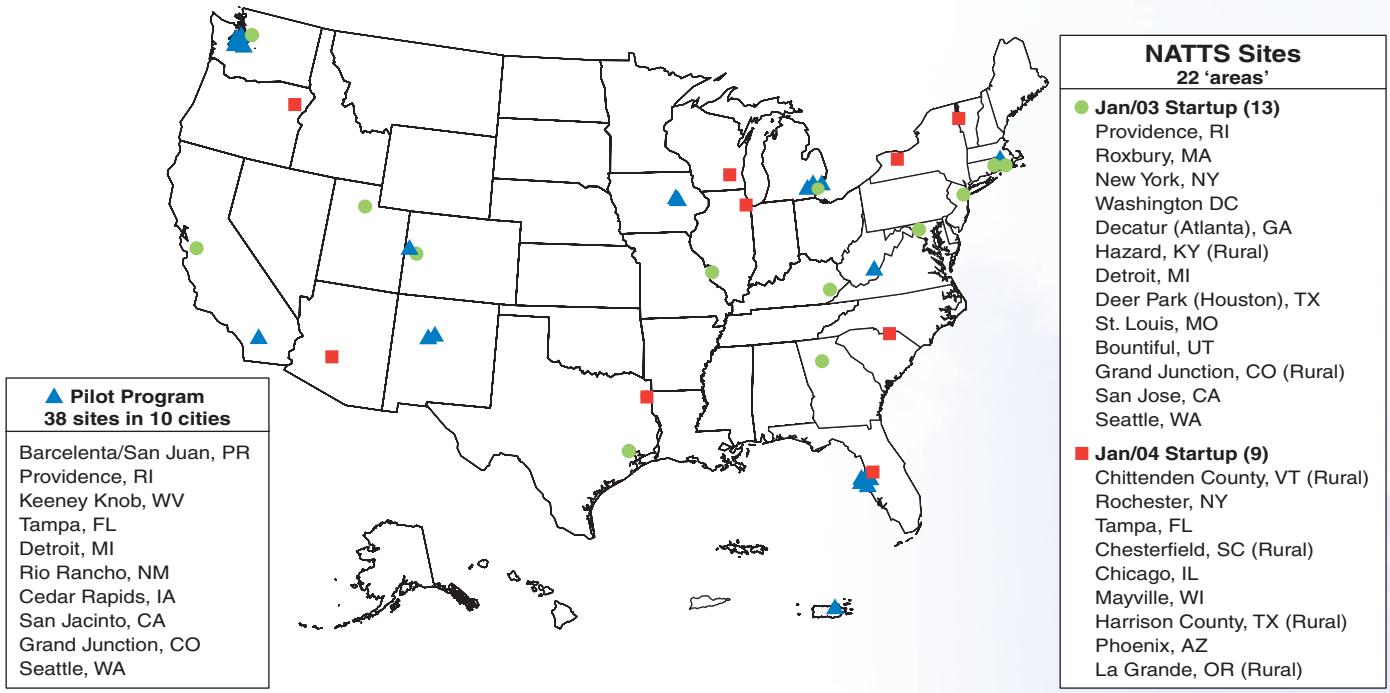
In addition to exposure from breathing air toxics, risks also are associated with the deposition of toxic pollutants onto soils or surface waters, where they are taken up by plants and ingested by animals and eventually magnified up through the food chain. Like humans, animals may experience health problems due to air toxics exposure.

Trends in Toxic Air Pollutants

EPA and states do not maintain an extensive nationwide monitoring network for air toxics as they do for many of the other pollutants discussed in this report. Although EPA, states, tribes, and local air regulatory agencies collect monitoring data for a number of toxic air pollutants, both the chemicals monitored and the geographic coverage of the monitors vary from state to state. Currently, there are about 300 air toxics monitoring sites in operation. The available monitoring data help air pollution control agencies track toxic air pollutant levels in various locations around the country. EPA is working with its regulatory partners to build on the existing monitoring sites to create a national monitoring network for a number of toxic air pollutants. The goal is to ensure that those compounds that pose the greatest risk are measured. EPA initiated a 12-month pilot monitoring project in 2001 in four urban areas and six small city/rural areas (see map below). The pilot program was developed to help answer several important national network design questions (e.g., sampling and analysis precision, sources of variability, minimal detection levels). A National Air Toxic Trend Site (NATTS) network was launched in early 2003. The central goal of the NATTS network is to detect trends in high-risk air toxics such as benzene, formaldehyde, 1,3-butadiene, acrolein, and chromium. By early 2004, 22 NATT sites (16 urban and 6 rural) will be operating (see map). For the latest information on national air toxics monitoring, see **www.epa.gov/ttn/amtic/airtxfil.html**.

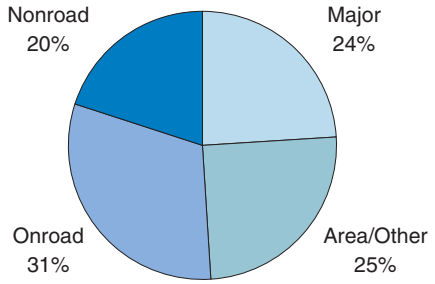
EPA also compiles an air toxics inventory as part of the National Emissions Inventory (NEI, formerly the National Toxics Inventory) to estimate and track national emissions trends for the 188 toxic air pollutants regulated under the Clean Air Act. In the NEI, EPA divides emissions into four types of sectors: (1) major (large industrial) sources; (2) area and other sources, which include smaller industrial sources like small dry cleaners and gasoline stations, as well as natural sources like wildfires; (3) onroad mobile sources, including highway vehicles; and (4) nonroad mobile sources like aircraft, locomotives, and construction equipment.

Recent National Air Toxics Monitoring Initiatives



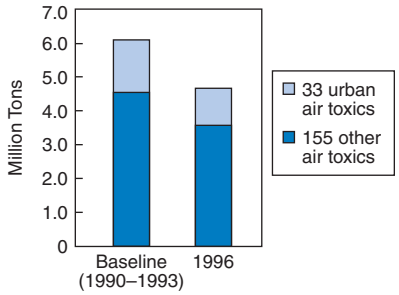
National Air Toxics Emissions, 1996

4.7 million tons



National Air Toxics Emissions

Total for 188 Toxic Air Pollutants



As shown in this pie chart, based on 1996 estimates (the most recent year of available data), the emissions of toxic air pollutants are relatively equally divided between the four types of sources. However, this distribution varies from city to city.

Based on the data in the NEI, estimates of nationwide air toxics emissions decreased by approximately 24 percent between baseline (1990-1993) and 1996. Thirty-three of these air toxics that pose the greatest threat to public health in urban areas have similarly decreased 31 percent. Although changes in how EPA compiled the national inventory over time may account for some differences, EPA and state regulations, as well as voluntary reductions by industry, have clearly achieved large reductions in overall air toxic emissions.

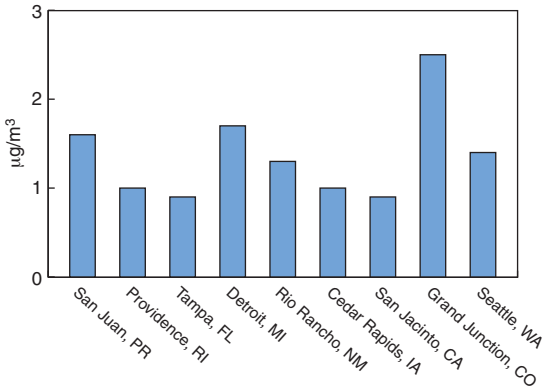
Trends for individual air toxics vary from pollutant to pollutant. Benzene, which is the most widely monitored toxic air pollutant, is emitted from cars, trucks, oil refineries, and chemical processes. The graph below shows trends for benzene at 95 urban monitoring sites around the country. These urban areas generally have higher levels of benzene than other areas of the country. Measurements taken at these sites show, on average, a 47 percent drop in benzene levels from 1994 to 2000. During this period, EPA phased in new (so-called tier 1) car emission standards; required many cities to begin

using cleaner burning gasoline; and set standards that required significant reductions in benzene and other pollutants emitted from oil refineries and chemical processes. EPA estimates that benzene emissions from all sources dropped 20 percent nationwide from 1990 to 1996. In the 2001 toxics pilot monitoring project, city averages of benzene ranged from about 0.9 to 2.5 μg/m^3.

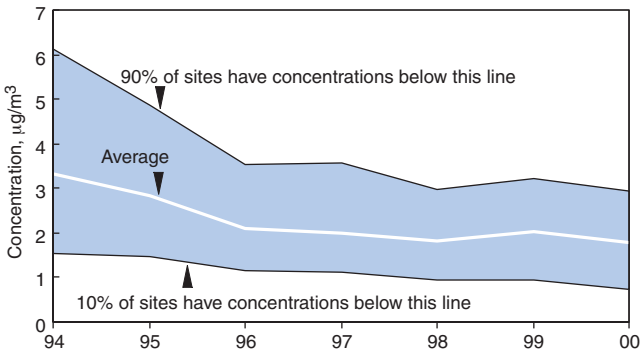
Risk Assessment

EPA has developed a National-Scale Air Toxics Assessment, which is a nationwide analysis of air toxics. It uses computer modeling of the 1996 NEI air toxics data as the basis for developing health risk estimates for 33 toxic air pollutants (a subset of the Clean Air Act's list of 188 air toxics plus diesel PM). The national-scale assessment is intended to provide state, local, and tribal agencies and others with a better understanding of the risks from inhalation exposure to toxic air pollutants from outdoor sources. It will help EPA and states prioritize data and research needs to better assess risk in the future and will provide a baseline to help measure future trends in estimated health risks. The next national-scale analysis will focus on 1999 data and is expected to be released by the end of 2003.

Benzene Levels in 2001 Pilot Monitoring Project



Ambient Benzene, Annual Average Urban Concentrations, Nationwide, 1994–2000



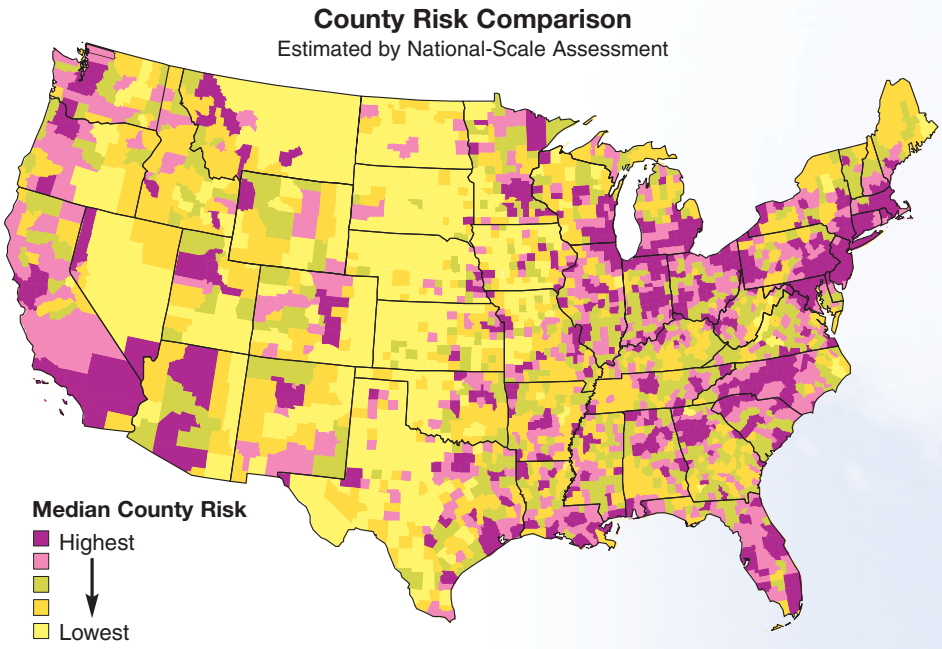
1994–00: 47% decrease

The map on page 23 shows a pattern of the distribution of relative cancer risk across the continental United States as estimated by the national-scale assessment. The highest ranking 20 percent of counties in terms of risk (622 counties) contain almost three-fourths of the U.S. population. Three air toxics (chromium, benzene, and formaldehyde) appear to pose the greatest nationwide carcinogenic risk. This map does not include the potential risk from diesel exhaust emissions. This is because existing health data are not sufficient to develop a numerical estimate of cancer risk for this pollutant. However, exposure to diesel exhaust is widespread, and EPA has concluded that diesel exhaust is a likely human carcinogen and ranks with the other substances that the national-scale assessment suggests pose the greatest relative risk. One air toxic, acrolein, is estimated to pose the highest potential nationwide risk for significant chronic adverse effects other than cancer. For more information, visit **www.epa.gov/ttn/atw/nata**.

This technical assessment represents an important step toward characterizing air toxics nationwide. It is designed to help identify general patterns in air toxics exposure and risk across the country and is not recommended as a tool to characterize or compare risk at local levels (e.g., to compare risks from one part of a city to another). More localized assessments, including monitoring and modeling, are under way to help characterize local-level risk.

Programs to Reduce Air Toxics

Since 1990, EPA's technology-based emission standards for industrial and combustion sources (e.g., chemical plants, oil refineries, dry cleaners, and municipal waste combustors) have proven extremely successful in reducing emissions of air toxics. Once fully implemented, these standards will cut annual emissions of toxic air pollutants by nearly 1.5 million tons from 1990 levels. Of this total reduction, dioxin emissions from municipal waste combustors and municipal waste incinerator units will have been reduced by approximately



99 percent and mercury emissions by 95 percent. Additional reductions are expected by 2005. EPA has also put into place important controls for motor vehicles and their fuels, including introduction of reformulated gasoline and low sulfur diesel fuel, and is taking additional steps to reduce air toxics from vehicles. Furthermore, air toxics emissions will further decline as the motor vehicle fleet turns over, with newer vehicles replacing older higher-emitting vehicles. By the year 2020, these requirements are expected to reduce emissions of a number of air toxics (benzene, formaldehyde, acetaldehyde, and 1,3-butadiene) from highway motor vehicles by about 75 percent and diesel PM by over 90 percent from 1990 levels.

In addition to national regulatory efforts, EPA's program includes work with communities on comprehensive local assessments, as well as federal and regional activities associated with protecting waterbodies from air toxics deposition (e.g., the Great Waters program, which includes the Great Lakes, Lake Champlain, Chesapeake Bay, and many coastal estuaries) and EPA initiatives concerning mercury and other persistent and bioaccumulative toxics. For indoor air toxics, EPA's program has relied on education and outreach to achieve reductions. Information about indoor air activities is available at **www.epa.gov/iaq/**.

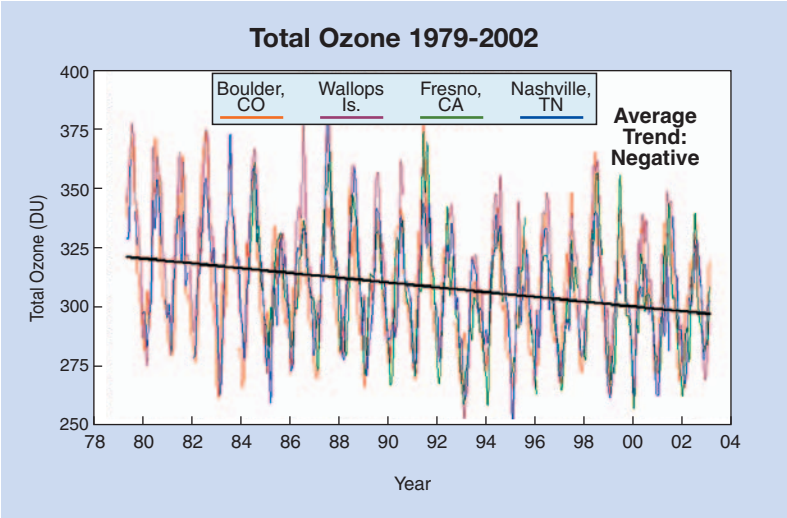
For more information about EPA's air toxics program, visit the Agency's Web site at **www.epa.gov/ttn/atw**.

Stratospheric Ozone

Nature and Sources of the Problem

The stratosphere, located about 6 to 30 miles above the Earth, contains a layer of ozone gas that protects living organisms from harmful ultraviolet-B radiation (UV-B) from the Sun. Over the past 3 decades, however, it has become clear that this protective shield has been damaged. Each year, an "ozone hole" forms over the Antarctic, and ozone levels there can fall to 60 percent below normal. Even over the United States, ozone levels are about 3 percent below normal in the summer and 5 percent below normal in the winter.

As the ozone layer thins, more UV-b radiation reaches the Earth. The 1998 and 2002 Scientific Assessments of Stratospheric Ozone firmly established the link between decreased ozone and increased UV-B radiation. In the 1970s, scientists had linked several substances associated with human activities to ozone depletion, including the use of chlorofluorocarbons (CFCs), halons, carbon tetrachloride, methyl bromide, and methyl chloroform. These chemicals are emitted from commercial air conditioners, refrigerators, insulating foam, and some industrial processes. Strong winds carry them through the lower part of the atmosphere, called the troposphere, and into the stratosphere. Once there, strong solar radiation reacts with the emitted chemicals to release chlorine and bromine atoms that attack protective ozone molecules. Scientists estimate that one chlorine atom can destroy 100,000 ozone molecules.



Data courtesy of the National Oceanic and Atmospheric Administration (NOAA), 2003. Monthly average total ozone measured in Dobson units (DU) at four mid-latitude stations across the United States from 1979 to 2002. Total ozone measurements from four midlatitude U.S. stations show a decline during the period. The large annual variation shown in each of the four cities is a result of ozone transport processes that cause increased levels in the winter and spring and lower ozone levels in the summer and fall at these latitudes.

Health and Environmental Effects

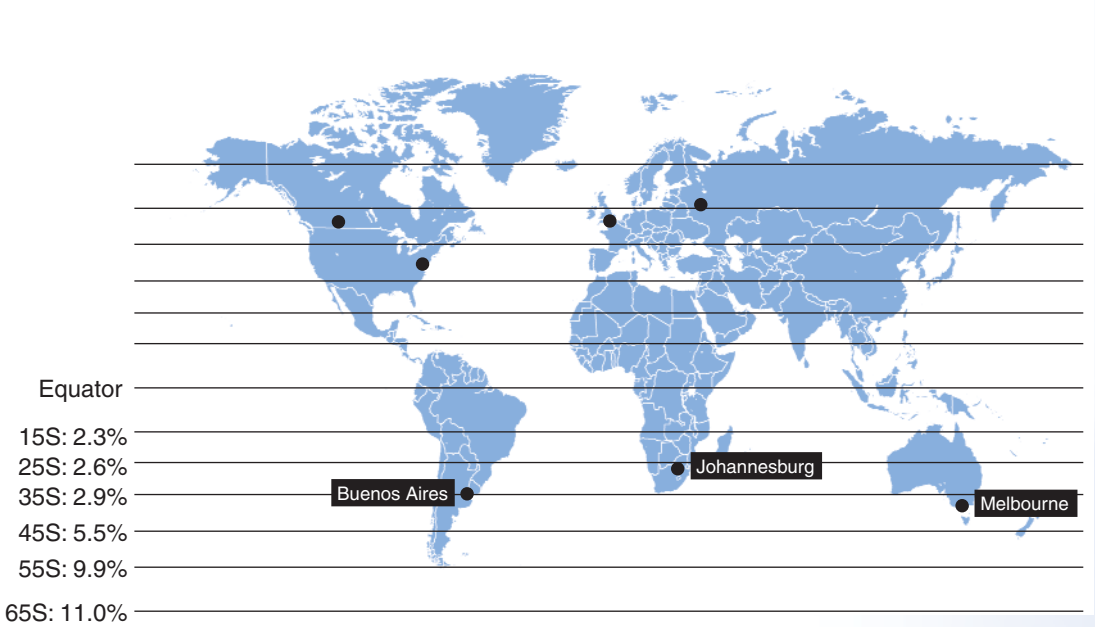
Ozone depletion allows for additional UV-B radiation to pass through the stratosphere and reach the Earth's surface, leading to increases in UV-related health and environmental effects. In humans, UV-B radiation is linked to skin cancer, including melanoma, the form of skin cancer with the highest mortality rate. It also contributes to cataracts and suppression of the immune system.

The effects of UV-B radiation on plant and aquatic ecosystems are not well understood. However, the growth of certain plants can be slowed by excessive UV-B radiation. In addition, some scientists suggest that marine phytoplankton, which are the base of the ocean food chain, are already under stress from UV-B radiation. This stress could have adverse consequences for human food supplies from the oceans.

Programs to Restore the Stratospheric Ozone Layer

In 1987, 27 countries signed the Montreal Protocol, a treaty that recognized the international nature of ozone depletion and committed the world to limiting the production of ozone-depleting substances. Today, more than 180 nations have signed the Protocol, which has been strengthened over time and now calls for the elimination of those chemicals that deplete stratospheric ozone.

The 1990 Clean Air Act Amendments established a U.S. regulatory program to protect the stratospheric ozone layer. In January 1996, U.S. production of many ozone-depleting substances virtually ended, including CFCs, carbon tetrachloride, and methyl chloroform. Production of halons ended in January 1994. Many new products that either do not affect or are less damaging to the ozone layer are now gaining popularity. For example, computer makers are using ozone-safe solvents to clean circuit boards, and automobile manufacturers are using HFC-134a, an ozone-safe refrigerant, in new motor vehicle air conditioners. In some industries,



the surface from 1986 to 1996. UV-B incidence is strongly dependent on latitude. At latitudes that cover the United States, UV-B levels are 4 to 5 percent higher than they were in 1986.

Source: National Oceanic and Atmospheric Administration (NOAA), 1998.

the transition away from ozone-depleting substances has already been completed.

EPA is also emphasizing efforts like the UV Index, a daily forecast of the strength of UV radiation to which people may be exposed outdoors, to educate the public about the health risks of overexposure to UV radiation and the steps they can take to reduce those risks. To educate the public about UV radiation levels and the associated health risks, EPA promotes the UV Index, a daily forecast of the strength of UV radiation, and its national SunWise School for grades K through 8. SunWise Partner Schools sponsor classroom and schoolwide activities to raise children's awareness of stratospheric ozone depletion, UV radiation, and simple sun safety practices. For more information on SunWise, visit **http://www.epa.gov/sunwise**.

Trends in Stratospheric Ozone Depletion

Scientific evidence shows that the approach taken under the Montreal Protocol has been effective to date. The latest 2002 Scientific Assessment of Ozone Depletion indicates that the rate of ozone depletion is slowing. Measurements have shown that atmospheric concentrations of methyl chloroform are falling, indicating that emissions have been greatly reduced. Concentrations of other ozone-depleting substances in the upper layers of the atmosphere, like CFCs, are also decreasing. It takes several years for these substances to reach the stratosphere and release chlorine and bromine. For this reason, stratospheric chlorine levels are near their peak and are expected to slowly decline in the years to come. Because of the stability of most ozone-depleting substances, the ozone layer will not fully recover until the second half of this century. All nations that signed the Protocol must complete implementation of ozone protection programs if full repair of the ozone layer is to be accomplished.

For more information on Stratospheric Ozone, visit **http://www.epa.gov/air/ozone/index.html**.

International Issues and U.S. Air Quality

The transboundary flow of air pollution affecting the United States and its neighboring countries is now well known and documented. Under bilateral agreements with Mexico and Canada, EPA is pursuing policies and technical efforts to better understand and reduce the transport of air pollution back and forth across our borders, particularly in areas where this transport threatens public health and attainment of ambient air quality standards. Also, there is increasing evidence of intercontinental pollution transport from Central America and Asia to the United States. Recent studies and satellite images illustrate the degree of transport (see sidebar). EPA participates with other agencies in various treaties and international cooperative efforts to characterize and address the intercontinental transport of air pollution. For example, EPA, in conjunction with other research organizations, is currently conducting a modeling study of intercontinental pollution transport from Asia and its potential effects on regional air quality. This modeling analysis will also study the intercontinental transport of air pollution from the United States to Europe.

Under a bilateral agreement with Mexico signed in 1983, also known as the La Paz Agreement, the United States and Mexico have developed and implemented a series of strategies to address air quality along our shared border. The United States and Mexico currently operate coordinated air monitoring networks, compile emission inventories, and conduct modeling analyses designed to support reasonable pollution control strategies to achieve national air quality standards on both sides of the border. One example resulting from this cooperative agreement is the U.S.–Mexico Border Information Center on Air Pollution. Additional information on the Border Information Center is available at the EPA Technology Transfer Network Web site, **www.epa.gov/ttn/catc/cica**.

Canada and the United States made a historic commitment to address transboundary air pollution with the signing of the U.S.–Canada Air Quality Agreement in 1991. Addressing acid rain and transboundary flows of ozone have been the primary focus of cooperation under

Air Pollution Transport

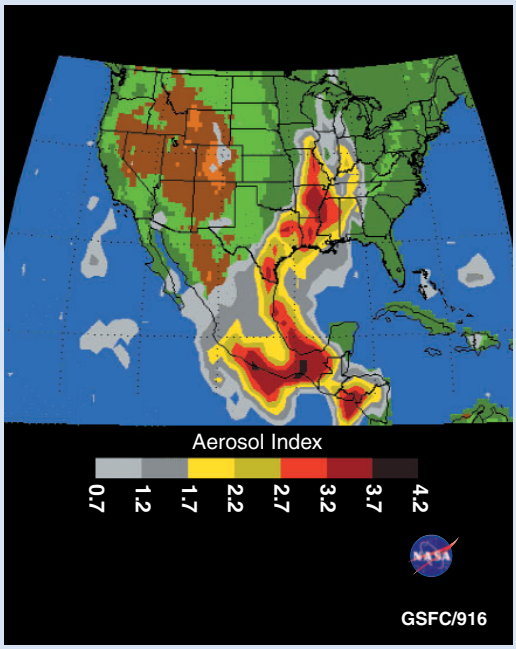
Modeling studies and satellite images show evidence of significant air pollution transport from Central America and southern Mexico. In addition, analysis of weather patterns reveals that upper air winds in summer months favor transport of airborne pollutants northward to the United States. With no mountain ranges to modify or impede them, air masses from Central America have an unobstructed path northward.

Pollution from Fires

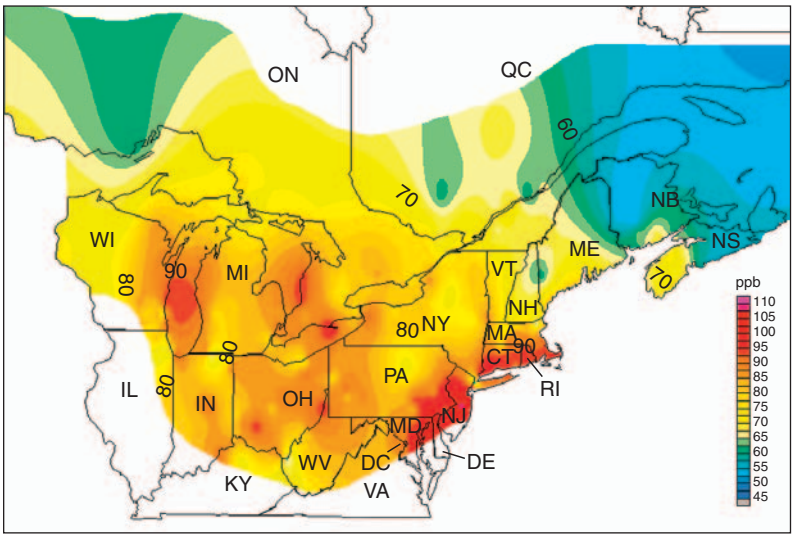
In May 1998, smoke from Central American and southern Mexican forest fires moved as far north as the Great Lakes and north-central Ontario. EPA and its many partners tracked the aerosol plumes, evaluating and publicizing the threats to public health as the plumes moved through the United States. In Texas, visibility was typically down to less than 1 mile in many large cities. A satellite image (courtesy of NASA) illustrating the extent of this aerosol plume transport is shown here.

Earth Probe TOMS

Smoke/Dust over North America for May 15, 1998

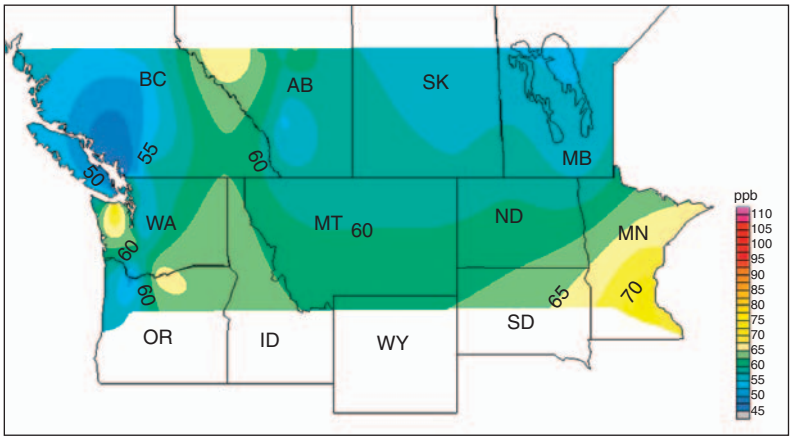


Ozone Concentrations in the Eastern Regions of the U.S. and Canada
(Average Annual 4th Highest Daily Maximum 8-hour Ozone, 1999-2001



Ozone concentrations are based on monitoring data from ozone sites located within approximately 500 km of the U.S.–Canadian border.

Ozone Concentrations in the Western Regions of the U.S. and Canada
(Average Annual 4th Highest Daily Maximum 8-hour Ozone, 1999-2001



the Agreement, and work to better understand the transboundary flows of fine particulate matter is under way. The Ozone Annex to this Agreement includes specific monitoring and reporting requirements of the two nations including (1) reporting ambient air quality within 500 km of the U.S.–Canadian border, (2) reporting annual emissions from major source categories beginning in 2004, and (3) developing joint analyses on ground-level ozone and precursors. The figures below illustrate the ozone concentration measurements within 500 km of the border in the eastern and western regions of the United States and Canada, respectively. These measurements represent the average annual fourth-highest daily maximum 8-hour ozone for 1999-2001(see **http://www.epa.gov/airmarkets/usca/**). The annual fourth-highest daily maximum 8-hour ozone is illustrative of the ambient air quality standard for 8-hour ozone.

The Convention on Long-Range Transboundary Air Pollution (LRTAP), under the United Nations Economic Commission for Europe, establishes a broad framework for cooperative action on air pollution in North America and Europe. The Convention establishes a process for negotiating specific measures to control air pollution through legally binding protocols. LRTAP initially focused on reducing the effects of acid rain through control of sulfur emissions. Later protocols have addressed the formation of ground-level ozone, persistent organic pollutants (POPs), and heavy metals. These multilateral efforts have established a foundation of international cooperation and understanding that has significantly advanced our ability to understand and address transboundary air pollution (see **http://www.unece.org/env/lrtap/**).

The United States is also actively leading, with other countries, global efforts to address POPs and mercury, pollutants that persist and are readily transported via air pollution pathways across borders and oceans. In 2001, the United States joined 151 other countries in signing the Stockholm Convention on Persistent Organic Pollutants. This treaty will help reduce the public health and environmental effects of pollutants such as DDT, chlordane, dioxins, and PCBs (see **http://www.pops.int**). Also in 2003, the United States joined the international community in endorsing a global effort to address mercury.

Conclusions

The Clean Air Act has resulted in many improvements in the quality of the air in the United States. Scientific and international developments continue to have an effect on the air pollution programs that are implemented by the U.S. Environmental Protection Agency and state, local, and tribal agencies. New data help identify sources of pollutants and the properties of these pollutants. Although much progress has been made to clean up our air, work must continue to ensure steady improvements in air quality, especially because our lifestyles create more pollution sources. Many of the strategies for air quality improvement will continue to be developed through coordinated efforts with EPA, state, local, and tribal governments, as well as industry and other environmental organizations.

Acronyms

AQI	Air Quality Index
CFCs	chlorofluorocarbons
CO_2	carbon dioxide
CO	carbon monoxide
DU	Dobson units
dv	deciviews
EPA	U.S. Environmental Protection Agency
FCCC	Framework Convention on Climate Change
ha	hectare
IMPROVE	Interagency Monitoring of Protected Visual Environments
IQ	intelligence quotient
kg	kilograms
km	kilometers
LRTAP	Long-Range Transboundary Air Pollutants
NAAQS	National Ambient Air Quality Standards
NATTS	National Air Toxic Trend Site
NEI	National Emissions Inventory
NO_2, NO_x	nitrogen dioxide, nitrogen oxides
NO	nitric oxide
NOAA	National Oceanic and Atmospheric Administration
O_3	ozone
OAQPS	Office of Air Quality Planning and Standards
Pb	lead
PM_{10}, $PM_{2.5}$	particulate matter (10 µm or less, 2.5 µm or less in diameter)
POPs	persistent organic pollutants
ppm	parts per million
SO_2, SO_x	sulfur dioxide, sulfur oxides
VOCs	volatile organic compounds
UV	ultraviolet

For Further Information

Web sites:

Office of Air and Radiation: **www.epa.gov/oar**

Detailed information on Air Pollution Trends: **www.epa.gov/airtrends**

Real-Time Air Quality Maps and Forecasts: **www.epa.gov/airnow**

On-line Air Quality Data: **www.epa.gov/air/data/index.html**

Air Toxics Information: **www.epa.gov/ttn/atw**

Ozone Depletion Web site: **www.epa.gov/ozone/**

Global Warming Emissions Information: **www.epa.gov/globalwarming/index.html**

Acid Rain Web site: **www.epa.gov/airmarkets/arplindex.html**

Office of Air Quality Planning and Standards: **www.epa.gov/oar/oaqps**

Office of Transportation and Air Quality: **www.epa.gov/otaq**

Office of Atmospheric Programs: **www.epa.gov/air/oap.html**

Office of Radiation and Indoor Air: **www.epa.gov/air/oria.html**

Hotlines:

Acid Rain Hotline: **(202) 564-9620**

Energy Star (Climate Change) Hotline: **(888) STAR-YES**

Mobile Sources National Vehicles and Fuel Emissions Lab: **(734) 214-4200**