



Latest Findings on National Air Quality: 1999 Status and Trends



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National Air Quality

This summary report highlights the U.S. Environmental Protection Agency's (EPA's) most recent evaluation of status and trends in our nation's air quality.

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



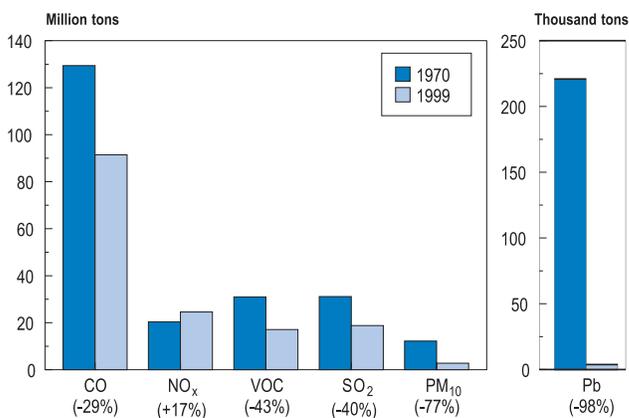
Six Principal Air Pollutants Tracked Nationally

- Carbon Monoxide (CO)
- Lead (Pb)
- Nitrogen Dioxide (NO₂)
- Ozone (O₃) – formed by volatile organic compounds (VOCs) and nitrogen oxides (NO_x)
- Particulate Matter (PM)
- Sulfur Dioxide (SO₂)

Highlights

- Overall, national air quality levels measured at thousands of monitoring stations across the country have shown improvement over the past 20 years for all six principal pollutants.
- Despite this progress, over 150 million tons of air pollution were released into the air in 1999 in the United States, and approximately 62 million people lived in counties where monitored data showed unhealthy air for one or more of the six principal pollutants.
- While the national trends continue to improve, air quality trends for some areas, including rural locations, have actually worsened. Some national parks, including the Great Smoky Mountains and Shenandoah, have high air pollution concentrations resulting from the transport of pollutants many miles from their original sources. In 1999, for the second consecutive year, average rural 1-hour ozone (smog) levels were greater than the average levels observed for urban sites.
- Between 1900 and 1970, emissions of the six principal pollutants increased significantly. For example, estimated emissions of nitrogen oxides (NO_x) increased 690 percent, volatile organic compounds increased 260 percent, and sulfur dioxide increased 210 percent. Without the pollution controls resulting from amendments to the Clean Air Act, emissions would have continued to increase at a higher rate.
- Since the 1970 Clean Air Act was signed into law, emissions of each of the six pollutants decreased, with the exception of NO_x. Between 1970 and 1999, emissions of NO_x increased 17 percent. The majority of this increase can be attributed to heavy-duty diesel vehicles and coal-fired power plants. EPA has major initiatives to reduce emissions of NO_x considerably from these sources. Emissions of NO_x contribute to the formation of ground-level ozone (smog), acid rain, and other environmental problems, even after being carried by the wind hundreds of miles from their original source.
- Estimates of nationwide air toxic emissions have dropped approximately 23 percent between 1990 and 1996. For example, perchloroethylene monitored in 16 urban sites in California showed a drop of 60 percent from 1989 to 1998. Benzene is another widely monitored toxic air pollutant. It is emitted from cars, trucks, oil refineries, and chemical processes. Measurements taken from 84 urban monitoring sites around the country show a 39-percent drop in benzene levels from 1993 to 1998.
- Since implementation of EPA's acid rain program in 1995, there have been dramatic reductions (10 to 25 percent) in sulfates deposited in many of the most acid sensitive ecosystems located in the Northeastern United States.
- Certain pollutants (such as some metals and organic chemicals) that are emitted from industrial sources can be deposited into water bodies and magnified through the food web, adversely affecting fish-eating animals and

Comparison of 1970 and 1999 Emissions



humans. Currently, about 2500 U.S. water bodies are under fish consumption advisories resulting from chemicals such as PCBs, chlordane, dioxins, and mercury.

- Scientific evidence shows that efforts taken to protect the stratospheric ozone layer have been effective to date. In 1996, measurements in the upper layers of the atmosphere showed concentrations of methyl chloroform had started to fall, indicating emissions had been greatly reduced. Concentrations of other ozone-depleting substances, like chlorofluorocarbons, are also beginning to decrease.

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. The average American breathes 3,400 gallons of air each day. Children are at greater risk because they are more active outdoors and their lungs are still developing. The elderly are also more sensitive to air pollution because they often have heart or lung diseases.

Air pollution, such as acid rain, ground-level ozone, and air toxics, can also significantly affect ecosystems. For example, ground-level ozone has been estimated to cause over \$500 million in annual reductions of agricultural and commercial forest yields, and airborne releases of NO_x are one of the largest sources of nitrogen pollution in certain water bodies such as the Chesapeake Bay.

The Causes

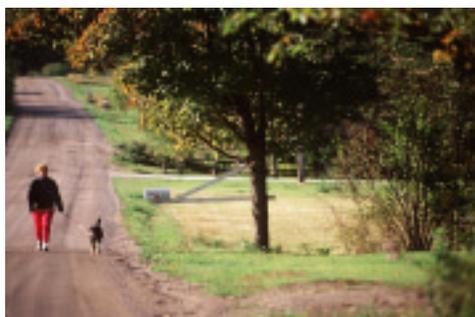
Air pollution comes from many different sources. “Stationary sources,” such as factories, power plants, and smelters; “area sources,” which are smaller sources such as dry cleaners and degreasing operations; “mobile sources,” such as cars, buses, planes, trucks, and trains; and “natural sources,” such as windblown dust and wildfires, all contribute to air pollution.

The Law

The Clean Air Act provides the principal framework for national, state, tribal, and local efforts to protect air quality. Under the Clean Air Act, which was last amended in 1990, EPA has a number of responsibilities, including:

- Setting national ambient air quality standards (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 sulfur dioxide and nitrogen oxides that cause acid rain.
- Reducing air pollutants such as particulate matter, sulfur oxides, and nitrogen oxides that can cause visibility impairment across large regional areas, including many of the nation’s most treasured parks and wilderness areas.
- Ensuring that sources of toxic air pollutants that cause or may cause cancer and other adverse human health and environmental effects are well controlled, and that 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.

While the focus of this report is on *national* air pollution, *global* air pollution issues such as destruction of the stratospheric ozone layer and the effect of global warming on the Earth’s climate are major concerns and are also discussed.



Six Principal Pollutants

Revised Ozone and Particulate Matter Standards

In 1997, EPA revised national air quality standards for ozone and particulate matter. The PM standard added an indicator for PM_{2.5} (particles less than or equal to 2.5 micrometers) to strengthen protection against smaller particles. The ozone standard changed from a 1-hour standard to an 8-hour standard to better reflect ozone health studies. In May 1999, the U.S. Court of Appeals for the District of Columbia Circuit remanded these standards back to EPA for further consideration. Following a denial of a petition for a rehearing by the D.C. Circuit, the Supreme Court has agreed to hear the case. Updates on this action can be found at <http://www.epa.gov/airlinks>.



Under the Clean Air Act, EPA establishes air quality standards to protect public health, including the health of “sensitive” populations such as asthmatics, children, and the elderly. EPA also sets limits to protect public

welfare, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

EPA has set national air quality standards for six principal pollutants (also referred to as criteria pollutants): carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO₂), ozone (O₃), particulate matter (PM), and sulfur dioxide (SO₂). [Note: The pollutant ozone is not emitted directly into the air, but is formed when sunlight acts on emissions of nitrogen oxides (NO_x) and volatile organic compounds (VOCs).]

Each year EPA examines changes in levels of these pollutants over time and summarizes the current air pollution status.

Percent Change in Air Quality
1980–1999 1990–1999

CO	-57	-36
Pb	-94	-60
NO ₂	-25	-10
O ₃ 1-hr	-20	-4
8-hr	-12	no change
PM ₁₀	—	-18
SO ₂	-50	-36

Summary of Air Quality and Emissions Trends

EPA tracks trends in *air quality* based on actual measurements of pollutant concentrations in the ambient (outside) air at monitoring sites across the country. Monitoring stations are operated by state, tribal, and local government agencies as well as some federal agencies, including EPA. Trends are derived by averaging direct measurements from these monitoring stations on a yearly basis. The chart at the left shows that the air quality based on concentrations of the principal pollutants has improved nationally over the last 20 years (1980–1999). The most notable improvements are seen for Pb, CO, and SO₂ with 94-, 57- and 50-percent reductions, respectively.

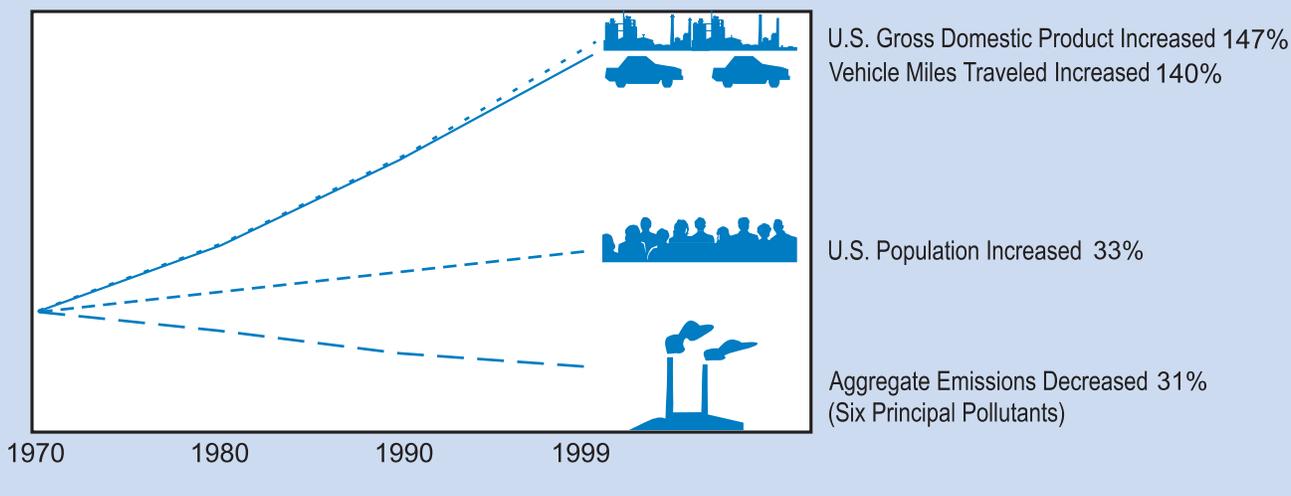
Percent Change in Emissions
1980–1999 1990–1999

CO	-22	-7
Pb	-95	-23
NO _x	+1	+2
VOC	-33	-15
PM ₁₀	-55	-16
SO ₂	-28	-21

EPA estimates nationwide *emissions* 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 the level of industrial activity, technology developments, fuel consumption, vehicle miles traveled, and other activities that cause air pollution. Emissions estimates also reflect changes in air pollution regulations and installation of emissions controls. The 1999 emissions reported in this summary report are projected numbers based on available 1999 information and historical trends. Check <http://www.epa.gov/ttn/chief> for updated emissions information. As shown in the chart at the lower left, emissions of the principal pollutants have decreased over the last 20 years (1980–1999), with the exception of NO_x. Nitrogen oxides emissions increased 1 percent over the last 20 years and 2 percent over the more recent 10-year period, 1990 to 1999.

Air quality concentrations do not always track nationwide emissions. Because most monitors are located in or near urban areas, air quality trends are affected by urban emissions which are sometimes different than nationwide emissions. Year-to-year air quality trends can also be affected by atmospheric conditions and other factors.

Comparison of Growth Areas and Emission Trends

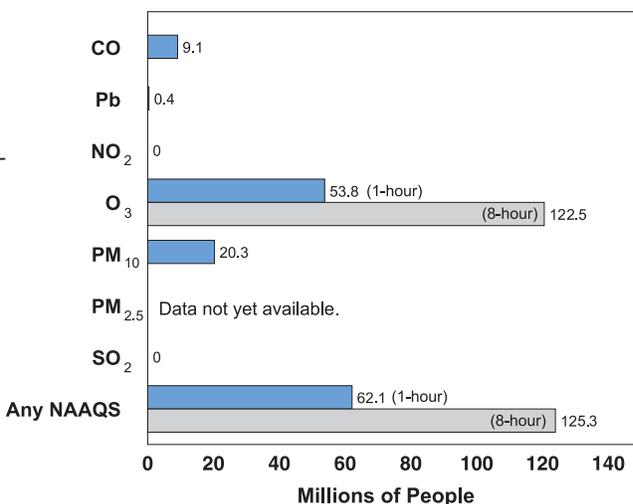


Between 1970 and 1999, U.S. population increased 33 percent, vehicle miles traveled increased 140 percent, and gross domestic product increased 147 percent. At the same time, total emissions of the six principal air pollutants decreased 31 percent.

Between 1970 and 1999, total emissions of the six principal air pollutants decreased 31 percent. This dramatic improvement occurred simultaneously with significant increases in economic growth and population. The improvements are a result of effective implementation of clean air laws and regulations, as well as improvements in the efficiency of industrial technologies.

Despite great progress in air quality improvement, approximately 62 million people nationwide still lived in counties with pollution levels above the national air quality standards in 1999. This number does not take into consideration the 8-hour ozone standard.

Number of People Living in Counties with Air Quality Concentrations Above the Level of the NAAQS in 1999

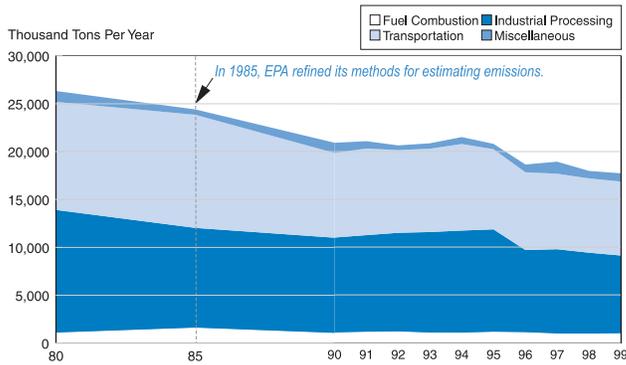


Blue bars represent 8-hour standard for ozone.

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Ground-Level Ozone (O₃)

VOC Emissions, 1980–1999

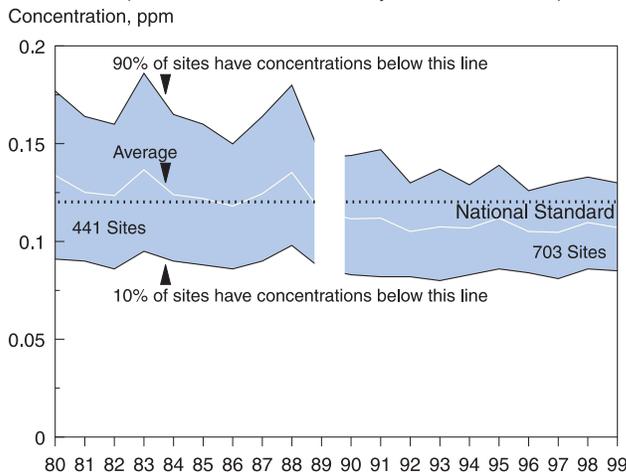


1980–99: 33% decrease
1990–99: 15% decrease

Air quality concentrations do not always track nationwide emissions. Because most monitors are located in or near urban areas, air quality trends are affected by urban emissions which are sometimes different than nationwide emissions. Year-to-year air quality trends can also be affected by atmospheric conditions and other factors.

Ozone Air Quality, 1980–1999

(Based on Annual 2nd Daily 1-Hour Maximum)



1980–99: 20% decrease
1990–99: 4% decrease

Because few sites have 20 years of data, EPA used two consecutive 10-year periods to construct this 20-year trend.



Nature and Sources of the Pollutant

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

Ozone occurs naturally in the stratosphere and provides a protective layer high above the Earth. See page 22 for more information on the stratospheric ozone layer.

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. Nitrogen oxides are 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 precursor pollutants that cause ozone also can be transported into an area from pollution sources found hundreds of miles upwind.

Health and Environmental Effects

Short-term (1–3 hours) and prolonged (6–8 hours) exposures to ambient ozone have been linked to a number of health effects of concern. For example, increased hospital admissions and emergency room visits for respiratory causes have been associated with ambient ozone exposures. Exposures to ozone can make people more susceptible to respiratory infection, result in lung inflammation, and aggravate pre-existing respiratory diseases such as asthma. Other health effects attributed to ozone exposures include significant decreases in lung function and increased respiratory symptoms such as chest pain and cough. These effects generally occur while individuals are engaged in exertion. 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 pre-existing respiratory disease such as asthma and chronic lung 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 worsen chronic respiratory illnesses.

Ozone also affects vegetation and ecosystems, leading to reductions in agricultural 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 also can decrease the aesthetic value of ornamental species as well as the natural beauty of our national parks and recreation areas.

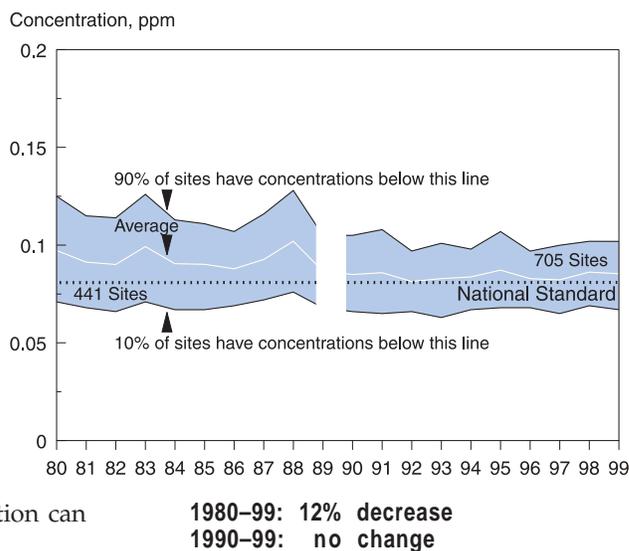
Trends in Ozone Levels

In 1997, EPA revised the national ambient air quality standard for ozone by setting a new 8-hour 0.08 ppm standard. Currently, EPA is tracking trends based on the 1-hour and 8-hour data. As of the publication date of this report, the 8-hour standard is under legal challenge. Updates on this action can be found at <http://www.epa.gov/airlinks>.

Over the past 20 years, ambient ozone levels decreased 20 percent based on 1-hour data, and 12 percent based on 8-hour data. Between 1980 and 1999, emissions of VOCs have decreased 33 percent. During that same time period, emissions of NO_x increased 1 percent.

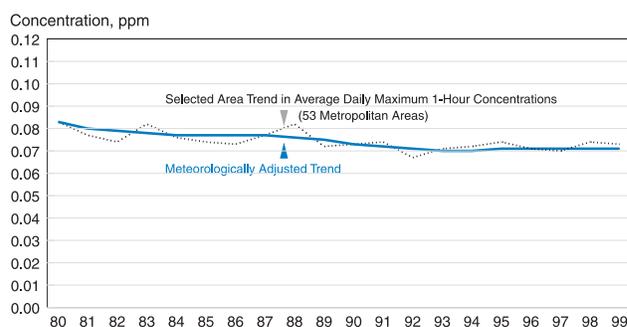
Because sunlight and heat play a major role in ozone formation, changing weather patterns contribute to yearly differences in ozone concentrations. To better reflect the changes that emissions have on measured air quality concentrations, EPA is able to make analytical adjustments to account for this annual variability in meteorology. For 53 metropolitan areas, the adjusted trend for 1-hour ozone levels shows steady improvement from 1980 through the mid-1990s. The adjusted ozone levels decreased an average of 1 percent per year through 1994. However, beginning in 1994, the improvement appears to slow.

Ozone Air Quality, 1980–1999
(Based on Annual 4th Daily 8-Hour Maximum)



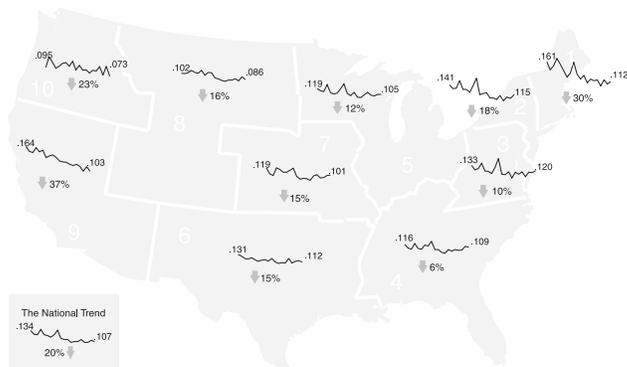
Because few sites have 20 years of data, EPA used two consecutive 10-year periods to construct this 20-year trend.

Comparison of Actual and Meteorologically Adjusted 1-hour Ozone Trends, 1980–1999



Trend in 1-Hour Ozone Levels, 1980–1999 Averaged Across EPA Regions

(Based on Annual Second Highest Daily Maximum)



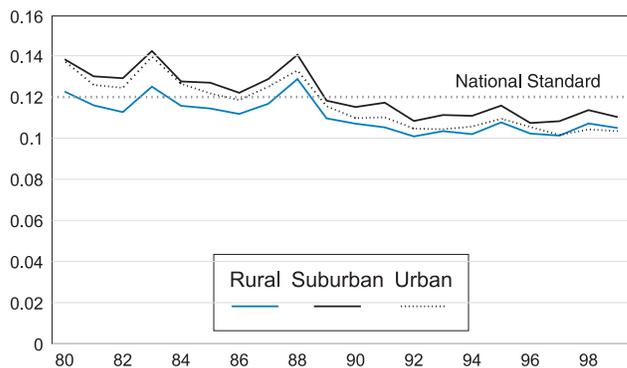
Alaska is in EPA Region 10; Hawaii, EPA Region 9; and Puerto Rico, EPA Region 2. Concentrations are ppm.

For the period 1980 to 1999, the downward trend in 1-hour ozone levels seen nationally is reflected in every broad geographic area in the country. The Northeast and West exhibit the most substantial improvement while the South has experienced the least rapid progress in lowering ozone concentrations.

Across the country, the highest ambient ozone concentrations are typically found at suburban sites, consistent with the downwind transport of emissions from urban centers. During the past 20 years, ozone concentrations decreased almost 25 percent at urban sites (121 such sites between 1990 and 1999, and 96 between 1980 and 1989) and declined by 20 percent at suburban sites (325 such sites between 1990 and 1999, and 215 between 1980 and 1989). For the more recent 10-year period, urban sites show decreases of approximately 6 percent and suburban sites show 4-percent decreases. However, at rural monitoring locations, 1-hour ozone levels for 1999 are only 14 percent lower than those in 1980 and only 2 percent below 1990 levels. In 1999, for the second consecutive year, average rural 1-hour ozone levels are greater than the levels observed for the urban sites.

Trend in 1-Hour Ozone Levels, 1980–1999 by Location of Site

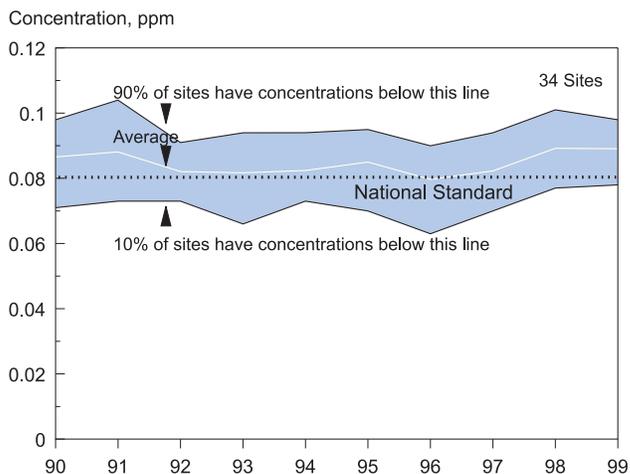
(Based on Annual Second Highest Maximum)



Over the last 10 years, 8-hour ozone levels in 25 of our national parks increased nearly 8 percent. Nine monitoring sites in eight of these parks experienced statistically significant upward trends in 8-hour ozone levels: Great Smoky Mountain (TN), Big Bend (TX), Cape Romain (SC), Cowpens (SC), Denali (AK), Everglades (FL), Mammoth Cave (KY), and Voyageurs (MN). For the remaining 17 parks, the 8-hour ozone levels at eight increased only slightly between 1990 and 1999, while seven showed decreasing levels, and two were unchanged.

Trend in 8-Hour Ozone Levels, 1990–1999 At Rural Eastern U.S. Monitoring Locations

(Based on Annual Fourth Highest Maximum)



Additional data from rural sites in the eastern United States show increases in 8-hour ozone levels similar to those found in the national parks over the last 10 years. The 8-hour ozone levels at these 34 rural sites, which were the highest during the hot and dry summers of 1991 and 1998, increased 6 percent over the last 10 years.

Particulate Matter (PM₁₀)

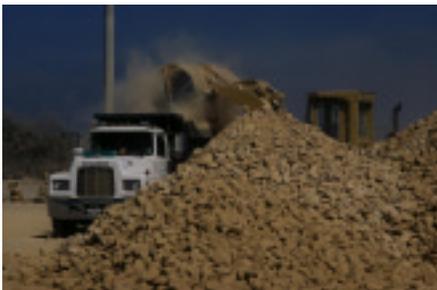
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Nature and Sources of the Pollutant

Particulate matter (PM) is the general term used for a mixture of solid particles and liquid droplets found in the air. Some particles are large or dark enough to be seen as soot or smoke. 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 micrometers in diameter. “Coarse” particles refers to particles greater than 2.5, but less than or equal to 10 micrometers in diameter. PM₁₀ refers to all particles less than or equal to 10 micrometers in diameter. Ten micrometers are about one-seventh the diameter of human hair. These particles originate from many different stationary and mobile sources as well as from natural sources. Fine particles result from fuel combustion from motor vehicles, power generation, and industrial facilities, as well as from residential fireplaces and wood stoves. Coarse particles are generally emitted from sources such as vehicles traveling on unpaved roads, materials handling, crushing and grinding operations, and windblown dust. Some particles are emitted directly from their sources, such as smokestacks and cars. In other cases, gases such as SO₂, NO_x, and VOCs interact with other compounds in the air to form fine particles. Their chemical and physical compositions vary depending on location, time of year, and weather.

Health and Environmental Effects

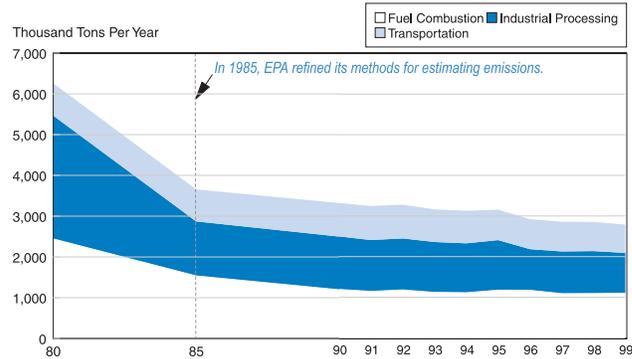
Particulate matter includes both fine and larger coarse particles. When breathed, these particles can accumulate in the respiratory system and are associated with numerous health effects. Exposure to coarse particles is primarily associated with the aggravation of respiratory conditions, such as asthma. Fine particles are most closely associated with such health effects as increased hospital admissions and emergency room visits for heart and lung disease, increased respiratory symptoms and disease, decreased lung function, and even premature death. Sensitive groups that appear to be at greatest risk to such effects include the elderly, individuals with cardiopulmonary disease such as asthma, and children. 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.



Trends in PM₁₀ Levels

Between 1990 and 1999, average PM₁₀ concentrations decreased 18 percent, while PM₁₀ emissions decreased 16 percent.

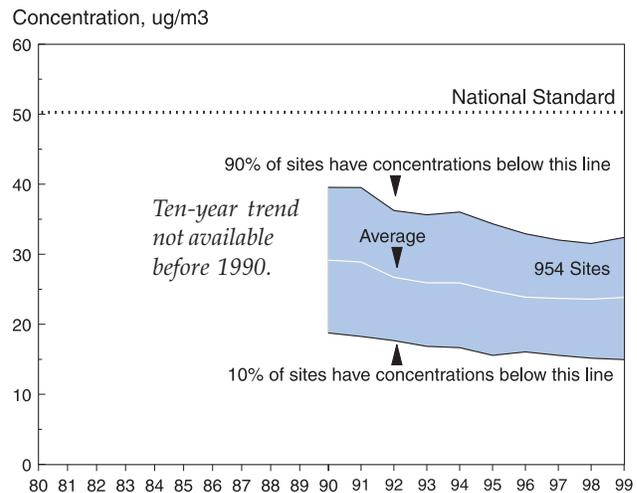
PM₁₀ Emissions from Man-Made Sources, 1980–1999



1980–99: 55% decrease
1990–99: 16% decrease

Air quality concentrations do not always track nationwide emissions. Because most monitors are located in or near urban areas, air quality trends are affected by urban emissions which are sometimes different than nationwide emissions. Year-to-year air quality trends can also be affected by atmospheric conditions and other factors.

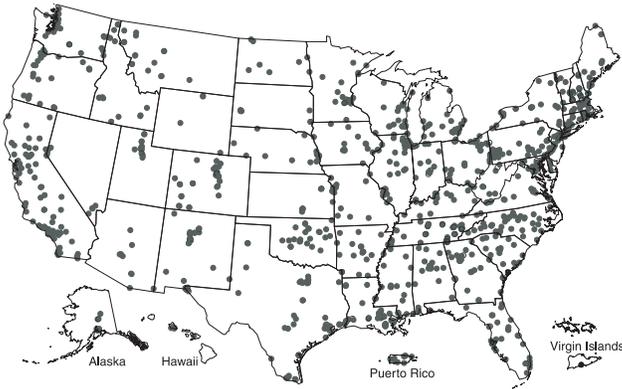
PM₁₀ Air Quality, 1980–1999
(Based on Annual Arithmetic Mean)



1990–99: 18% decrease

Fine Particulate Matter (PM_{2.5})

New PM_{2.5} Monitoring Network



Complete data from the new PM_{2.5} monitoring network will be available later in 2000. However, EPA is able to present PM_{2.5} data from a preexisting monitoring network of rural sites. The map below shows that rural PM_{2.5} concentrations vary regionally, with sites in the East typically having higher annual average concentrations. The pie charts indicate the chemical constituents of PM_{2.5} at each location.

Characterizing PM_{2.5} Trends

EPA is not yet able to characterize long term trends for PM_{2.5} for urban areas. In early 1999 EPA initiated a new monitoring network to begin assessing the nature of the PM_{2.5} problem. By December 2000 the network will consist of approximately 1,700 monitors at over 1,100 sites, as shown in the map on the left. EPA will begin analyzing preliminary PM_{2.5} monitoring data later in 2000 and future reports will reflect data gathered from this new network.

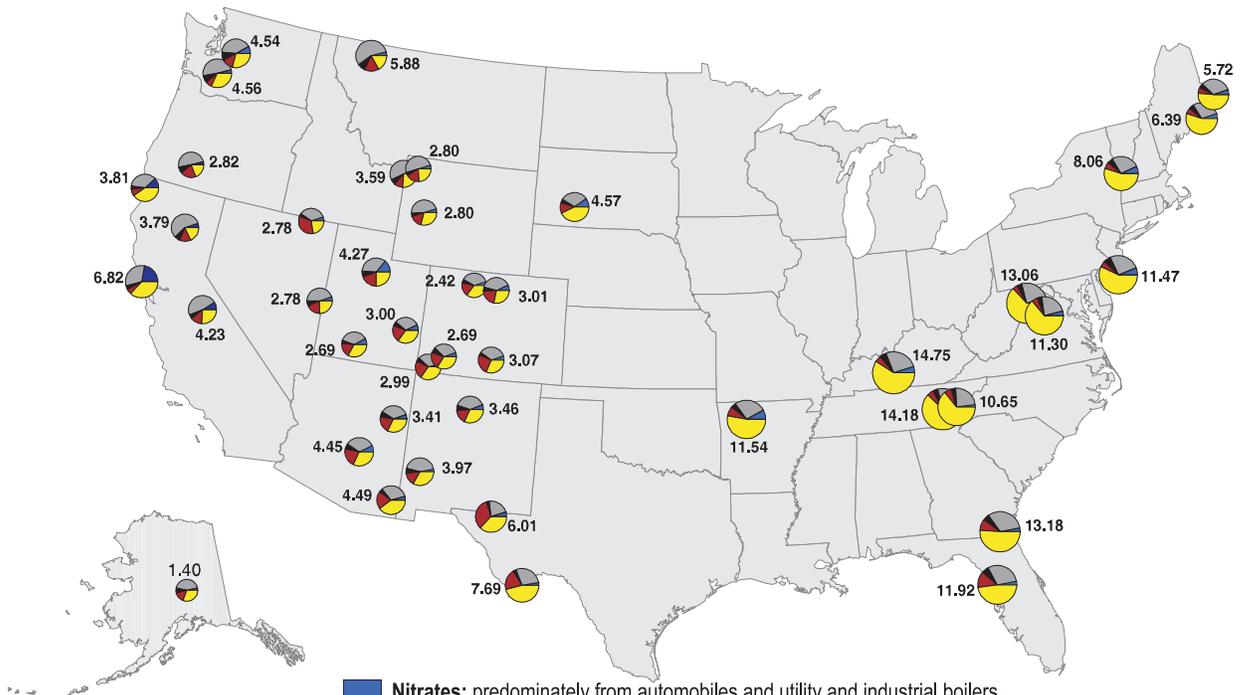
EPA does have some air quality monitoring data for PM_{2.5} from a network that has tracked levels of this pollutant at National Parks and other rural sites.

While these data cannot be used for compliance purposes (i.e., to tell whether or not an area meets the PM_{2.5} standard), they provide a good indication of PM_{2.5}

Revised Particulate Matter Standards

In 1997, EPA added two new PM_{2.5} standards, set at 15 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) and 65 $\mu\text{g}/\text{m}^3$, respectively, for the annual and 24-hour standards. EPA is beginning to collect monitoring data on PM_{2.5} concentrations.

1998 Annual Average PM_{2.5} Concentrations (in $\mu\text{g}/\text{m}^3$) in Rural Areas



Source: Interagency Monitoring of Protected Visual Environments Network, 1998.

- Nitrate: predominately from automobiles and utility and industrial boilers.
- Organic Carbon: from sources such as automobiles, trucks, and industrial processes.
- Elemental Carbon (soot): from diesel, wood, and other combustion.
- Crustal Material (soil dust): from roads, construction, and agricultural activities.
- Sulfate: predominately from utility and industrial boilers.

concentrations and trends in rural areas, as well as the sources of the fine particles at the various locations.

As shown in the map, rural PM_{2.5} concentrations vary regionally. Sites in the rural east typically have higher PM_{2.5} concentrations. Of the 12 eastern sites, 10 have higher annual averages of measured PM_{2.5} than any sites in the west. Much of this difference can be attributed to the high amounts of sulfate at the eastern sites. Sulfates predominately result from sulfur dioxide emissions from coal-fired power plants and industrial boilers.

Sulfate and organic carbon (from sources such as automobiles, trucks, and industrial processes) constitute most of the PM_{2.5} concentrations in both the east and the west. However, sites in the east have on average a much higher percentage of sulfate concentrations than those in the west.

Percent Contribution to PM_{2.5} by Pollutant, 1998

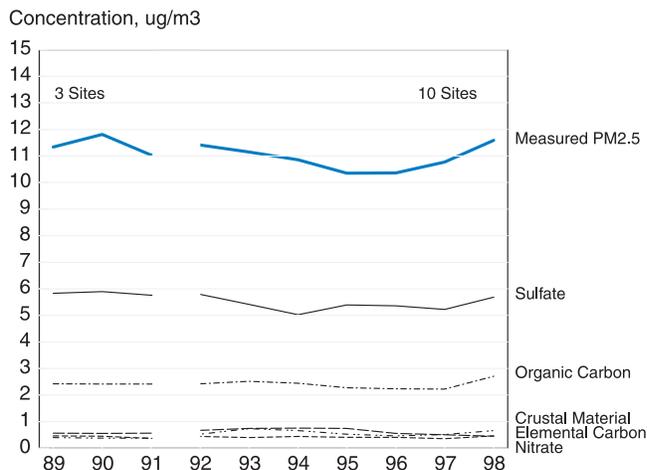
	East	West
Sulfate	56	33
Organic Carbon	27	36
Nitrate	5	8
Elemental Carbon (soot)	5	6
Crustal Material (soil dust)	7	17

PM_{2.5} Trends in Rural Areas

Because of the significant regional variations in rural PM_{2.5} concentrations, the analysis in this report aggregates the trends separately for the eastern and western parts of the nation. In the rural east, average PM_{2.5} concentrations decreased 9 percent between 1992 to 1995, then increased 12 percent from 1995 to 1998. Much of the recent increase tracks increased emissions of sulfur dioxide from coal-fired power plants not yet regulated under EPA's Acid Rain Program. Beginning in 2000, these plants will be controlled under Phase II of the Acid Rain Program. The net change in the average PM_{2.5} concentrations in the rural East between 1992 and 1998 is a 2-percent increase.

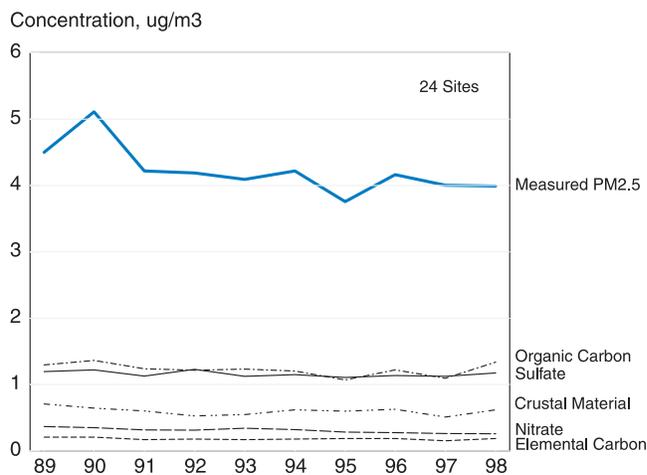
Average PM_{2.5} trends in the rural west showed a decrease of 5 percent from 1992 to 1998, and a decrease of 11 percent over the longer, 10-year period from 1989 to 1998.

Average PM_{2.5} Concentrations, 1989–1998 at Rural Eastern U.S. Sites



This plot shows average concentrations for sites having available trend data in the East. Ten sites have trend data between 1992 and 1998, and three of those 10 sites have trend data prior to 1992.

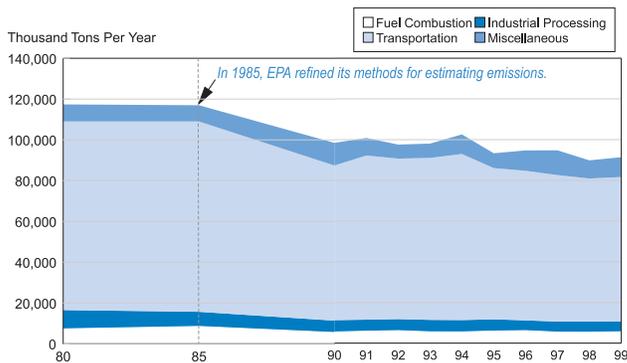
Average PM_{2.5} Concentrations, 1989–1998 at Rural Western U.S. Sites



This plot shows average concentrations for sites having available trend data in the West.

3 Carbon Monoxide (CO)

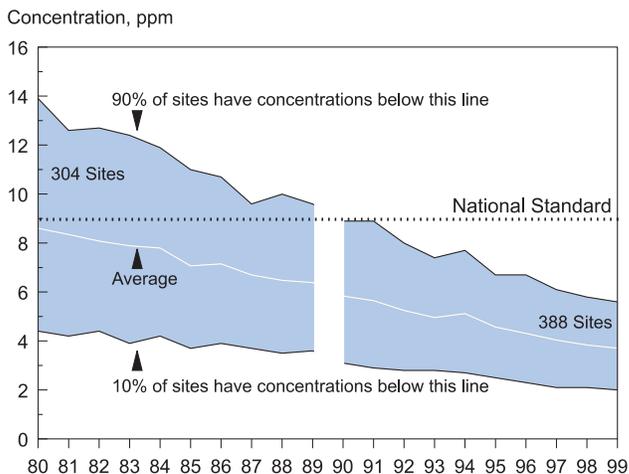
CO Emissions, 1980–1999



1980–99: 22% decrease
1990–99: 7% decrease

Air quality concentrations do not always track nationwide emissions. Because most monitors are located in or near urban areas, air quality trends are affected by urban emissions which are sometimes different than nationwide emissions. Year-to-year air quality trends can also be affected by atmospheric conditions and other factors.

CO Air Quality, 1980–1999
 (Based on Annual 2nd Maximum 8-hour Average)



1980–99: 57% decrease
1990–99: 36% decrease

Because few sites have 20 years of data, EPA used two consecutive 10-year periods to construct this 20-year trend.

Nature and Sources of the Pollutant

Carbon monoxide (CO) is a colorless, odorless and, at high levels, a poisonous 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. Non-road vehicles account for the remaining CO emissions from the transportation sources category. 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, non-transportation 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.

Health and Environmental Effects

Carbon monoxide enters the bloodstream through the lungs and reduces oxygen delivery to the body's organs and tissues. The health threat from lower levels of CO is most serious for those who suffer from cardiovascular disease, such as angina pectoris. At much higher levels of exposure, CO can be poisonous, and 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

Nationally, the 1999 ambient average CO concentration is 57 percent lower than that for 1980 and is the lowest level recorded during the past 20 years. CO emissions levels decreased 22 percent over the same period. Between 1990 and 1999, ambient CO concentrations decreased 36 percent, and the estimated number of exceedances of the national standard decreased 93 percent while CO emissions fell 7 percent. This improvement occurred despite a 30-percent increase in vehicle miles traveled in the United States during this period.



Lead (Pb) 4



Nature and Sources of the Pollutant

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, the contribution from the transportation sector has declined over the past decade. Today,

industrial processes, primarily metals processing, are the major source of lead emissions to the atmosphere. The highest air concentrations of lead are found in the vicinity of nonferrous and ferrous smelters, and battery manufacturers.

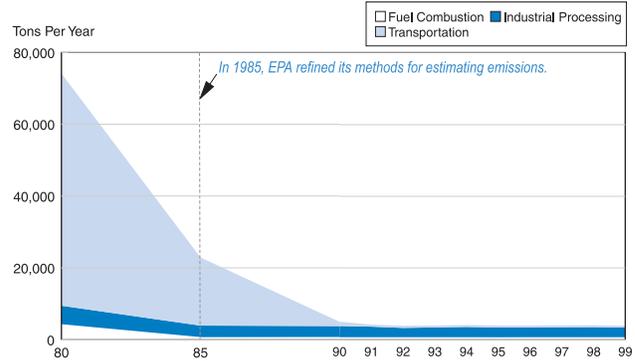
Health and Environmental Effects

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. Lead 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.

Trends in Lead Levels

Because of the phase-out of leaded gasoline, lead emissions and concentrations decreased sharply during the 1980s and early 1990s. The 1999 average air quality concentration for lead is 94 percent lower than in 1980. Emissions of lead decreased 95 percent over that same 20-year period. Today, the only violations of the lead national air quality standard occur near large industrial sources such as lead smelters.

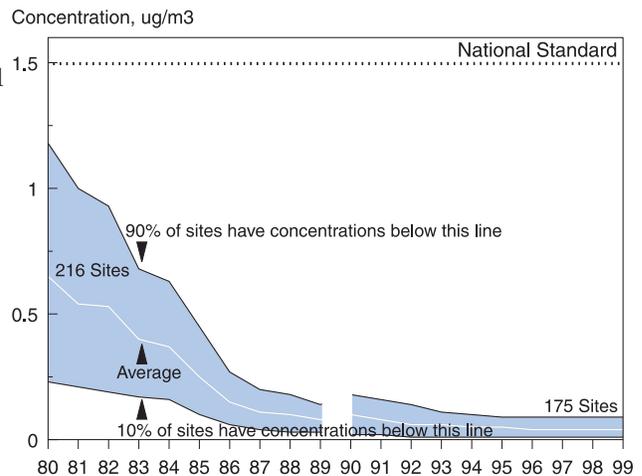
Lead Emissions, 1980–1999



1980–99: 95% decrease
1990–99: 23% decrease

Air quality concentrations do not always track nationwide emissions. Because most monitors are located in or near urban areas, air quality trends are affected by urban emissions which are sometimes different than nationwide emissions. Year-to-year air quality trends can also be affected by atmospheric conditions and other factors.

Lead Air Quality, 1980–1999
(Based on Annual Maximum Quarterly Average)

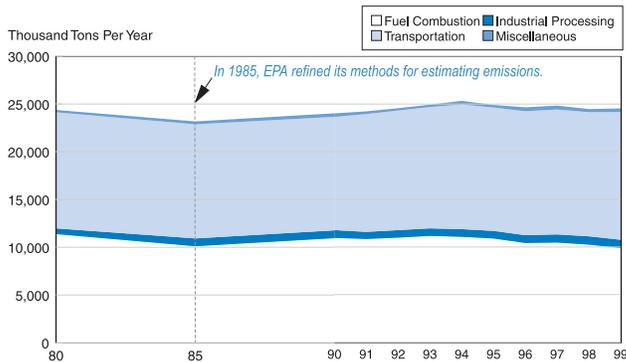


1980–99: 94% decrease
1990–99: 60% decrease

Because few sites have 20 years of data, EPA used two consecutive 10-year periods to construct this 20-year trend.

5 Nitrogen Dioxide (NO₂)

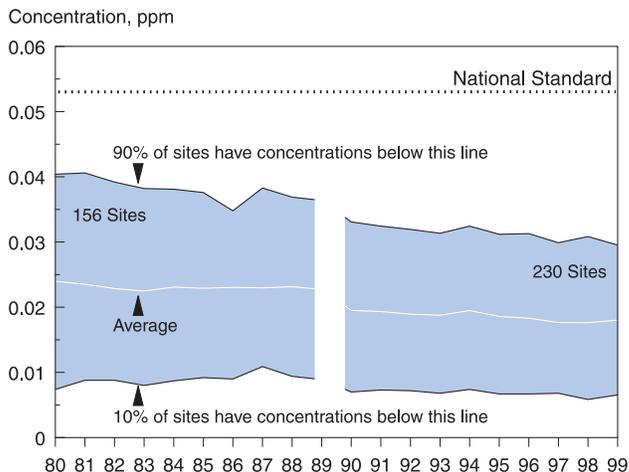
NO_x Emissions, 1980–1999



1980–99: 1% increase
1990–99: 2% increase

Air quality concentrations do not always track nationwide emissions. Because most monitors are located in or near urban areas, air quality trends are affected by urban emissions which are sometimes different than nationwide emissions. Year-to-year air quality trends can also be affected by atmospheric conditions and other factors.

NO₂ Air Quality, 1980–1999
 (Based on Annual Arithmetic Average)



1980–99: 25% decrease
1990–99: 10% decrease

Because few sites have 20 years of data, EPA used two consecutive 10-year periods to construct this 20-year trend.

Nature and Sources of the Pollutant

Nitrogen dioxide (NO₂) 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 term used to describe the sum of NO, NO₂ and other oxides of nitrogen, play a major role in the formation of ozone, particulate matter, and acid rain. The major sources of man-made NO_x emissions are high-temperature combustion processes, such as those occurring in automobiles and power plants. Home heaters and gas stoves also produce substantial amounts of NO₂ in indoor settings.

Health and Environmental Effects

Short-term exposures (e.g., less than 3 hours) to low levels of nitrogen dioxide (NO₂) may lead to changes in airway responsiveness and lung function in individuals with pre-existing respiratory illnesses and increases in respiratory illnesses in children (5–12 years old). Long-term exposures to NO₂ may lead to increased susceptibility to respiratory infection and may cause permanent alterations in the lung. Nitrogen oxides react in the air to form ground-level ozone and fine particle pollution which are both associated with adverse health effects.

Nitrogen oxides contribute to a wide range of environmental effects, including the formation of acid rain and potential changes in the composition and competition of some species of vegetation in wetland and terrestrial systems, visibility impairment, acidification of freshwater bodies, eutrophication (i.e., excessive algae growth leading to a depletion of oxygen in the water) of estuarine and coastal waters (e.g., Chesapeake Bay), and increases in levels of toxins harmful to fish and other aquatic life.

Trends in NO₂ Levels

Over the past 20 years, monitored levels of NO₂ have decreased 25 percent. All areas of the country that once violated the national air quality standard for NO₂ now meet that standard. While levels around urban monitors have fallen, national emissions of nitrogen oxides (which include NO, NO₂ and other oxides of nitrogen) have actually increased over the 20 years by one percent. This increase is the result of a number of factors, the largest being an increase in nitrogen oxides emissions from off-highway diesel vehicles. This increase is of concern because NO_x emissions contribute to the formation of ground-level ozone (smog), but also to other environmental problems, like acid rain and nitrogen loadings to water bodies.



Sulfur Dioxide (SO₂) 6

Nature and Sources of the Pollutant

Sulfur dioxide belongs to the family of sulfur oxide gases. These gases are formed when fuel containing sulfur (mainly coal and oil) is burned and during metal smelting and other industrial processes. Most SO₂ monitoring stations are located in urban areas. The highest monitored concentrations of SO₂ are recorded in the vicinity of large industrial facilities. Fuel combustion, largely from coal-fired power plants, accounts for most of the total SO₂ emissions.

Health and Environmental Effects

High concentrations of SO₂ can result in temporary breathing impairment for asthmatic children and adults who are active outdoors. Short-term exposures of asthmatic individuals to elevated SO₂ levels while at moderate exertion may result in breathing difficulties that may be accompanied by such symptoms as wheezing, chest tightness, or shortness of breath. Other effects that have been associated with longer-term exposures to high concentrations of SO₂, in conjunction with high levels of PM, include respiratory illness, alterations in the lungs' defenses, and aggravation of existing cardiovascular disease. The subgroups of the population that may be affected under these conditions include individuals with cardiovascular disease or chronic lung disease, as well as children and the elderly.

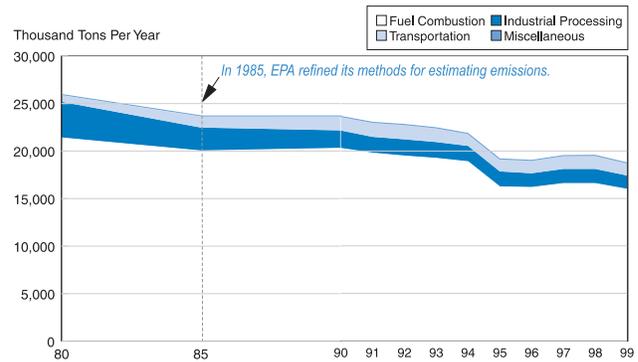
Together, SO₂ and NO_x are the major precursors to acidic deposition (acid rain), which is associated with the acidification of soils, lakes, and streams, accelerated corrosion of buildings and monuments. Sulfur dioxide also is a major precursor to PM_{2.5}, which is a significant health concern as well as a main pollutant that impairs visibility.

Trends in SO₂ Levels

Nationally, average SO₂ ambient concentrations have decreased 50 percent from 1980 to 1999 and 36 percent over the more recent 10-year period 1990–1999. SO₂ emissions decreased 28 percent from 1980 to 1999 and 21 percent from 1990 to 1999. Reductions in SO₂ concentrations and emissions since 1994 are due, in large part, to controls implemented under EPA's Acid Rain Program beginning in 1995.



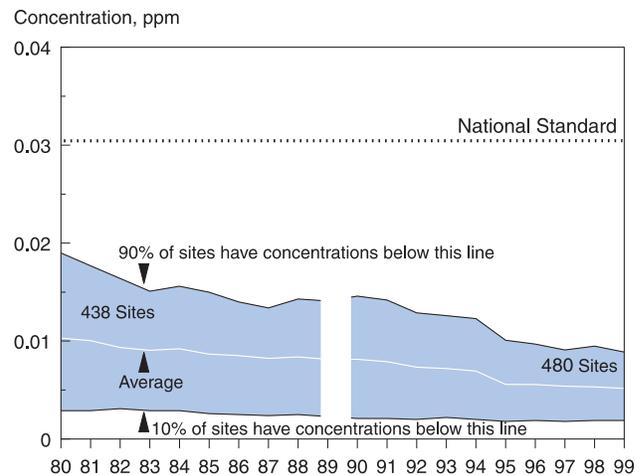
SO₂ Emissions, 1980–1999



1980–99: 28% decrease
1990–99: 21% decrease

Air quality concentrations do not always track nationwide emissions. Because most monitors are located in or near urban areas, air quality trends are affected by urban emissions which are sometimes different than nationwide emissions. Year-to-year air quality trends can also be affected by atmospheric conditions and other factors.

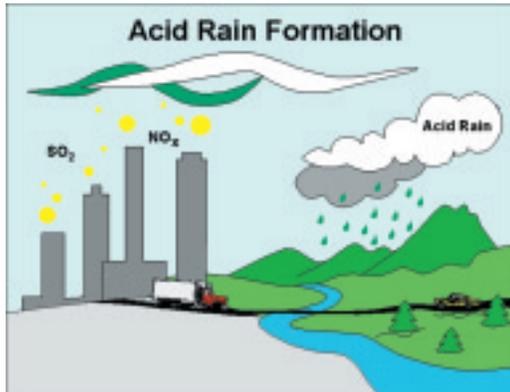
SO₂ Air Quality, 1980–1999
(Based on Annual Arithmetic Mean)



1980–99: 50% decrease
1990–99: 36% decrease

Because few sites have 20 years of data, EPA used two consecutive 10-year periods to construct this 20-year trend.

Acid Rain



Coal-fired electric utilities and other sources that burn fossil fuels emit sulfur dioxide and nitrogen oxides.

Nature and Source of the Problem

Acidic deposition or “acid rain” occurs when emissions of sulfur dioxide (SO₂) and oxides of nitrogen (NO_x) 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 64 percent of annual SO₂ emissions and 26 percent of NO_x emissions are produced by electric utility plants that burn fossil fuels.

Health and Environmental Effects

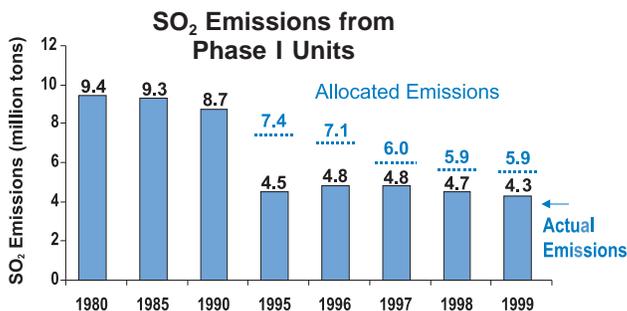
Before falling to the Earth, SO₂ and NO_x gases and related particulate matter (sulfates and nitrates) contribute to poor visibility and impact public health. Major human health concerns associated with their exposure include effects on breathing and the respiratory system, damage to lung tissue, and premature death. In the environment, acid rain raises the acid levels in soils and water bodies (making the water unsuitable for some fish and other wildlife), and damages some trees at high elevations. It also speeds the decay of buildings, statues, and sculptures that are part of our national heritage. Reductions in SO₂ and NO_x have begun to greatly reduce these negative environmental effects and are leading to significant improvements in public health.

Program Structure

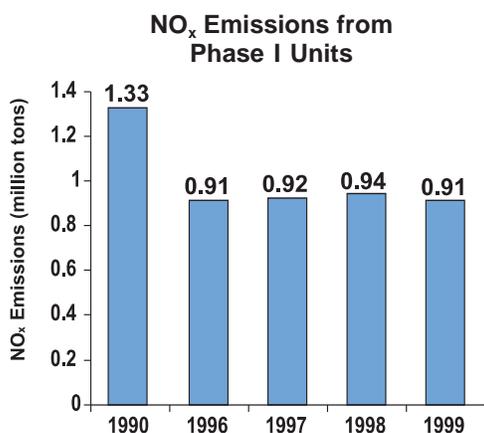
The goal of EPA’s Acid Rain Program, established by the Clean Air Act, is to improve public health and the environment by reducing emissions of SO₂ and NO_x. The program is being implemented in two phases: Phase I began in 1995 for SO₂ and targets the largest and highest-emitting coal-fired power plants (boilers). Phase I for NO_x began in 1996. Phase II for both pollutants began in 2000 and sets restrictions on smaller coal-, gas-, and oil-fired plants.

The Acid Rain Program will reduce annual SO₂ emissions by 10 million tons from 1980 levels by 2010. The program sets a permanent cap on the total amount of SO₂ that may be emitted by power plants nationwide at about half of the amount emitted in 1980. An emissions trading program is in effect to achieve the required emission reduction more cost effectively. This approach gives utilities the flexibility and incentive to reduce emissions at the lowest cost, while ensuring that the overall emission limit is met.

The NO_x component of the Acid Rain Program establishes an emission rate limit for all affected utilities, resulting in a 2 million ton NO_x reduction from 1980 levels by year 2000. Under this program, the industry can choose to over-control 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.



In 1999, actual emissions at the 263 highest-emitting Phase I units were 1.6 million tons below their allocated level.



1999 emissions from 265 NO_x Phase I units decreased 32 percent from 1990 levels.

Emissions and Atmospheric Trends

SO₂ emissions reductions have been significant in the first 5 years of compliance with EPA’s Acid Rain Program. As shown in the graph to the left, the Phase I utility units continued to emit well below the allocated emission levels required by the Clean Air Act. Additional units elected to participate early, bringing the total number of Phase I units to 398 in 1999. These 398 units emitted 4.9 million tons, which continues to be well below (28 percent) the 1999 allocated emissions level for SO₂.

Actual NO_x emissions, as shown in the graph to the left, have also declined since 1990. NO_x emissions decreased by approximately 424,000 tons (32 percent) from 1990 levels. NO_x emissions in 1999 decreased slightly (3 percent) from 1998 levels.

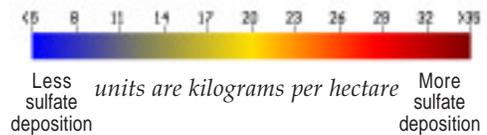
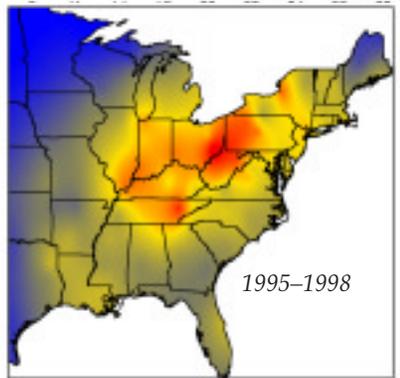
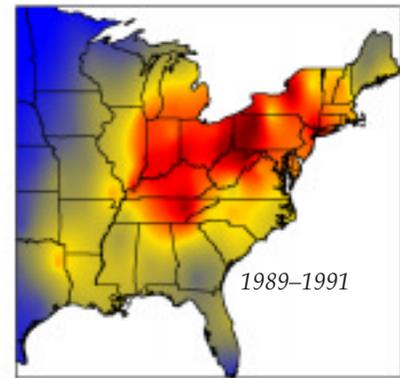
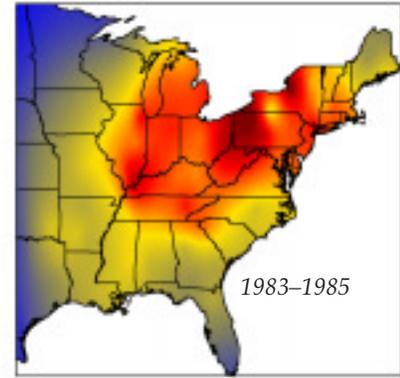
For all years from 1995 through 1998, both deposition and concentrations of sulfates in precipitation exhibited dramatic and unprecedented reductions over a large area of the eastern United States.

Deposition vs. Concentration

Think of putting the same amount of salt into two different glasses of water (one full and one half-full). The total amount (deposition) is the same, but the solution in the half-full glass has a greater concentration.

Sulfate concentrations have been estimated to be 10 to 25 percent lower than they would have been if the trend from 1983 through 1994 had continued. Similarly, sulfate deposition has also been reduced (10 to 25 percent) over a large portion of the eastern United States (see figures at right). These reductions in acid precipitation are directly related to the large regional decreases in SO₂ emissions resulting from Phase I of the Acid Rain Program. The largest reductions in sulfate concentrations occurred along the Ohio River Valley and in states immediately downwind. The largest reductions in wet sulfate depositions occurred across the Mid-Appalachian and Northeast regions of the country. 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. Nitrate concentrations were not appreciably different in 1995 to 1998 from historical levels.

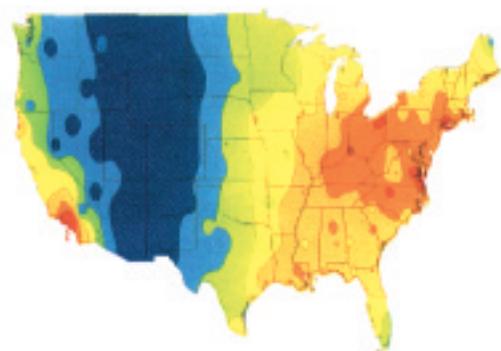
Trends in Sulfate Deposition in Precipitation



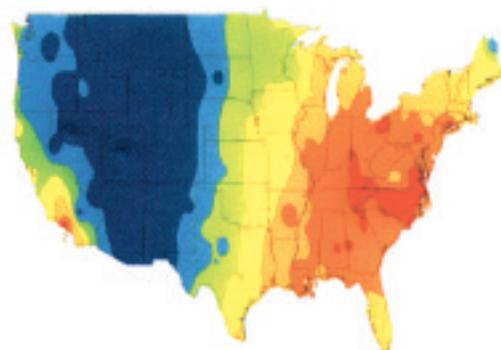
These maps represent snapshots of wet sulfate deposition over time. As shown in the lower map, the most significant reductions occur following the 1995 implementation of EPA’s Acid Rain Program. The greatest reductions occur in the northeastern United States, where many of the most acid sensitive ecosystems are located.

Source: J. A. Lynch, et al., 2000. Atmospheric Environment and GAO Report (GAO/RCED-00-47).

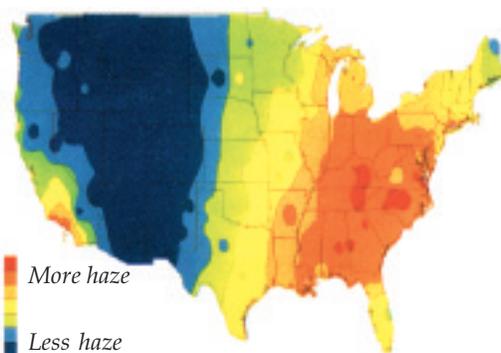
Visibility



1970



1980



1990

Maps from airport visual data show the amount of summertime haze (visibility impairment). Haze in the Eastern United States increased significantly between 1970 and 1980 and decreased slightly between 1980 and 1990.

The Clean Air Act provides for the protection of visibility in national parks and wilderness areas, also known as class I areas. These include many of the best known and most treasured natural areas, such as the Grand Canyon, Yosemite, Yellowstone, Mount Rainier, Shenandoah, the Great Smokies, Acadia, and the Everglades. 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.

Nature and Sources of the Problem

Visibility impairment is one of the most obvious effects of air pollution. Visibility impairment occurs as a result of the scattering and absorption of light by air pollution, including particles and gases. In addition to limiting the distance that we can see, the scattering and absorption of light caused by air pollution can also degrade the color, clarity, and contrast of scenes. The same particles that are linked to serious health effects can also significantly affect our ability to see.

Both primary emissions and secondary formation of particles contribute to visibility impairment. "Primary" particles, such as dust from roads or elemental carbon (soot) from wood combustion, are emitted directly into the atmosphere. "Secondary" particles are formed in the atmosphere from primary gaseous emissions. Examples include sulfate, formed from sulfur dioxide (SO_2) emissions from power plants and other industrial facilities; and nitrates, formed from nitrogen oxides (NO_x) emissions from power plants, automobiles, and other types of combustion sources. In the Eastern United States, reduced visibility is mainly attributable to secondarily-formed sulfates. While these secondarily-formed particles still account for a significant amount in the West, primary emissions from sources like wood smoke contribute a larger percentage of the total particulate loading than in the East.

Humidity can significantly increase the effect of pollution on visibility. Some particles, such as sulfates, accumulate water and grow in size, becoming more efficient at scattering light and causing visibility impairment. Annual average relative humidity levels are 70 to 80 percent in the East as compared to 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.

Long-term Trends

Visibility impairment has been analyzed using visual range data collected since 1960 at 280 monitoring stations located at airports across the country. At these stations, measurements of visual range (the maximum distance at which an observer can discern the outline of an object) were recorded. The maps to the left show the amount of haze during the summer months of 1970, 1980, and 1990. The dark blue color represents less haze and red represents more haze. Overall, the maps show that visibility impairment in the Eastern United States increased greatly between 1970 and 1980 and decreased slightly

between 1980 and 1990. This follows the overall trend in emissions of sulfur oxides during these periods.

Visibility Monitoring Network and Current Conditions

In 1987, a visibility monitoring network for national parks and wilderness areas was established as a cooperative effort between the EPA, states, National Park Service, U.S. Forest Service, Bureau of Land Management, and U.S. Fish and Wildlife Service. The network is designed to track progress toward the Clean Air Act’s national goal. The network is the largest in the country devoted to fully characterizing visibility. Data are collected and analyzed to determine the types of sources and pollutants primarily responsible for reduced visibility. EPA is currently in the process of expanding the network to include monitors in 110 national parks and wilderness areas across the country.

Data collected from this network show that, currently, visibility impairment is generally worse in the rural East compared to most of the West. For example, the average visual range in most Eastern class I areas is 15–25 miles as compared to estimated natural visibility of about 90 miles. In the West, where pristine conditions should be about 140 miles, the average visual range is 35–90 miles for most class I areas.

Programs to Improve Visibility

EPA issued a new regional haze program in April 1999. 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 five years and revise any strategies as necessary.

Other air quality programs are expected to lead to emission reductions that will improve visibility in certain regions of the country. EPA’s Acid Rain Program is designed to achieve significant reductions in SO_x emissions, which is expected to reduce sulfate haze, particularly in the Eastern United States. Additional control programs on sources of NO_x to reduce the formation of ground-level ozone can also improve regional visibility conditions. In addition, programs to meet the national ambient air quality standards, mobile source and fuel standards, air toxics, and programs to improve wood stove efficiency can benefit areas adversely impacted by visibility impairment.



Great Smoky Mountains National Park under a range of visibility conditions.

	East	West
Sulfates	60–80%	25–65%
Organic Carbon	10–30%	15–35%
Nitrates	5–15%	5–45%
Elemental Carbon (soot)	5–15%	5–15%
Crustal Material (soil dust)	5–15%	5–20%

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.

Toxic Air Pollutants



Nature and Sources

Toxic air pollutants are those pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects, or 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., building materials and activities such as cleaning). Some air toxics are also released from natural sources such as volcanic eruptions and forest fires.

Health and Environmental Effects

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

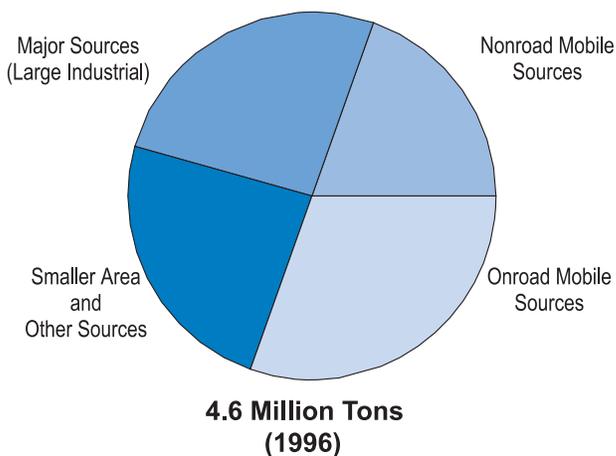
EPA and states do not maintain a nationwide monitoring network for air toxics, as they do for many of the other pollutants discussed in this report. EPA has developed a National Toxics Inventory (NTI) to estimate and track national emissions trends for the 188 toxic air pollutants regulated under the Clean Air Act. In the NTI, 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 drycleaners and gasoline stations, as well as natural sources, like wildfires; 3) onroad mobile, including highway vehicles; and 4) nonroad mobile sources, like aircraft, locomotives, and construction equipment.

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

While EPA and the states collect monitoring data for a number of toxic air pollutants, the chemicals monitored, and the geographic coverage of the monitors varies from state to state. Together with the emissions data from the NTI, the available monitoring data help track trends in toxic air pollutants in various locations around the country. EPA is in the process of expanding the national monitoring network for a number of toxic air pollutants.

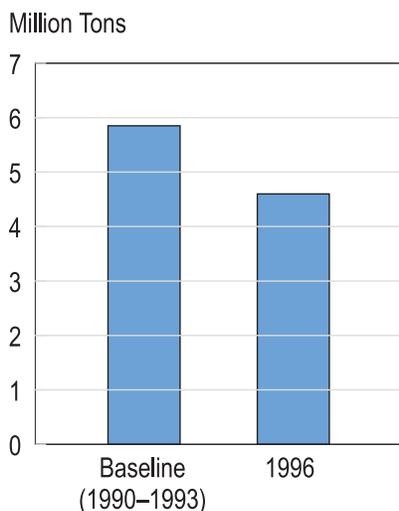
Based on the data in the NTI, estimates of nationwide air toxics emissions have dropped approximately 23 percent between 1990 and 1996. Although changes in how EPA compiled the national inventory over time

National Air Toxics Emissions



Note: These emissions are from outdoor sources. Also, mobile source emissions do not include diesel particulates.

National Air Toxics Emissions
(Total for 188 Toxic Air Pollutants)



may account for some differences, EPA and state regulations, as well as voluntary reductions by industry, have played an important role in achieving large reductions in overall air toxic emissions.

Individual trends for different air toxics vary from pollutant to pollutant. For example, data taken from California's monitoring network for 16 urban sites show a nearly 60-percent reduction in measured levels of perchloroethylene for the period 1989 to 1998. Perchloroethylene is a chemical widely used in the drycleaning industry. The NTI estimates that nationwide perchloroethylene emissions dropped 66 percent from 1990 to 1996. These reductions reflect state and federal efforts to regulate emissions of this pollutant, and industry efforts to move to other processes using less toxic chemicals.

Benzene is another widely monitored toxic air pollutant. It is emitted from cars, trucks, oil refineries, and chemical processes. The graph at the lower right shows measurements of benzene taken from 84 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 a 39-percent drop in benzene levels from 1993 to 1998. 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 nationwide benzene emissions from all sources dropped 25 percent from 1990 to 1996.

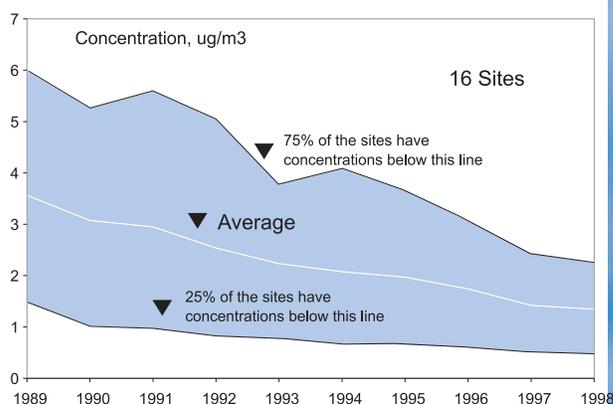
Programs to Reduce Air Toxics

As mentioned above, EPA has put into place important controls for fuels and is continuing to take additional steps to reduce air toxics from vehicles. By 2020, EPA anticipates there will be a 75-percent reduction in key air toxics from highway vehicles from 1990 levels.

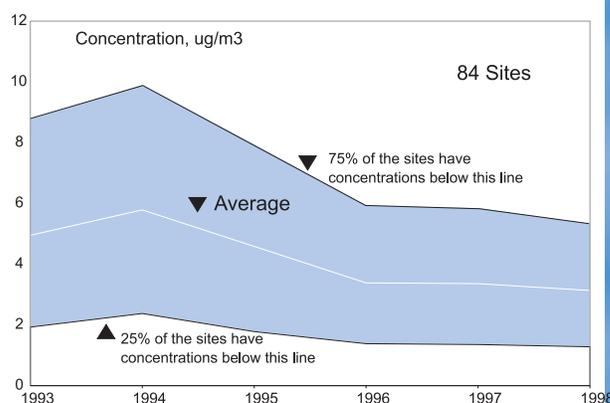
EPA has also taken important steps to reduce toxic air emissions from large industrial sources such as chemical plants, oil refineries, and steel mills, as well as some smaller sources such as drycleaners, chrome electroplaters, and commercial sterilizers. When fully implemented, emission standards covering 82 stationary source categories (e.g., pulp and paper mills, steel mills, oil refineries) are projected to reduce annual air toxic emissions by 1.5 million tons. EPA is continuing to develop additional air toxic emissions standards for the remaining (96) industrial categories.

As part of the Agency's National Air Toxics Assessment, EPA is using emissions from the NTI together with computer models to estimate population exposures in 1996 and potential health effects associated with 33 priority air toxic pollutants. This work will help focus future efforts to reduce air toxics and resultant health effects. EPA, states, and others are working to improve the NTI and to expand the air toxics monitoring networks to obtain more data to better understand air toxic emissions and ambient concentrations nationally and locally.

Ambient Perchloroethylene Annual Average Urban Concentrations in CA
(58-percent reduction, 1989–1998)



Ambient Benzene Annual Average Urban Concentrations, Nationwide
(39-percent reduction, 1993–1998)



For more information about EPA's air toxics program, visit the Agency's website at <http://www.epa.gov/ttn/uatw>.

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 radiation (UV-b) from the sun. Over the past two decades, however, this protective shield has been damaged. Each year, an “ozone hole” forms over the Antarctic, and ozone levels fall to 70 percent below normal. Even over the United States, ozone levels are about 5 percent below normal in the summer and 10 percent below normal in the winter. The trend line in the figure below shows a 3.4 percent decrease per decade in average total ozone over Northern Hemisphere mid-latitudes since 1979.

As the ozone layer thins, more UV-b radiation reaches the Earth. In 1996, scientists demonstrated for the first time that UV-b levels over most populated areas have increased. In the 1970s, scientists had linked several substances associated with human activities to ozone depletion, including the use of chlorofluorocarbons (CFCs), halons, carbon tetrachloride, and methyl chloroform. These chemicals are emitted from commercial air conditioners, refrigerators, insulating foam, and other industrial processes. Strong winds carry them through the lower part of the atmosphere, called the troposphere,

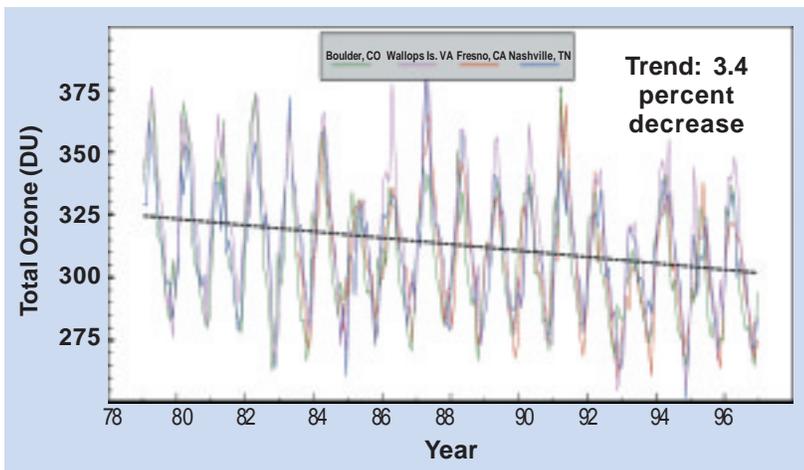
and into the stratosphere. There, strong solar radiation releases chlorine and bromine atoms that attack protective ozone molecules. Scientists estimate that one chlorine atom can destroy 100,000 ozone molecules.

Health and Environmental Effects

Some UV-b radiation reaches the Earth’s surface even with normal ozone levels. However, because the ozone layer normally absorbs most UV-b radiation from the sun, ozone depletion is expected to lead to increases in harmful effects associated with UV-b radiation. In humans, UV-b radiation is linked to skin cancer, including melanoma, the form of skin cancer with the highest

fatality rate. It also causes 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 food 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. Because they absorb CO₂ from the atmosphere, significant harm to phytoplankton populations could increase global warming (see following section on Global Warming and Climate Change).



Source: National Oceanic and Atmospheric Administration, 1998.

Monthly average total ozone measured in Dobson Units (DU) at four mid-latitude stations across the United States from 1979 to 1997. The trend line shows a 3.4 percent decrease in average total ozone over mid-latitudes in the United States since 1979. The large annual variation shown in each of the four cities is a result of ozone transport processes which cause increased levels in the winter and spring and lower ozone levels in the summer and fall at these latitudes.

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, over 170 nations have signed the Protocol, which has been strengthened five times and now calls for the elimination of those chemicals that deplete stratospheric ozone.

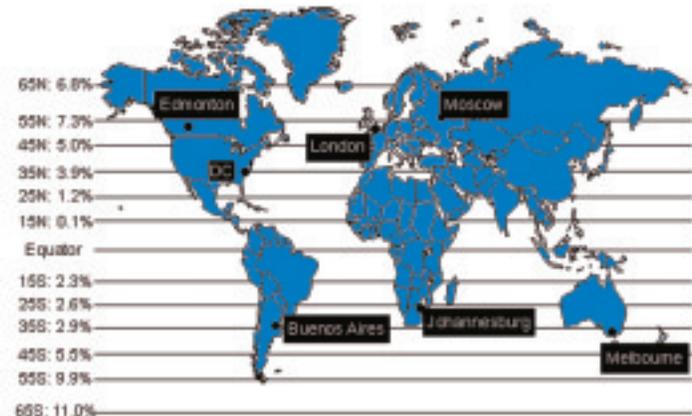
The 1990 Clean Air Act Amendments established a U.S. regulatory program to protect the stratospheric ozone layer. In January 1996, U.S. production of many ozone-depleting substances virtually ended, including CFCs, carbon tetrachloride, and methyl chloroform. Production of halons ended in January 1994. 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 sectors, the transition away from ozone-depleting substances has already been completed. EPA is also emphasizing new efforts like the UV Index, a daily forecast of the strength of UV radiation people may be exposed to outdoors, to educate the public about the health risks of overexposure to UV radiation and the steps they can take to reduce those risks.

Trends in Stratospheric Ozone Depletion

Scientific evidence shows that the approach taken under the Montreal Protocol has been effective to date. In 1996, measurements showed that the concentrations of methyl chloroform had started to fall, indicating that emissions had been greatly reduced. Concentrations of other ozone-depleting substances in the upper layers of the atmosphere, like CFCs, are also beginning to decrease. It takes several years for these substances to reach the stratosphere and release chlorine and bromine. For this reason, stratospheric chlorine levels are expected to peak early in 2000, and then slowly decline. Because of the stability of most ozone-depleting substances, chlorine will be released into the stratosphere for many years, and the ozone layer will not fully recover until well into the century. All nations that signed the Protocol must complete implementation of ozone protection programs if full repair of the ozone layer is to happen.

In 1996, scientists developed a new technique allowing them to draw conclusions about UV-b radiation at ground level. According to satellite-based trend analyses, major populated areas have experienced increasing UV-b levels over the past 15 years. As shown by the figure above, at latitudes that cover the United States, UV-b levels are 4–5 percent higher than they were 10 years ago.

UV-b Radiation Increases by Latitude



A 1996 study using satellite-based analyses of UV-b trends demonstrated that UV-b levels had increased at ground level. This figure shows the percent increases in average annual UV-b reaching the surface over the past 10 years. UV-b incidence is strongly dependent on latitude. At latitudes that cover the United States, UV-b levels are 4–5 percent higher than they were 10 years ago.

Global Warming & Climate Change

Nature and Sources

The Earth's climate is fueled by the Sun. Most of the Sun's energy, called solar radiation, is absorbed by the Earth, but some is reflected back into space. Clouds and a natural layer of atmospheric gases absorb a portion of Earth's heat and prevents it from escaping to space. This keeps our planet warm enough for life and is known as the natural "greenhouse effect," as illustrated in the diagram below. Without the natural greenhouse effect, the Earth's average temperature would be much colder, and the planet would be uninhabitable.

Recent scientific evidence shows that the greenhouse effect is being increased by release of certain gases to the atmosphere that cause the Earth's temperature to rise. This is called "global warming." Carbon dioxide (CO₂) accounts for about 81 percent of greenhouse gases released in the United States. Carbon dioxide emissions are largely due to the combustion of fossil fuels in electric power generation and in the transportation and industrial sectors. Methane (CH₄) emissions, which result from agricultural activities, landfills, and other sources, are the next largest contributors to

greenhouse gas emissions in the United States and worldwide.

Industrial processes such as foam production, refrigeration, dry cleaning, chemical manufacturing, and semiconductor manufacturing produce other greenhouse gas emissions, such as hydrofluorocarbons (HFCs). Smelting of aluminum produces another greenhouse gas called perfluorinated compounds (PFCs). Emissions of NO_x and VOCs from automobile exhaust and industrial processes contribute to the formation of ground-level ozone or smog, also a greenhouse gas.

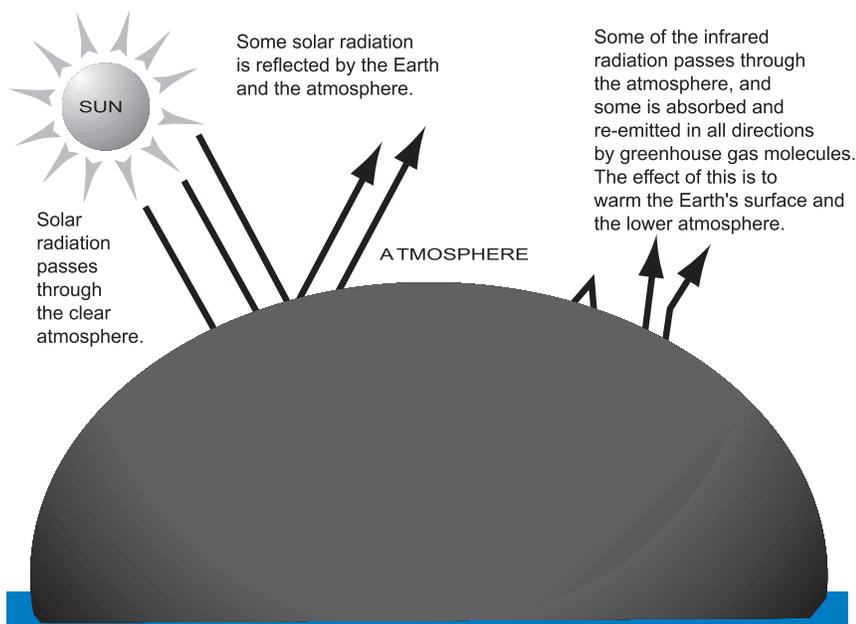
Health and Environmental Effects

In 1988, the Intergovernmental Panel on Climate Change (IPCC) was formed to assess the available scientific and economic information on climate change. In 1995, the IPCC published a report representing the work of more than 2,000 of the world's leading scientists. The IPCC concluded that humans are changing the Earth's climate, and that "climate change

is likely to have wide-ranging and mostly adverse impacts on human health, with significant loss of life."

According to the IPCC, greenhouse gas emissions could cause a 2° to 6° Fahrenheit rise in temperature during the next century, if atmo-

The Greenhouse Effect



The greenhouse effect is being accelerated by releases of certain gases to the atmosphere that are causing the Earth's temperature to rise.

spheric levels are not reduced. Although this change may appear small, it could lead to more extreme weather events such as droughts and floods, threaten coastal resources and wetlands by raising sea level, and increase the risk of certain diseases by producing new breeding sites for pests and pathogens. Agricultural regions and woodlands are also susceptible to changes in climate that could result in increased insect populations and plant disease. This degradation of natural ecosystems could lead to reduced biological diversity.

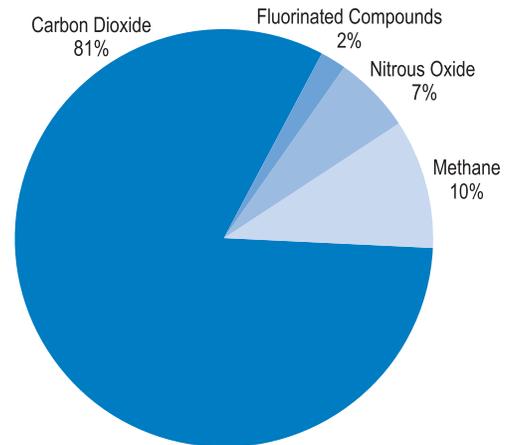
International Developments

In 1992, 150 countries signed the Framework Convention on Climate Change (FCCC), which has the objective of stabilizing the concentration of greenhouse gases in the atmosphere at levels that would prevent dangerous interference with the climate system. Under the FCCC, industrialized countries agreed to aim to reduce greenhouse gas emissions to 1990 levels by the year 2000. It now appears that most industrialized countries, including the United States, will not meet this target. In light of the 1995 scientific findings of the IPCC and the continued rise in greenhouse gas emissions, parties to the FCCC formulated the “Kyoto Protocol” at a 1997 conference held in Kyoto, Japan. The Kyoto Protocol includes greenhouse gas emission targets for industrialized countries for the period of 2008–2012. The average reduction target for all industrialized countries for this period is 5 percent below 1990 emission levels. The reduction target varies across countries to account for differing circumstances, with the United States’ target being a 7-percent reduction below 1990 levels. The Kyoto Protocol also provides for market-based measures, such as international emissions trading, to help countries meet their commitments at the lowest possible cost. (The U.S. Administration will seek the Senate’s consent for ratification of the Kyoto Protocol after working for further progress on the details of the market mechanisms and on the involvement of key developing countries.)

U.S. Programs to Mitigate Climate Change

The United States implemented a Climate Change Action Plan (CCAP) in 1993 to reduce greenhouse gas emissions and help achieve the goals of the FCCC. Thousands of companies and nonprofit organizations are working together to effectively reduce their emissions. The Plan involves more than 40 programs implemented by EPA, the Department of Energy, the Department of Agriculture, and other government agencies. In 1999, EPA’s voluntary programs reduced greenhouse gas emissions by 44 million tons of carbon, equivalent to eliminating the greenhouse gas emissions from about 35 million cars. By investing in products that use energy more efficiently, consumers and businesses have also saved more than \$4 billion on their 1999 energy bills while achieving these environmental benefits.

1998 Greenhouse Gas Emissions in the United States



1998 total greenhouse gas emissions rose 11 percent from 1990 baseline levels. The major contributor to these emissions is carbon dioxide (CO₂) from fossil fuel combustion. Other contributors include methane gas (CH₄) from landfills, fermentation, natural gas systems, and coal mining; nitrous oxide (N₂O) from agricultural management and mobile sources, and fluorinated compounds from such processes as aluminum and magnesium production and electrical transmission and distribution systems.

Conclusion

Acronyms

CO	Carbon Monoxide
Pb	Lead
NO ₂ , NO _x	Nitrogen Dioxide, Nitrogen Oxides
O ₃	Ozone
PM ₁₀	Particulate Matter (10 micrometers in diameter or less)
PM _{2.5}	Particulate Matter (2.5 micrometers in diameter or less)
SO ₂ , SO _x	Sulfur Dioxide, Sulfur Oxides

Other Pollutants

CFCs	Chlorofluorocarbons
CH ₄	Methane
CO ₂	Carbon Dioxide
HFCs	Hydrofluorocarbons
N ₂ O	Nitrous Oxide
PCBs	Polychlorinated Biphenyls
PFCs	Perfluorinated Carbons
VOCs	Volatile Organic Compounds

Other Acronyms

CCAP	Climate Change Action Plan
DU	Dobson Unit(s)
EPA	Environmental Protection Agency
FCCC	Framework Convention on Climate Change
IPCC	Intergovernmental Panel on Climate Change
NAAQS	National Ambient Air Quality Standards
NTI	National Toxics Inventory

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 and local 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.

For Further Information

Detailed information on Air Pollution Trends:
<http://www.epa.gov/airtrends>

Real-Time Air Quality Maps and Forecasts:
<http://www.epa.gov/airnow>

On-line Air Quality Data:
<http://www.epa.gov/airsdata>

Acid Rain Website: <http://www.epa.gov/acidrain>

Global Warming Emissions Information:
<http://www.epa.gov/globalwarming/emissions/national/index.html>

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

Stratospheric Ozone Hotline: (800) 296-1996