How clean is the air?

Air Quality in the Tennessee Valley Region

TVA

July 2003

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Tennessee Valley Authority | 400 W. Summit Hill Drive | Knoxville, Tennessee 37902 | **www.tva.com**

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OVERVIEW

The Clean Air Act has resulted in substantial emission reductions and in significant improvements in outdoor air quality. Overall, local and regional air quality is better today than it was twenty-four years ago when the Tennessee Valley Authority (TVA) published the first "How Clean is Our Air?" A few highlights for National Ambient Air Quality Standard (i.e., "criteria") pollutants in the east-central US include the following:

- Total suspended particulates, sulfur dioxide, and carbon monoxide have improved dramatically with levels reduced more than 40 percent. All areas meet clean air standards for these pollutants.

- Particulate matter less than 10 microns in diameter and nitrogen dioxide have improved significantly with air quality levels improving between 20 and 30 percent. All areas meet clean air standards for these pollutants.

- Ozone was a challenge in 1979 when we first published "How Clean is Our Air" and continues to be a challenge today. There has been marginal improvement in maximum 1-hour ozone levels (from 6 to 9 percent reduction) and minimal improvement in maximum 8-hour levels (from 3 to 6 percent reduction). Clearly, some ozone seasons are better and others worse depending on climatic conditions. Currently, two areas (Atlanta, Georgia and Birmingham, Alabama) do not meet the 1-hour ozone standard. The 8-hour standard is not yet used to determine clean air status, but once this standard is implemented, many areas are expected to exceed it.

- Lead has improved overall with air quality levels improving about 30 percent. However, local industries cause problems in two small areas in Jefferson and Iron Counties, Missouri, which do not meet lead clean air standards.

- Fine particle air pollution–particulate matter less than 2.5 microns in diameter–will likely be a concern in the coming years. The new fine particle standards are not yet used to determine clean air status, but once these standards are implemented, many areas are expected to exceed them.

There are a number of other air quality issues of continuing concern that are not currently measured by National Ambient Air Quality Standards. Here are a few highlights regarding several of these important issues.

- Acidic deposition (i.e., acid rain) levels have improved as the emission of strong acid gases–sulfur dioxide and nitrogen oxides–continues to decline. There is ongoing concern, however, about the effects of acidic deposition on the most sensitive, high-elevation forests and streams.

- Visibility impairment is a special problem for our National Parks and Wilderness Areas. The Great Smoky Mountains National Park–one of our country's most visited National Parks–is subject to periods of reduced visibility due to regional haze. Visibility should improve as sulfur dioxide and nitrogen oxide emissions continue to decline.

- Persistent bioaccumulating toxic pollutants, such as mercury, are of concern because of their global mobility, persistence, and their ability to accumulate through the food chain. Clearly, more research is needed on the fate and effects of toxic air pollutants.

- Indoor air quality is a major public health concern. From a health perspective, indoor air quality is more important than outdoor air quality. Air quality in our homes and workplaces dominates personal exposure to many kinds of air pollutants.

- As scientific understanding improves, the issue of human-caused global climate change appears less theoretical and more "real." Global temperatures as well as greenhouse gas emissions (carbon dioxide, methane, and nitrous oxides) are increasing.

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FOREWORD

> *"Man can no longer live his life for himself alone. We realize that all life is valuable and that we are related to all this life. From this knowledge comes our spiritual relation to the universe."*
>
> Albert Schweitzer

It is now, and has always been, a question of balance. How do we, as a society, equitably balance the distribution of resource-consuming, pollution-causing goods and services to an ever-growing, ever-more-demanding global economy, and still address the ecological imperative of maintaining a sustainable and diverse natural environment? For centuries humankind has focused on learning how to "overcome" the limitations placed upon us by a poorly-understood, seemingly all-powerful, and often feared natural environment. Now, through our ingenuity, we have become significant agents of environmental change. In some ways, the balance has shifted. However, so has our understanding and appreciation for our inter-relatedness to the environment. We know that environmental damage ultimately injures us. More than ever, it is necessary to design our lives with nature in mind.

Environmental protection and resource management are not new issues. They are simply restatements of the age-old wisdom of not biting the hand that feeds you. Just as we recognize the importance of industry and agriculture to sustain the economic requirements of our lives, we also recognize and value the environment in sustaining the ecological basis of our lives. We need to develop a perspective in environmental stewardship similar to health care, where the focus has shifted from the treatment of disease to the avoidance of disease. Preventative medicine seeks to reduce infirmity by teaching us to adopt a more healthy lifestyle. Similarly, environmental stewardship promotes a conservation ethic which minimizes unintentional or unwanted environmental impacts through adopting ecologically sound behaviors. Filling this "prescription" will be neither quick nor easy but it should be done. Through research and education, we must make informed, responsible choices about how best to protect and maintain the environment.

We must establish realistic goals and expectations and recognize that environmental protection is subject to the same economic and political checks and balances as many other worthy activities. A cleaner, better-managed environment costs money. Cleaner energy, for example, is usually more expensive energy, and more expensive energy is a hardship to society's neediest individuals. The thrust of most environmental research, directly or indirectly, helps us better define and quantify the "costs" and "benefits" associated with environmental management. While the economic cost of environmental controls can be estimated with a relatively high degree of certainty, the resulting environmental benefits are often much less certain.

And so it goes. It is, after all, a question of balance.

INTRODUCTION

Through the first half of the 20th century, every sanitary engineer and public health professional was taught that "the solution to pollution is dilution." No environmental problem was so big that it couldn't be moved elsewhere. Too much smoke–build taller stacks. Too much waste–flush it, burn it, bury it, inject it, or ship it out of town. Unfortunately, sometime during all that moving we ran out of "elsewheres." As our population and global economy grows and our understanding of ecological interrelatedness expands, we find that there are fewer and fewer environmental problems belonging to "you" or "me" and lots more belonging to "us."

In the more developed countries, the second half of the 20th century amounted to a renaissance in environmental awareness. The lessons came hard. The deadly air pollution episodes in Donora, Pennsylvania, in 1948 and London, England, in 1952, got our attention. Engineers and scientists began to take a serious look at the consequences of too much air pollution. The importance of environmental protection in the US moved center stage in 1970 with the first Earth Day and, more importantly, the establishment of the Environmental Protection Agency (EPA), a Federal agency with a broad mandate to protect public health and the environment.

This report focuses on one aspect of environmental concern–air quality–as it relates to the east-central US since 1979. Contrary to many headlines, the country and region have made significant strides towards improved air quality. Because sound environmental management and pollution controls often increase the cost of doing business, some economically marginal industries have closed their doors while others took it in stride and worked long and hard to develop and maintain a positive environmental record. It is increasingly evident that, although there's no free lunch, what's good for the environment can also be good–in the long run–for business.

During the years since the Tennessee Valley Authority (TVA) began publishing public information reports on regional air quality (How Clean is Our Air? An Assessment of Air Quality in the Tennessee Valley, 1979; How Clean is Our Air? An Update, 1984; and How Clean is Our Air? A Decade of Change, 1990) there has been steady progress in understanding and resolving many long-standing air pollution problems. Much has been learned. Continuing vigilance by local, state, and federal regulatory agencies, as well as private citizens, has helped ensure that environmental regulations are enforced and that appropriate resource management guidelines are used to promote more environmentally friendly industrial development. In addition to the more familiar air quality problems of the past, our earlier reports considered important emerging air quality issues such as acid rain, hazardous (i.e., toxic) air pollutants, inhalable particulates, indoor air pollution, and visibility impairment. Although these issues are now better understood, they are with us still.

The goal of this report is to provide an up-to-date look at where we've been, where we are, and where we're going with regard to air quality in the east-central US. The study area (586,000 kilometers^2 or 226,500 miles^2) includes the entire state of Tennessee, as well as portions of North Carolina, South Carolina, Georgia, Alabama, Mississippi, Arkansas, Missouri, Illinois, Indiana, Kentucky, West Virginia, and Virginia. We look back on more than two decades of change, considering, whenever possible, air quality trends from 1979 through 2002. All information summarized in this report is available to the public. The air quality monitoring information was acquired from the EPA Air Quality System (AQS) Database. Emission

estimates are based on the 1999 emissions estimates contained in the EPA National Emissions Trends (NET) Database. The acidic deposition monitoring information is from the National Atmospheric Deposition Program/National Trend Network (NADP/NTN).

Each and every day, it seems, we are faced with new environmental challenges. It is encouraging to see that the new millennium heralds unprecedented levels of cooperation between industry, regulatory organizations, developers, and environmental special interest groups across the nation and around the world. Although there are still many avenues of disagreement and dispute, many of the strongly adversarial stances of the past are being replaced with a new spirit of respect and cooperation. After all, we are all in this together.

NATIONAL AMBIENT AIR QUALITY STANDARDS

With few exceptions, the air is much cleaner today than more than two decades ago. This doesn't mean that we can rest on our laurels. In fact, the air quality problems and solutions we face are more complex and challenging than ever. As the science of air quality improves, so does our appreciation of the nature and extent of potential problems. Monitoring and measurement capabilities are such that we now can accurately and precisely measure trace compounds at infinitesimal concentrations. Also, as understanding improves, the clean air yardsticks by which we measure progress become more stringent. The recently revised particulate matter and ozone clean air standards, for example, will be a real challenge. Our clean air "yardsticks"–referred to as the National Ambient Air Quality Standards (NAAQS)–are established by EPA. There are two types of NAAQS. "Primary" standards establish air quality limits protecting public health, including the health of sensitive populations or subgroups such as asthmatics, children and the elderly. "Secondary" standards set limits protecting public "welfare," including protection against building materials damage, injury to animals, crops, vegetation, and visibility impairment.

EPA has set NAAQS for six pollutants (referred to as "criteria" pollutants): particulate matter (PM), sulfur dioxide (SO_2), ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), and lead (Pb). Areas of the country that are as of yet unable to meet these clean air standards are referred to as "non-attainment" areas. These areas must develop and implement strategies to bring themselves into "attainment" with the standard.

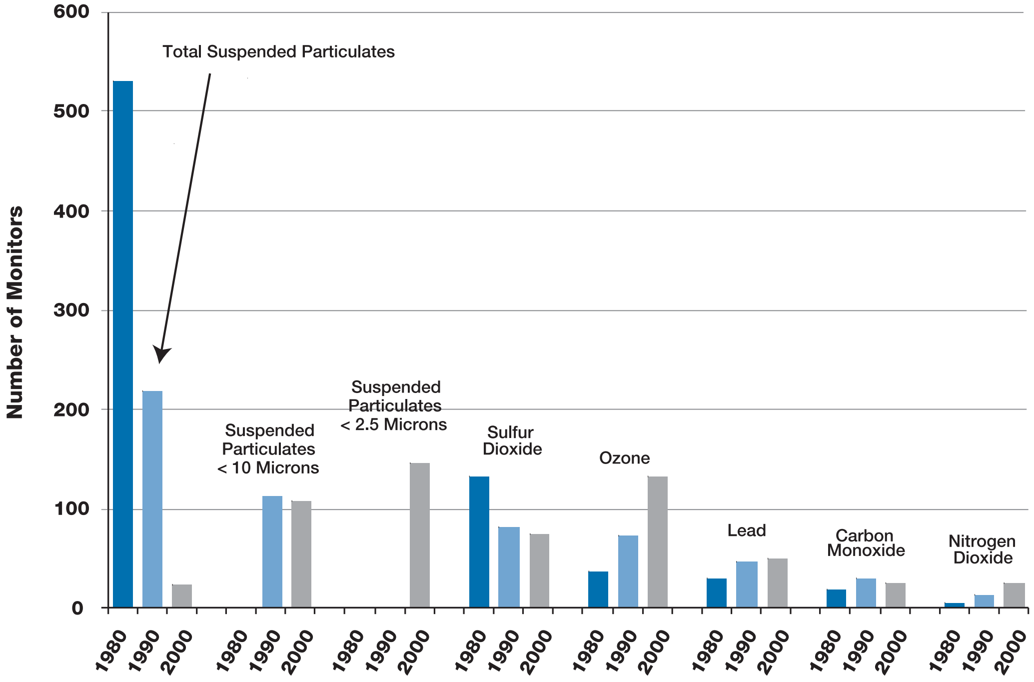
In order to keep NAAQS standards current, the EPA reviews these standards periodically and, if warranted, recommends revisions. In 1997, for example, EPA proposed stringent revisions to the NAAQS for particulate matter and ozone. A listing of the current

Table 1. National Ambient Air Quality Standards.
(Source: EPA)

Pollutant	Standard Value*	Standard Type
Particulate<10 micrometers (PM_{10})		
Annual Arithmetic Mean	50 $\mu g/m^3$	Primary & Secondary
24-Hour Average	150 $\mu g/m^3$	Primary & Secondary
Particulate<2.5 micrometers ($PM_{2.5}$)		
Annual Arithmetic Mean	15 $\mu g/m^3$	Primary & Secondary
24-Hour Average	65 $\mu g/m^3$	Primary & Secondary
Sulfur Dioxide (SO_2)		
Annual Arithmetic Mean	30 ppb (80 $\mu g/m^3$)	Primary
24-Hour Average	140 ppb (365 $\mu g/m^3$)	Primary
3-Hour Average	500 ppb (1300 $\mu g/m^3$)	Secondary
Ozone (O_3)		
1-Hour Average	120 ppb (235 $\mu g/m^3$)	Primary & Secondary
8-Hour Average	80 ppb (157 $\mu g/m^3$)	Primary & Secondary
Nitrogen Dioxide (NO_2)		
Annual Average	53 ppb (100 $\mu g/m^3$)	Primary & Secondary
Carbon Monoxide (CO)		
8-Hour Average	9 ppm (10 mg/m^3)	Primary
1-Hour Average	35 ppm (40 mg/m^3)	Primary
Lead (Pb)		
Quarterly Average	1.5 mg/m^3	Primary & Secondary

* *ppm=parts per million, ppb=parts per billion, mg/m^3=milligrams per cubic meter, and $\mu g/m^3$=micrograms per cubic meter. Parenthetical values are an approximately equivalent concentration.*

Figure 1. Number and Type of Air Quality Monitors in the East-Central U.S.
(Source: EPA AQS Database)



primary (health based) and secondary (welfare based) NAAQS is found in Table 1.

In any assessment of long-term air quality it is important to consider the number and location of air quality monitors since there have been dramatic changes in our regional and national monitoring strategies. Figure 1 indicates the number and kind of air quality monitors in the east-central US in 1980, 1990, and 2000. There has been a substantial decline in the number of total suspended particulate and sulfur dioxide monitors as clean air goals were met and there has been a substantial increase in the number of samplers measuring ozone, particulate matter less than 10 micrometers in diameter (PM_{10}) and particulate matter less than 2.5 micrometers in diameter ($PM_{2.5}$).

Particulate Matter

Particulate matter (PM) consists of small solid "dust" particles or liquid droplets–some just large enough to be seen with the naked eye, but others too small to be seen without the aid of a powerful microscope. The composition and shape of these particles are as different as their many sources. Particles emitted directly from a pollution source are called primary particles, whereas those formed after emission–by the chemical/physical conversion of gaseous pollutants–are referred to as secondary particles. Generally speaking, primary particles tend to be larger, heavier and are deposited close to their source. Smaller and lighter secondary particles may remain aloft for days at a time and can disperse over wide areas. Where problems exist, primary particle emissions are generally considered a local pollution problem and secondary particles a more regional concern.

Particles have many natural and human-made sources. Natural sources include wind-blown dust or soil, volcanoes, forest fires, and ocean spray. Human-made sources include agricultural activities, waste incineration, industrial processes, fossil-fuel combustion, transportation, construction, demolition, and mining. Although, on a global scale, natural emissions far exceed human-made emissions, human-made emissions predominate in urban and industrial areas. Figures 2a and 2b display regional human-made particulate emissions estimates. Particulate matter became a focus of early air pollution control efforts because of the obvious visual impact of smoke and its association with extreme air pollution episodes in Donora, Pennsylvania, and in London, England, when many people became ill and some died from the stress brought on by urban/industrial air pollution. Smokestacks belching dark clouds of ash and soot, once symbols of industrial might and a growing economy, became obvious targets for early environmental regulation. Particle control measures have been very successful in lowering primary particle emissions from power generation and industrial

Figure 2a. Human-made Inhalable Particulate Matter Emissions in the East-Central U.S.
(PM_{10}, Source: EPA National Emissions Trends Database, 1999)

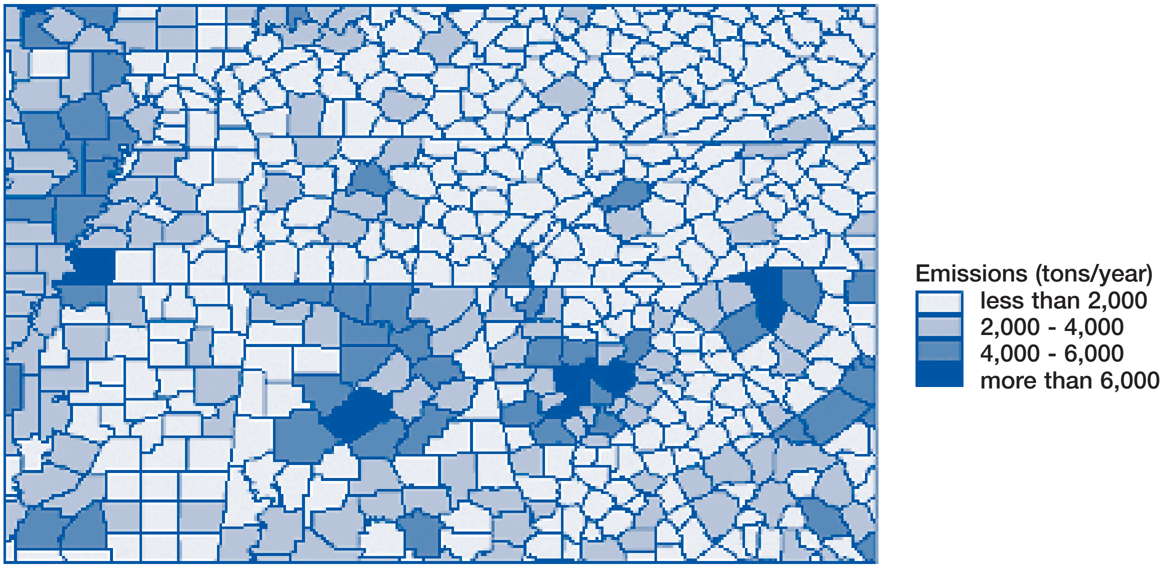
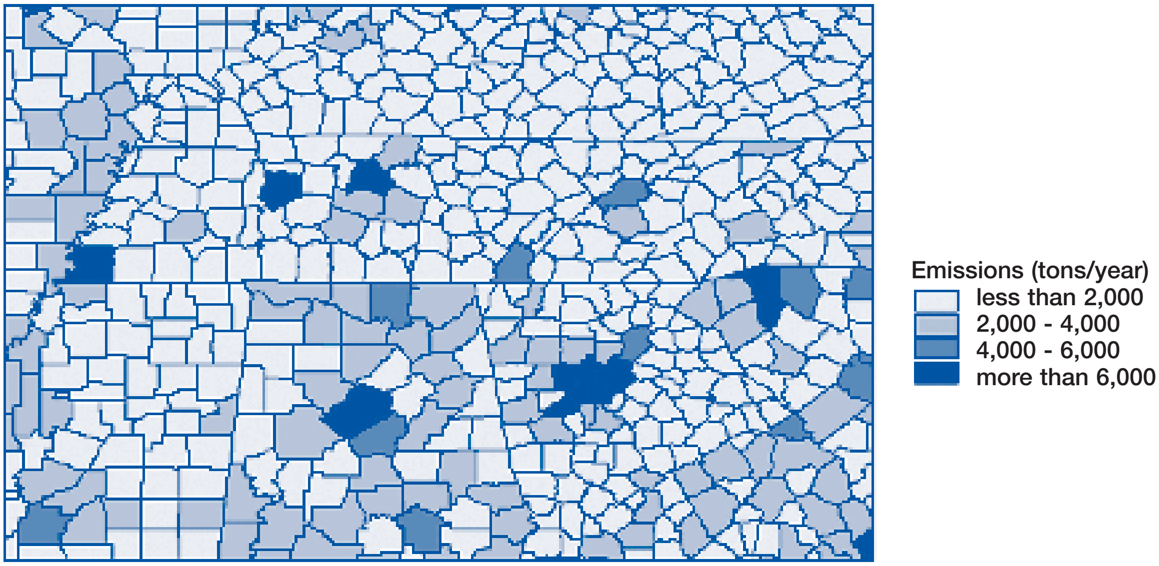


Figure 2b. Human-made Fine Particulate Matter Emissions in the East-Central U.S.
($PM_{2.5}$, Source: EPA National Emissions Trends Database, 1999)

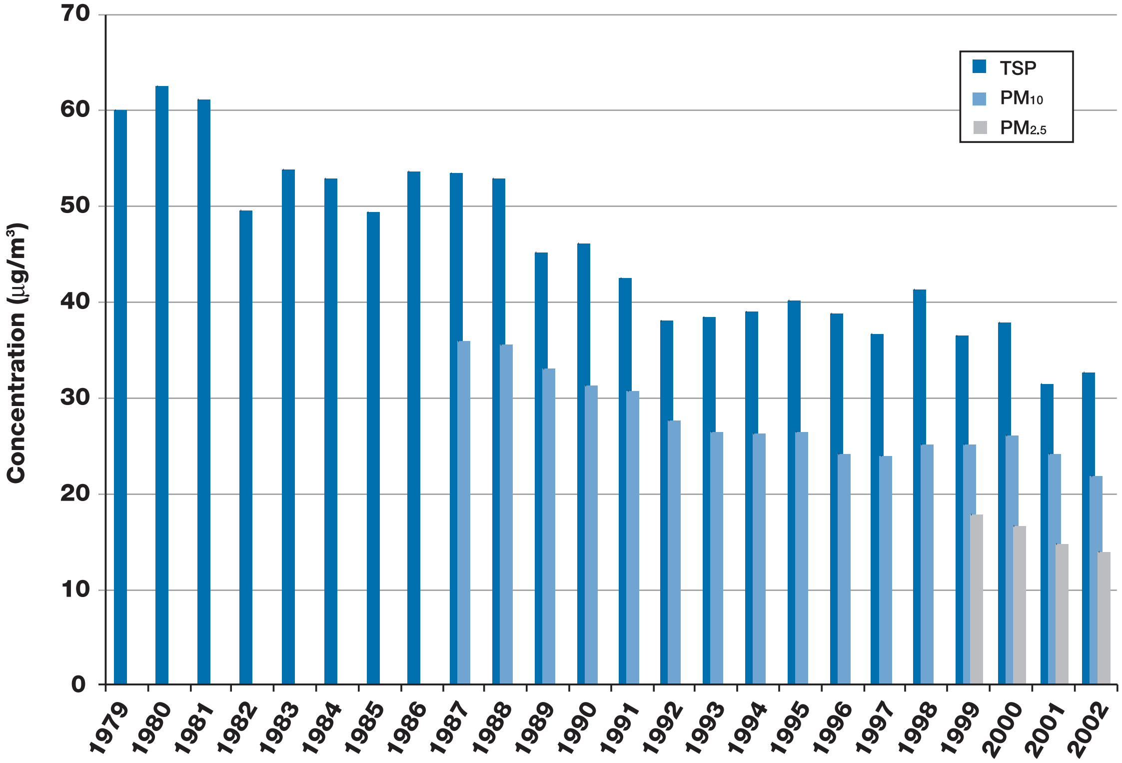


facilities. Removal efficiencies of 98 percent or more (by weight) are now typical.
The potential adverse effects of particles depend not only on their concentration but also on their size and composition. While large particles are removed by the nose and throat, fine particles can be drawn deeper into the lungs. It is these fine particles which are of greatest concern from both health and environmental perspectives. Fine particles also contribute to the regional problems of acidic deposition, visibility impairment, and toxic air pollution.

Recognition of the importance of fine particles is evidenced by evolutionary revisions to the particulate matter NAAQS from total suspended particulates (TSP) in 1971, to TSP and particulate matter less than 10 micrometers in diameter (PM_{10}) in 1987 and then to PM_{10} and particulate matter less than 2.5 micrometers in diameter ($PM_{2.5}$) in 1997.

As shown in Figure 3, both TSP and PM_{10} particle levels have steadily improved over the years. Annual average TSP concentrations improved by more than 40 percent between 1979 and 2002 and annual average PM_{10} levels improved by 30 percent between 1987 and 2002. Wide scale $PM_{2.5}$ monitoring, which didn't begin until 1999, is not yet sufficient to establish trends. Figure 4 identifies potential $PM_{2.5}$ problem areas based on 2000-2002 monitoring information. Although the $PM_{2.5}$ standards are not yet used to establish attainment,

Figure 3. Particulate Matter Air Quality Trends 1979-2002 in the East-Central U.S.
(Source: EPA AQS Database)

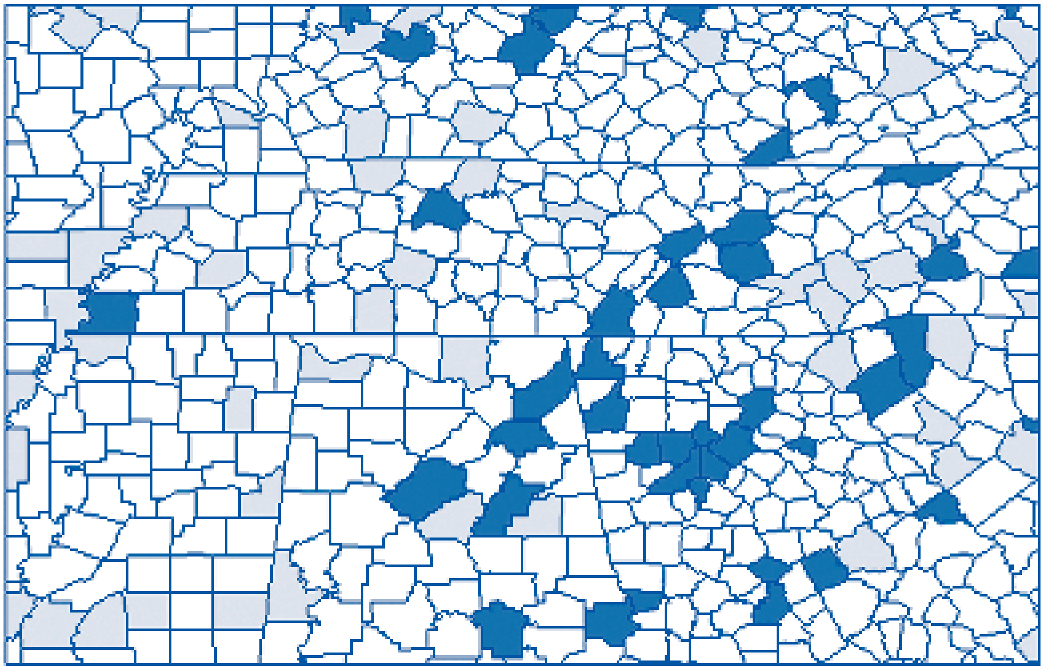


TSP=Total suspended particles
PM_{10}=Particulates less than 10 micrometers in size
$PM_{2.5}$=Particulates less than 2.5 micrometers in size

The primary and secondary National Ambient Air Quality Standards for particulates <10 micrometers are 50 µg/m³ on an annual basis and 150 µg/m³ for the 24-hour average. The primary and secondary National Ambient Air Quality Standards for particulates <2.5 micrometers are 15 µg/m³ on an annual basis and 65 µg/m³ for the 24-hour average.

Figure 4. Areas with Fine Particle Concentrations Above the Annual Standard in the East-Central U.S. (Annual $PM_{2.5}$ Standard, 2000-2002 data)

(Source: EPA AQS Database)



Note: Dark blue counties are greater than the standard, light blue are less than the standard, and white have insufficient monitoring.

Early Fine Particle Partnership Monitoring Effort Provides Insight

Beginning on Earth Day 1997, Alabama, Kentucky, and Tennessee environmental regulators joined with the Tennessee Valley Authority in establishing the first cooperative fine particle ($PM_{2.5}$) monitoring network in the east-central US. With the primary objective of estimating annual average and 24-hour maximum $PM_{2.5}$ concentrations in Tennessee Valley urban areas, special purpose $PM_{2.5}$ monitors were sited in Memphis, Nashville, Chattanooga, and Knoxville, Tennessee; Paducah, Kentucky; and Decatur and Huntsville, Alabama. A single background station was sited in Lawrence County, Tennessee. Study highlights include the following.

- With more than 1500 samples collected, all stations, except rural Lawrence County, exceeded the level of the annual $PM_{2.5}$ standard (15 micrograms per cubic meter [$\mu g/m^3$]) during one or more study years. Attaining the annual standard will be a challenge for many urban and some rural areas.
- With the exception of a single sample collected during a regional forest fire event in November 2000, no station exceeded the level of the 24-hour $PM_{2.5}$ standard (65 $\mu g/m^3$).
- Urban fine particles are dominated (about half) by carbon-containing particles from transportation and industrial sources. Rural fine particles show a high fraction (about 50 percent) of sulfur-containing particles from coal and oil combustion sources.
- Although urban fine particle concentrations are often 20 to 40 percent higher than rural levels, both reflect similar patterns. Weather conditions favoring the production and accumulation of fine particles are common across large areas.
- Elevated fine particle concentrations can occur during any season although the highest average monthly concentrations occur in July/August and the lowest in December/January.

This partnership effort ended in 2001 with the broad implementation of EPA-supported state and local $PM_{2.5}$ sampling.

it's always a good idea to consider what problems we might have in the future.

Sulfur Dioxide

Sulfur dioxide (SO_2) is an odorless, colorless gas at most outdoor concentrations. Biological decay, volcanoes, hot springs, and other natural sources provide about half of the world's atmospheric sulfur while the remainder comes from human-made sources including oil- and coal-burning power plants, industrial boilers, ore processing facilities, pulp and paper mills, and petroleum refineries. While natural sources are generally dispersed, human-made sources can concentrate emissions in relatively small areas. In developed countries, human-made sulfur emissions exceed natural emissions. In the US, for example, human-made sources account for about 90 percent of gaseous sulfur emissions–largely in the form of sulfur dioxide from coal or oil combustion. Figure 5 shows the regional distribution of human-made sulfur dioxide emissions.

Sulfur dioxide itself is an upper respiratory irritant. Coupled with fine particles, sulfur dioxide can also be carried deep into the lungs where, in high concentrations, it can endanger the health of sensitive individuals, such as the very young, the very old, or those with preexisting health problems. In addition to its potential effects on human health, sulfur dioxide can also injure vegetation, accelerate corrosion of building materials, produce secondary fine particles, and contribute to acidic deposition and reduced visibility.

Sulfur dioxide was selected as one of the first NAAQS criteria pollutants because of its association with deadly urban-industrial pollution episodes. Control programs in urban areas phased out the use of high-sulfur fuels for residential and commercial heating. Sulfur dioxide emissions from large industrial and utility sources were controlled by switching to lower sulfur fuels, removing sulfur from the fuels, removing sulfur dioxide from smokestacks, or some combination of these.

Initially, sulfur dioxide emission control strategies were designed to attain the NAAQS for sulfur dioxide and, more recently, to meet acid deposition emissions control requirements. These programs have been an unqualified success resulting in the virtual elimination of source-related impacts and violations of the sulfur dioxide standards and reducing acidic deposition. As seen in Figure 6, there have been dramatic improvements in ambient sulfur dioxide levels in the east-central U.S. Annual average and 24- and 3-hour maximum sulfur dioxide concentrations improved by 50 percent or more between 1979 and 2002.

Despite this success, concern remains about the continuing contribution of sulfur dioxide to secondary fine particles ($PM_{2.5}$). Sulfur-containing particles make up a significant portion (30 to 60 percent) of fine particles in the eastern US and it is likely that control strategies to meet the new $PM_{2.5}$ standard will require additional sulfur dioxide control. Since these same sulfur-containing fine particles are also significant contributors to regional haze, additional

Figure 5. Human-made Sulfur Dioxide Emissions in the East-Central U.S.
(Source: EPA National Emissions Trends Database, 1999)

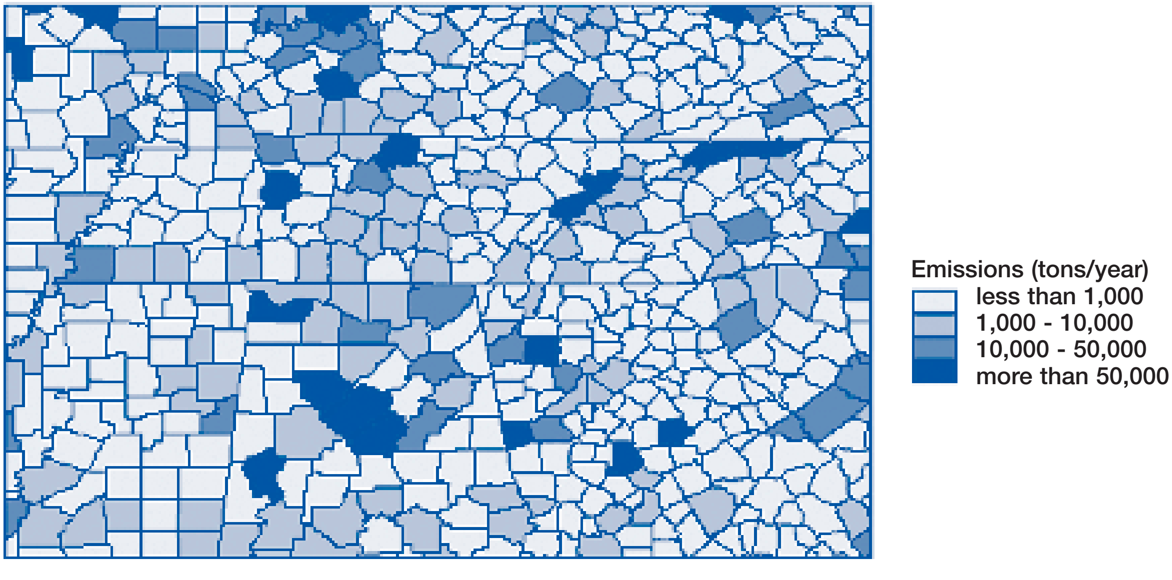
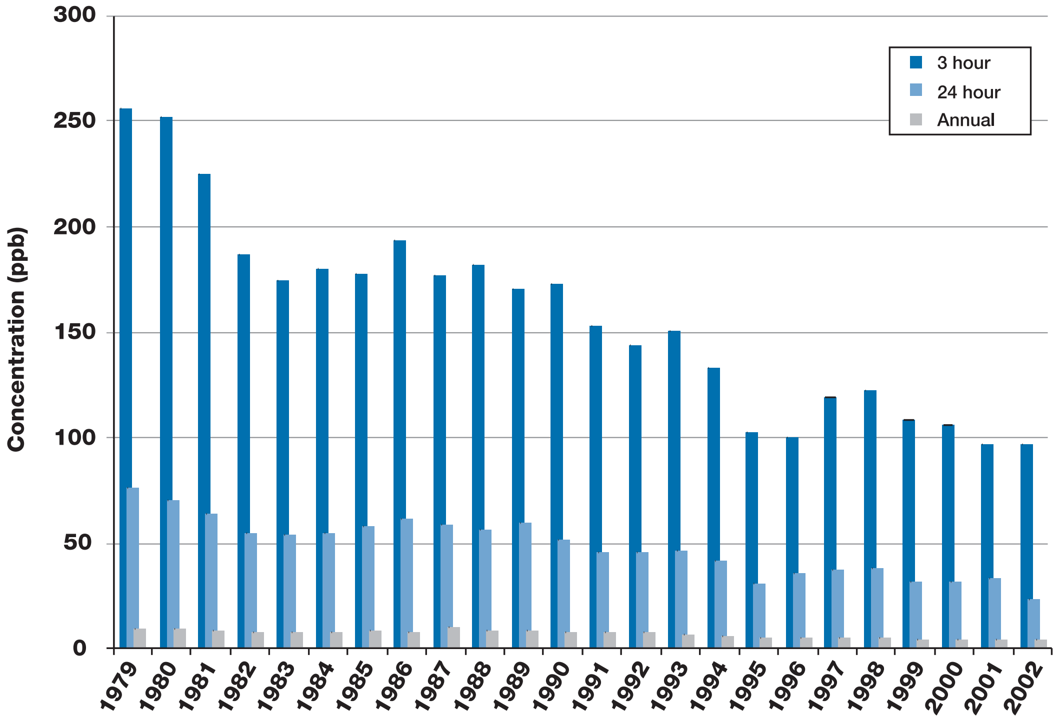


Figure 6. Sulfur Dioxide Air Quality Trends 1979-2002 in the East-Central U.S.
(Source: EPA AQS Database)



The primary National Ambient Air Quality Standard for sulfur dioxide is 30 ppb on an annual basis; 140 ppb on a 24-hour basis; and 500 ppb for the secondary 3-hour standard.

TVA’s Sulfur Dioxide Success Story

From peak system-wide annual sulfur dioxide emissions of just over 2.3 million tons in 1977, TVA has lowered its sulfur dioxide emissions by more than 76 percent, to 547 thousand tons in 2002. With the construction of additional new sulfur dioxide control systems, these emissions will be reduced again by a third (for an overall reduction of 80-85%) by 2010.

Airborne sulfur dioxide concentrations in the Tennessee Valley region improved in direct proportion to emission reductions and sulfur dioxide concentrations now average less than one-sixth the annual standard and less than one-fifth of the 24-and 3-hour standards. In 1980 there were seven sulfur dioxide non-attainment areas associated with TVA plants; none remain today.

TVA’s initial sulfur dioxide emissions control efforts (1978 through 1984) were designed to meet the sulfur dioxide standards. The second “phase” of TVA’s sulfur dioxide control program (1994-2000) achieved emissions limits meeting national acid deposition control program requirements. The third and ongoing “phase,” initiated voluntarily in 2002, is directed at further lowering TVA’s impact on fine particles ($PM_{2.5}$), visibility impairment, and acid deposition.

sulfur dioxide controls should also have a beneficial effect on visibility in our National Parks and Wilderness Areas.

Ozone

There is good ozone (O_3) and bad ozone or, as EPA says, it's "good up high and bad nearby." Naturally formed stratospheric ozone, some 10-30 miles above the earth's surface, serves as an invisible shield to filter out excess ultraviolet radiation which can cause skin cancer and cataracts and also damage crops and forests. Unfortunately this "good" ozone has been diminished by some human-made chemicals including long-lived CFCs (chlorofluorocarbons) found in refrigerants and aerosol sprays, halons (i.e., fire extinguishers), and some industrial solvents. The depletion of stratospheric ozone over the arctic and Antarctic is so dramatic during some winters that this phenomenon is frequently referred to as an "ozone hole." This global environmental issue is being addressed through the Montreal Protocol which calls for the phase out of most ozone-depleting chemicals by 2030.

While stratospheric ozone is "good," ozone in the lowest layer of the atmosphere, the troposphere, can be "bad." Only a portion of tropospheric ozone is natural. In high concentrations, such as those found around many of our large cities, exposure to human-caused ozone air pollution may trigger respiratory problems, damage plants, lower crop and forest productivity, and prematurely age rubber, plastics, cloth, and coatings. Ozone air pollution, often referred to as "smog," is formed in the atmosphere by a series of solar-powered reactions involving nitrogen oxides (NO_x) and volatile organic compounds (VOCs) (Figure 7). Both human activities and natural sources contribute to NO_x and VOC emissions. Since sunlight powers these reactions, ozone is mostly a summertime problem.

Nationally, natural VOC emissions–from vegetation, biological decay, and forest fires–are roughly equivalent to human-made sources. However, here in the vegetation-rich east-central US, natural VOC emissions are dominant (Figure 8). Human-made VOC sources, concentrated in urban/industrial areas and along transportation corridors, range from large petrochemical facilities and coating industries to small corner gas stations, paint shops, and dry cleaners. Figure 9 shows a map of human-made VOC emissions in the east-central U.S. In past years, the importance of natural VOCs in ozone production was largely unappreciated, but recent research confirms that natural emissions can be a very important contributor

Figure 7. Ground Level Ozone Formation.

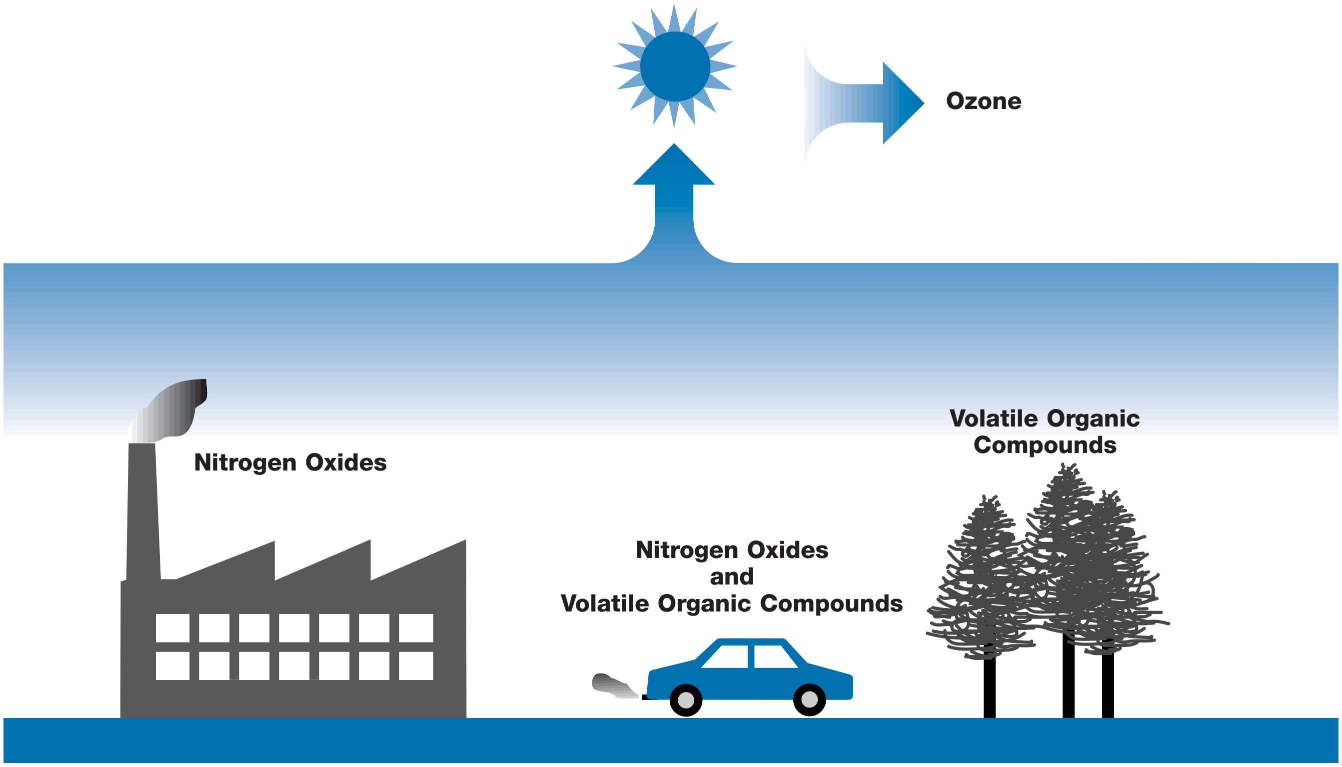


Figure 8. Sources of Volatile Organic Compounds in the Southeast.
(Source: EPA National Emissions Trends Database, 1996)

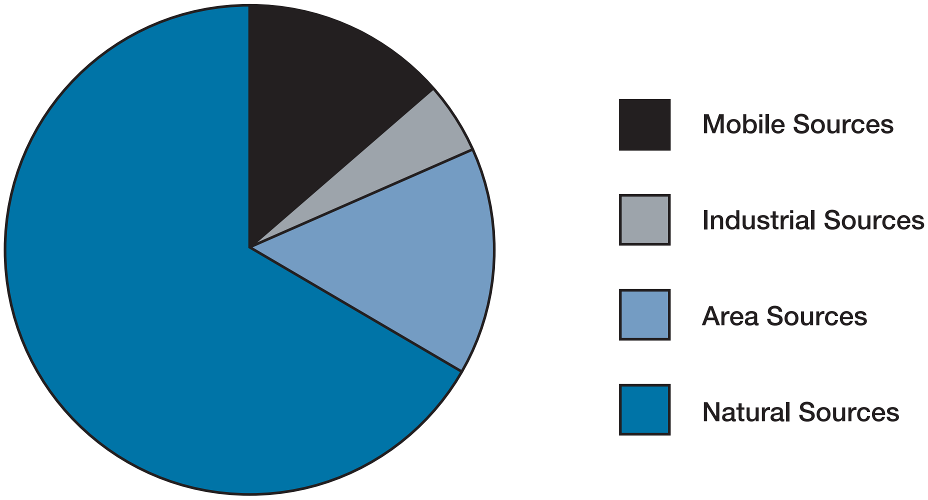
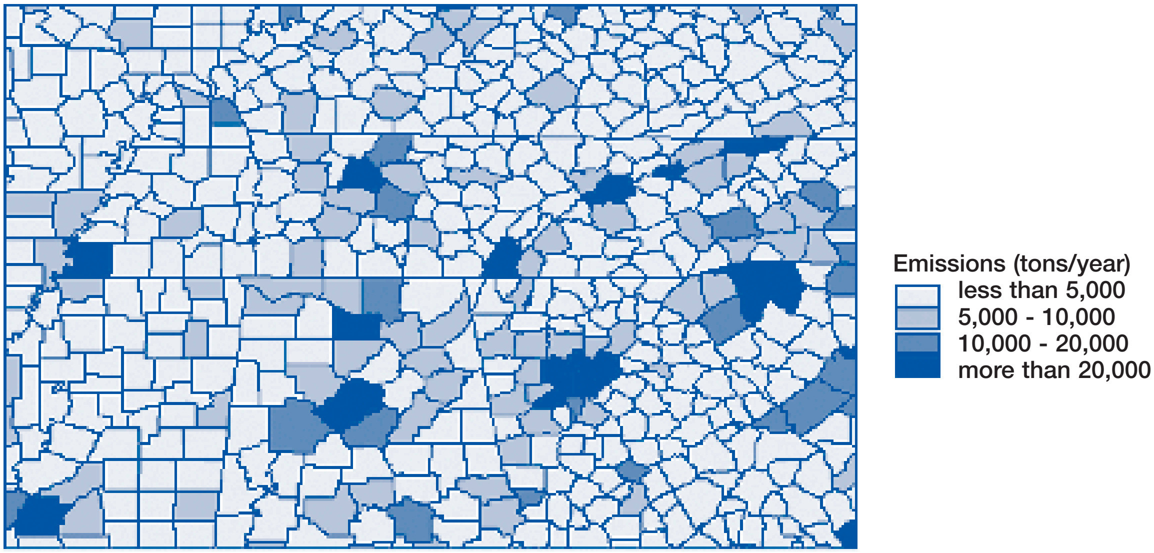


Figure 9. Human-made Volatile Organic Compound Emissions in the East-Central U.S.
(Source: EPA National Emissions Trends Database, 1999)



to ozone pollution.

Nationally and regionally, human-made emissions of NO_x exceed natural emissions. These sources include internal combustion engines, fossil-fuel power plants and industrial boilers, nitrogen fertilizers, and agricultural burning. Natural sources include biological decay, lightning, and forest fires. In 1996, most NO_x emissions in the southeastern U.S. were human-caused with mobile sources, fossil fuel power plants, and "everything else" each contributing about one-third (Figure 10). Figure 11 shows the county-by-county distribution of human-made emissions of NO_x.

Figure 10. Sources of Nitrogen Oxides in the Southeast.
(Source: EPA National Emissions Trends Database, 1996)

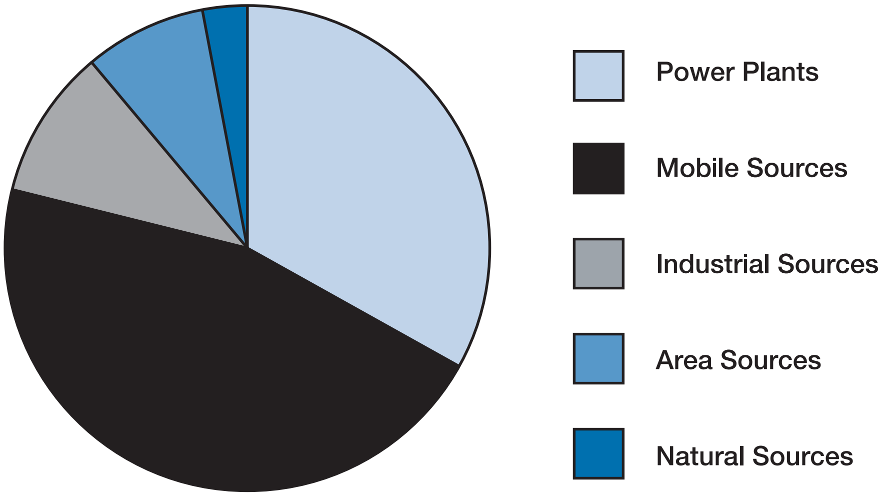
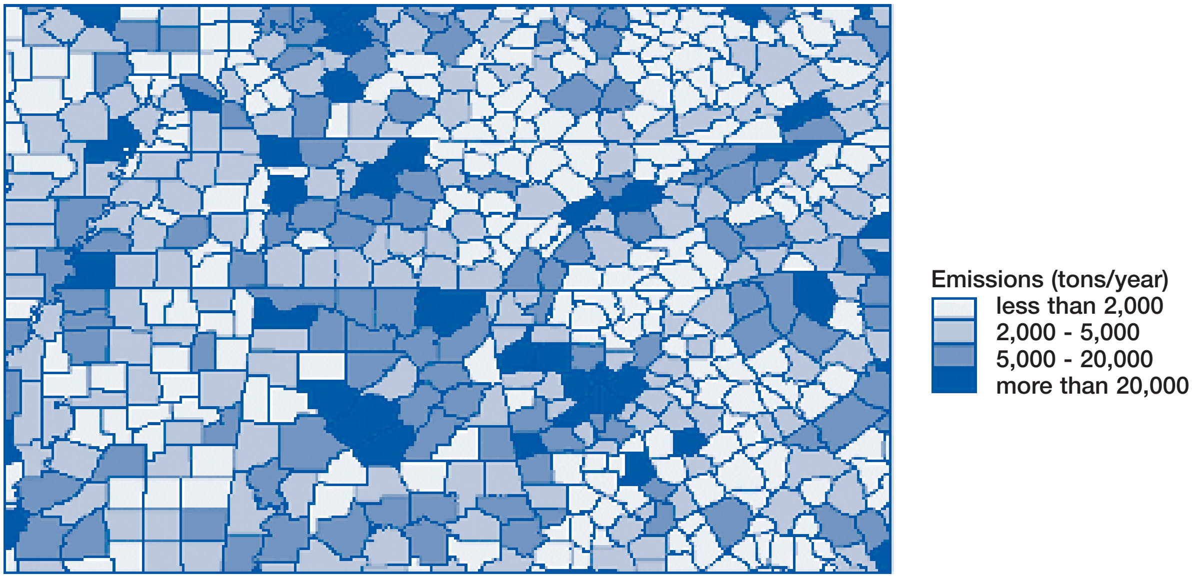


Figure 11. Human-made Nitrogen Oxides Emissions in the East-Central U.S.
(Source: EPA National Emissions Trends Database, 1999)

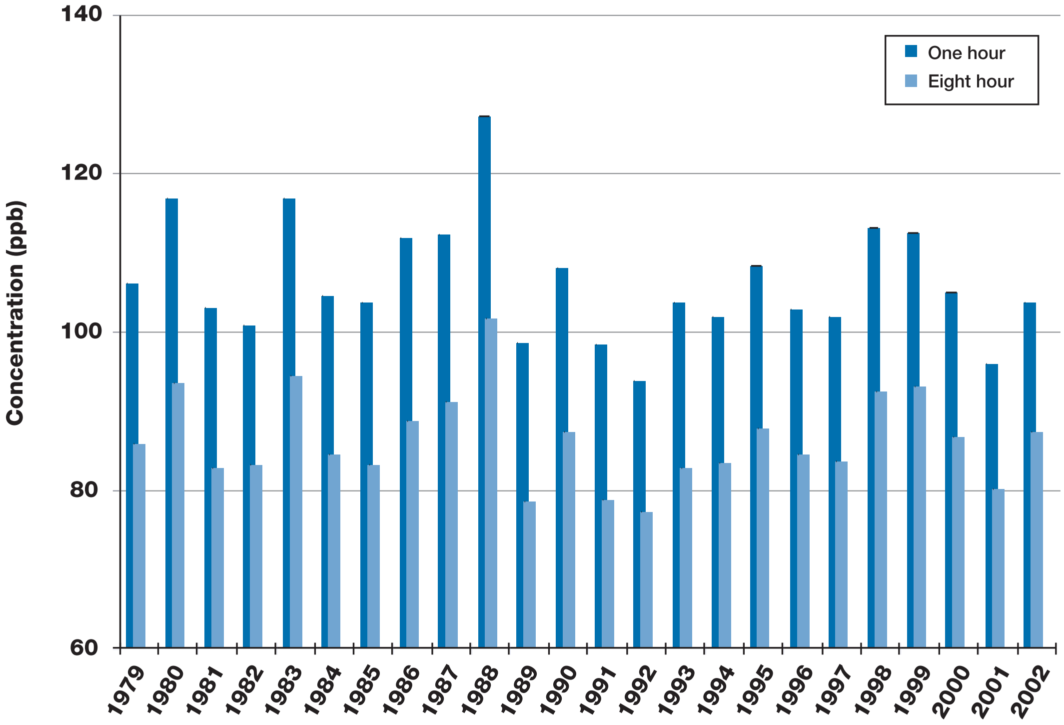


Until recently, ozone management strategies focused almost exclusively on lowering human-made emissions of VOCs through automotive emission control systems (catalytic converters and vapor recovery systems), refinery and chemical facility emissions controls, improved petrochemical storage, vehicle inspection and maintenance programs, and the phase-out of reactive VOCs from industrial processes (cleaning, coating, and lubricating). In some high-ozone urban areas, such as Los Angeles where natural emissions of VOCs are very low, these VOC-focused controls did significantly lower ozone concentrations. However, in many eastern high-ozone cities, such as Atlanta and Houston, VOC-focused strategies have been less successful. Clearly, the most effective ozone management strategies in eastern urban areas will address both human-made NO_x and VOC emissions. Given the abundance of natural VOCs, ozone management in eastern rural areas will primarily address human-made NO_x emissions.

The original NAAQS for ozone, established in 1971, was set at a 1-hour, 80 parts-per-billion (ppb) level. This standard was revised to a 1-hour, 120 ppb level in 1979 and revised again in 1997 to add an 8-hour, 80 ppb standard. Since the 8-hour, 80 ppb standard has not yet been implemented, the 1-hour, 120 ppb standard is still being used to establish attainment.

Figure 12 displays ozone-season (April 1st through October 31st) averages of the second highest 1-hour and fourth highest 8-hour ozone concentrations from 1979 through 2002. These values relate to both the 1- and 8-hour standards. While there are “good” ozone years and “bad” ozone years, there has been a slight improvement in the second highest 1-hour average concentration (down about 6 percent). It is important to note that while the average second highest 1-hour ozone level exceeded the level of the 1-hour standard only once (1988), the average fourth highest 8-hour level exceeded the level of the 8-hour standard in all but three years (1989, 1991,

Figure 12. Ozone Air Quality Trends 1979-2002 in the East-Central U.S.
(Average 2nd Highest 1-Hour & 4th Highest 8-Hour, Source: EPA AQS Database)

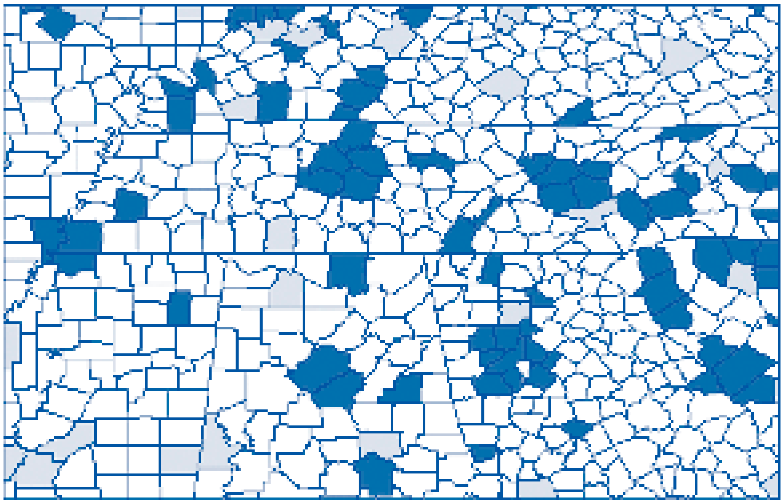


The primary and secondary National Ambient Air Quality Standards for ozone are 120 ppb on a 1-hour basis and 80 ppb on an 8-hour basis.

and 1992). Simply put, exceeding the level of the 1-hour standard has been the exception rather than the rule whereas exceeding the level of the 8-hour standard has been the rule rather than the exception.

Clearly, when the 8-hour standard is used to establish attainment, many areas will not meet this stringent clean air standard. These areas will likely include some rural areas as well as many large

Figure 13. Areas with Ozone Concentrations Above the Eight-Hour Standard in the East-Central U.S. (8-Hour Standard, 2000-2002 data)
(Source: EPA AQS Database)



Note: Dark blue counties are greater than the standard, light blue counties are less than the standard, and white have insufficient monitoring.

Air Quality Forecasting

Not only can hot and stagnant summer days be uncomfortable, they may also be unhealthy. During summer, ozone levels occasionally reach unhealthy levels for sensitive individuals–those with preexisting heart and breathing problems–and very rarely reach levels unhealthy for us all. In an effort to help inform residents when ozone concentrations may reach levels of concern, TVA, in partnership with state and local environmental and public health programs, initiated an ozone forecasting program for next-day 8-hour ozone levels in Nashville/Middle Tennessee and the Tri-Cities area of Tennessee and Virginia during the summer of 2001. In 2002 this effort expanded to include Memphis, Chattanooga, Knoxville and the Great Smoky Mountains National Park.

These forecasts–which estimate next-day maximum 8-hour outdoor ozone levels–are prepared the afternoon before the forecast day. The process consists of four steps: (1) collecting tomorrow's weather forecasts and today's ozone monitoring data; (2) applying these data to statistical forecast models; (3) reviewing and selecting the ozone forecast results; and, (4) providing these results to media outlets.

These forecasts are also used by the EPA AIRNow program which summarizes national air quality forecasts and real-time air quality information in easy-to-understand tables and maps that are carried by many newspapers and television and radio stations. A growing number of communities use these forecasts to support local ozone management programs. When elevated 8-hour ozone levels are predicted in the Tri-Cities area, for example, the East Tennessee/Southwest Virginia Ozone Action Partnership suggests residents and local businesses take voluntary steps to reduce ozone-forming emissions.

Like weather forecasts, these forecasts sometimes hit and sometimes miss the mark. Nevertheless, forecast accuracy is improving and, based on positive community response, the Tennessee forecasting partners will continue to provide ozone forecasts. In addition, the partners will look at possible fine particle ($PM_{2.5}$) forecasting beginning in 2004.

The Southern Oxidants Study

With the possible exceptions of Los Angeles, California, and Houston, Texas, more is known about ozone production and transport in the Nashville/Middle Tennessee area than any place in the world. In 1995 and 1999, TVA, Tennessee Department of Environment and Conservation, and the city of Nashville hosted major ozone field studies by the Southern Oxidants Study (SOS)–a group of "world-class" university, federal- and privately-funded air quality scientists and engineers.

With Nashville as a focal point, these researchers used instrumented aircraft and enhanced ground-based monitoring to provide detailed information on ozone production and transport. The studies were conducted during the mid-summer when ozone concentrations are greatest. Some of the more significant findings include the following:

- Although natural volatile organic compound (VOC) emissions play a significant role in regional ozone production, human-made VOC emissions predominate in Nashville. Urban ozone can be managed by reducing both nitrogen oxide (NO_x) and VOC emissions.
- Depending on the weather, NO_x emissions from fossil-fuel power plants can contribute to both rural and urban ozone pollution. Power plant NO_x emissions produce ozone less efficiently than urban emissions. Rural ozone can be managed by reducing NO_x emissions.
- Nitrogen oxides emissions from larger fossil-fuel power plants are, in fact, less efficient in producing ozone than smaller plants.
- Peak regional ozone concentrations occur above and downwind of Nashville during periods of sunny, stagnant, hot weather. Depending on the weather, peak ozone levels often miss ozone monitors.
- While peak short-term ozone concentrations occur near Nashville, maximum long-term ozone exposures occur in more distant rural areas. High elevation areas, in particular, have high cumulative ozone exposures.
- Indoor and personal exposure to ozone is much lower than outdoor exposure.

urban/industrial areas across the south-central US. Figure 13 displays potential 8-hour ozone problem areas based on 2000 to 2002 monitoring data.

Nitrogen Dioxide

Nitrogen dioxide (NO_2) is a colorless and odorless gas formed from natural sources and fossil-fuel combustion and is a component of nitrogen oxides. Natural sources of nitrogen dioxide include biological decay, lightning, and forest fires. Primary human-made sources are internal combustion engines (e.g., planes, trains, automobiles, and trucks), fossil-fuel power plants, and industrial boilers. Globally, natural emissions far exceed human-made, although human-made emissions predominate in urban and industrial areas. Figure 11, found in the previous section on ozone, shows human-made emissions of nitrogen oxides in the east-central US.

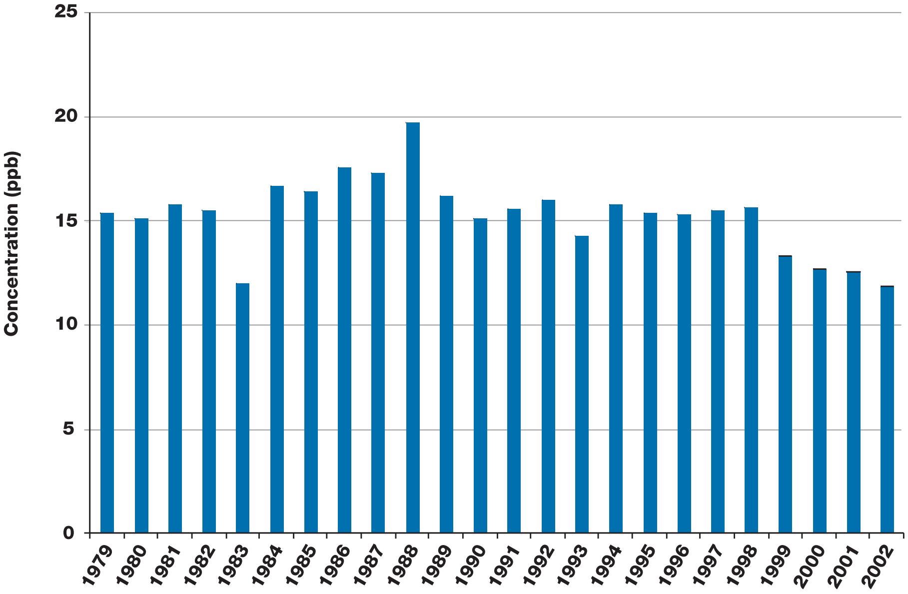
Although exposure to high levels of nitrogen dioxide is detrimental to health and can damage materials, the primary concern in this part of the country regarding human-made nitrogen oxides emissions centers on their role in the production of ozone, acid rain, and wintertime fine particles. As discussed in the previous section on ozone, nitrogen oxides figure prominently in ozone production. Also, next to sulfur dioxide, nitrogen oxides are the second largest human-made source of the excess acidity in acid rain.

As shown in Figure 14, regional nitrogen dioxide levels have improved by 20 percent over the years and all areas meet the nitrogen dioxide clean air standard.

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless gas. Natural sources of carbon monoxide include forest fires and plant respiration. The principal human-made source is fossil-fuel combustion. Outdoor carbon monoxide air pollution is largely an urban problem with the highest levels occurring during heavy traffic conditions in downtown urban “canyons” and tunnels. Figure 15 shows human-made carbon monoxide emissions in the east-central US.

Figure 14. Nitrogen Dioxide Air Quality Trends 1979-2002 in the East-Central U.S.
(Annual Average, Source: EPA AQS Database)



The primary and secondary National Ambient Air Quality Standard for nitrogen dioxide is 53 ppb on an annual basis.

Clean Air Initiative — TVA Lowers Nitrogen Oxide Emissions

In the summer of 1998 TVA initiated a $1.3 billion nitrogen oxides (NO_x) management program based largely on the installation of selective catalytic reduction (SCR) technology at seven TVA plants. Ammonia is injected into the exhaust gas, and as it passes through the reactor catalyst, much of the NO_x is transformed into harmless nitrogen gas and water vapor.

The first SCR was installed at TVA’s Paradise power plant in May 2000, and by 2005 the remaining plants will have SCR or equivalent technology installed. TVA has already added low-nitrogen-oxide burners or overfire air to many of its coal-fired boilers and others will be optimized to reduce nitrogen oxides emissions. When completed, TVA will have reduced its ozone-season NO_x emissions by 75 percent.

Although the region has made great strides in improving overall air quality, even more is being required with the recent revisions to the ozone and particulate matter standards, in particular, providing new clean air challenges. In addition to improving regional ozone and fine particle concentrations, lowering NO_x emissions will also have a beneficial effect on other air quality problems as well, including acid rain, nitrogen deposition, and visibility impairment. In partnership with federal and state regulatory organizations, TVA is committed to being part of the solution to air pollution through its comprehensive environmental management and research programs. In the long-run, what’s good for the environment is good for us all. The benefits of cleaner air will help the Tennessee Valley continue to be a good place to work and live.

Much is known about the adverse effects of carbon monoxide exposure at high levels because of its involvement in accidental deaths. However, much less is known about the effects of carbon monoxide at lower concentrations, such as those typically found in the outdoor air. Exposure to carbon monoxide reduces the oxygen carrying capacity of blood; consequently, the physical effects of carbon monoxide exposure relate to the degree of oxygen deprivation. The nervous system, heart muscle, and liver are especially sensitive to carbon monoxide. Smokers, who subject themselves to carbon monoxide levels many times in excess of outdoor pollution standards, are exposed to levels of carbon monoxide well into the range known to cause adverse health effects. Figure 16 shows carbon monoxide levels in urban areas of the east-central US. There has been a steady improvement in average carbon monoxide levels throughout the last two decades. Average 1- and 8-hour carbon monoxide concentrations improved by 60 percent or more. In 1979—the time of our

Figure 15. Human-made Carbon Monoxide Emissions in the East-Central U.S.
(Source: EPA National Emissions Trends Database, 1999)

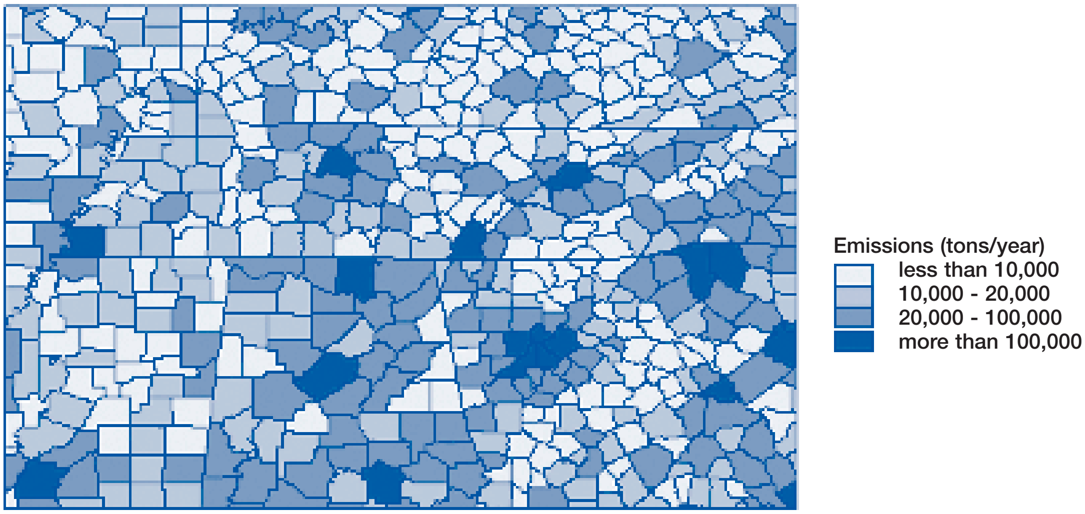
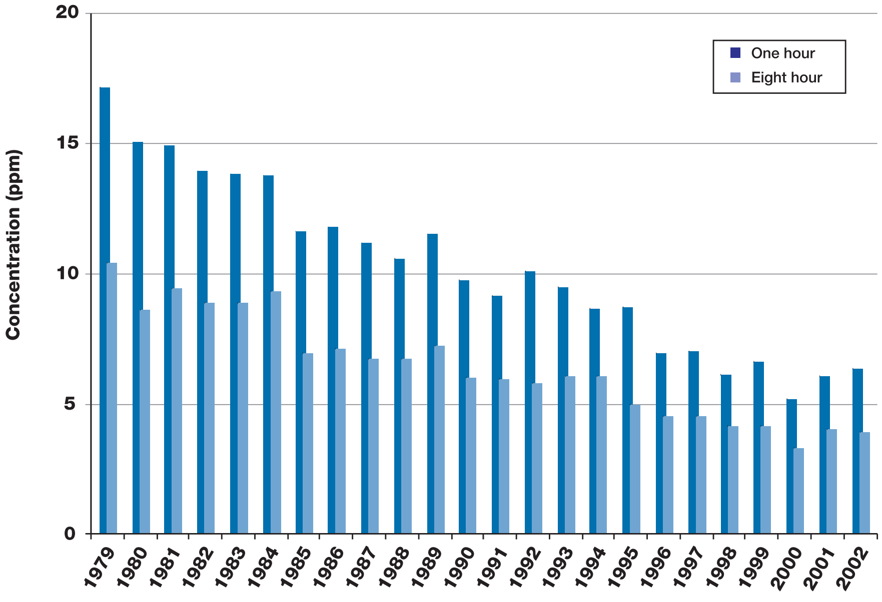


Figure 16. Carbon Monoxide Air Quality Trends 1979-2002 in the East-Central U.S.
(Average Maximum 1-Hour & 8-Hour, Source: EPA AQS Database)



The primary National Ambient Air Quality Standards for carbon monoxide are 35 ppm on a 1-hour basis and 9 ppm on an 8-hour basis. There is no secondary standard for carbon monoxide.

first air quality evaluation—there were four counties designated as carbon monoxide non-attainment areas; now all areas meet these clean air standards.

Lead

Lead (Pb) is a bluish-gray, naturally occurring metal. Thirty years ago the primary source of human-made lead emissions–and human exposure–was gasoline engine exhaust. Tetraethyl lead, an anti-knock gasoline additive, was emitted through automobile and truck tailpipes along with other air pollutants including carbon monoxide, hydrocarbons, and nitrogen oxides. Now, after a concerted effort to remove lead from gasoline, the principal human-made sources of airborne lead are metal processing industries–smelters and battery manufacturing and processing plants.

Excessive exposure to lead, through breathing, eating and drinking, can damage the kidneys, liver, and nervous system. Fetal exposure to lead is thought to impair the development of the central nervous system. Environmental exposures to lead can also harm animals.

Figure 17 shows average maximum quarterly lead levels in the east-central US from 1979 through 2002. Overall, lead concentrations have improved by 30 percent. Although these levels remain well below the level of the national standard, two lead non-attainment areas are found in the east-central US–parts of Iron and Jefferson Counties, Missouri. With few exceptions, most lead monitoring is now conducted in the vicinity of potential problem areas. EPA and state regulatory agencies are working with these emission sources to bring these two areas into compliance with the lead air quality standard.

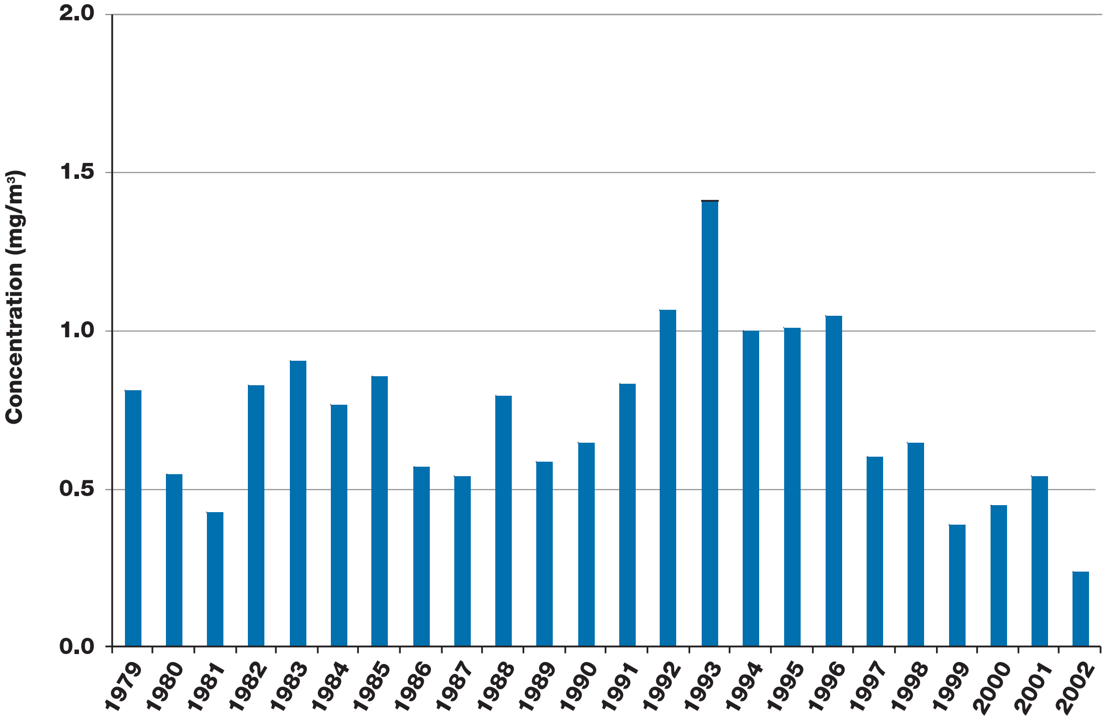
CURRENT ISSUES

Acid Rain

Acid rain (also called acidic deposition or atmospheric deposition) refers to the distribution and effects of human-made acidifying air pollutants. Acid rain was, arguably, the first air pollution issue to attract widespread international attention.

Humans' principal influence on rainfall acidity is through the emission of sulfur dioxide and nitrogen oxides which are eventually deposited as gases, small particles, and in rainfall, snow, and fog. Acid rain has been associated

Figure 17. Lead Air Quality Trends 1979-2002 in the East-Central U.S.
(Maximum Quarterly Concentration, Source: EPA AQS Database)



The primary and secondary National Ambient Air Quality Standard for lead is 1.5 mg/m^3 on a quarterly basis.

with a number of potential environmental effects including declines in fish, agricultural, and forest productivity; accelerated weathering and corrosion of building products; and adverse health effects. The acidity of precipitation (rain, fog, or snow) can be expressed on a logarithmic scale of 0 to 14 called the pH scale. Figure 18 shows the pH of some common solutions and the range of acid rainfall.

Theoretically, "pure" rainfall is slightly acidic, with a pH of approximately 5.7. However, it is thought that the actual average pH of preindustrial rainfall in eastern North America was closer to 5.0 because of natural acidic emissions. During the past two decades the annual average rainfall pH in the Tennessee Valley has ranged from about 4.4 to 4.6, about 3 times more acid than preindustrial rainfall. Figure 19 shows average annual rainfall acidity, measured as hydrogen ion concentration, for 1979 through 2002.

The effects of acid rain on the environment largely depend on the ability of the environment to neutralize or buffer incoming acidity. Ecosystems differ widely in their ability to neutralize these acid inputs.

Figure 18. The pH scale

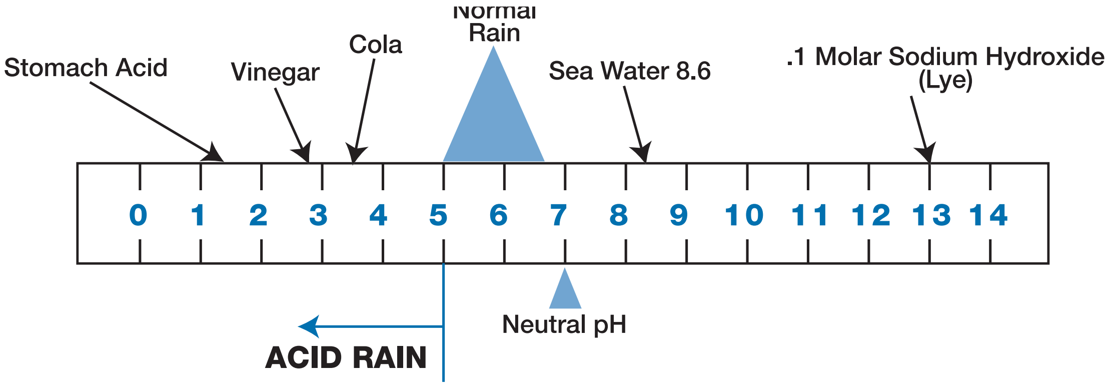
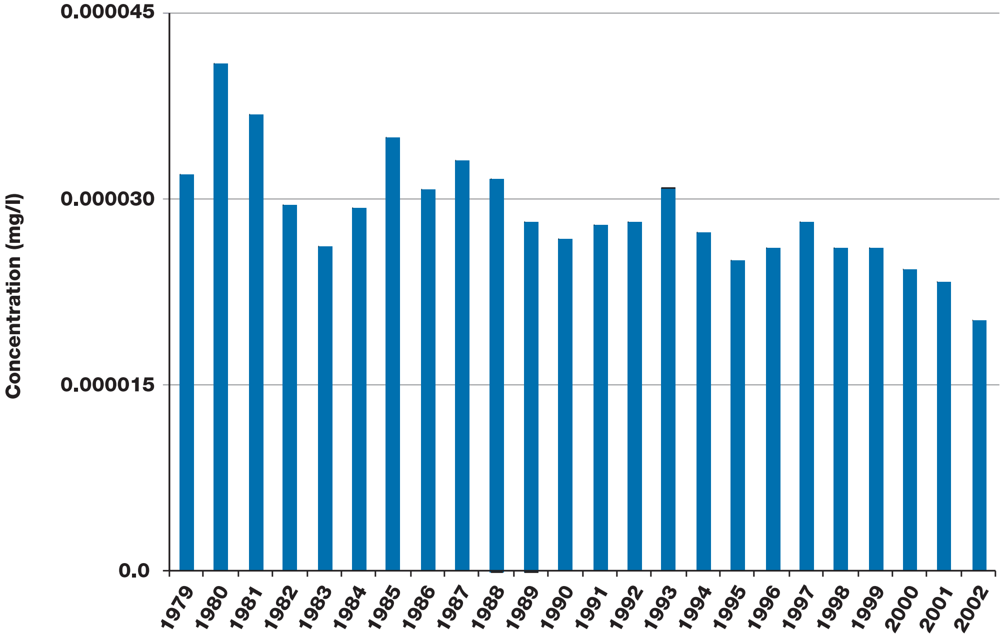


Figure 19. Precipitation Hydrogen Ion Concentration Trends 1979 - 2002 in the East-Central U.S.
(Milligrams per liter, Source: NADP/NTN)

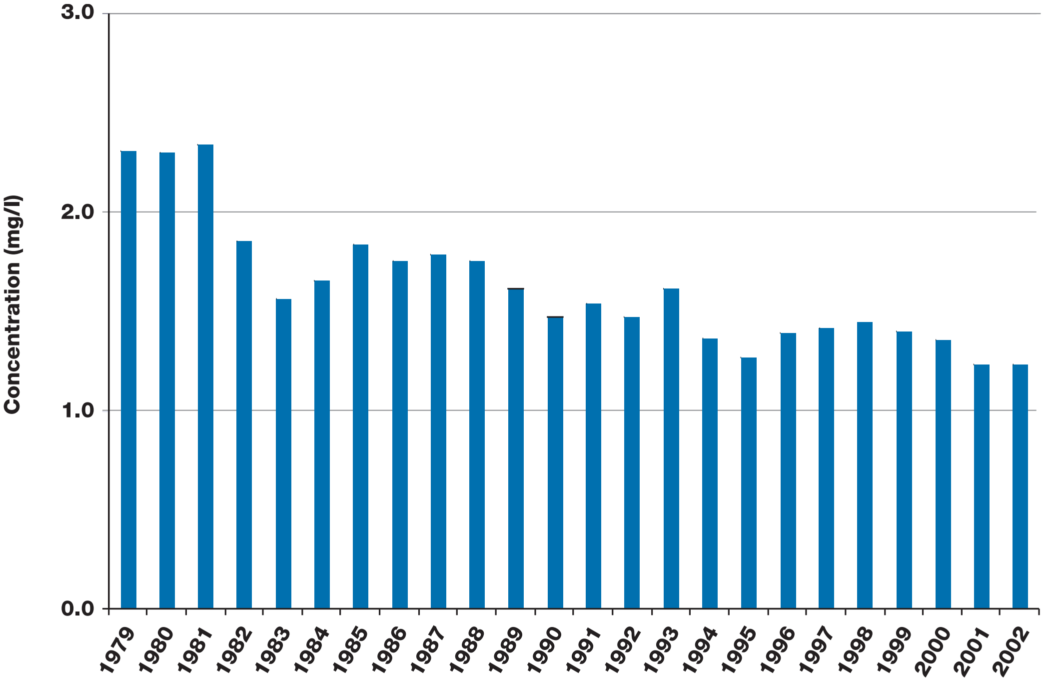


Note: Lower hydrogen concentration means less acidity.

Differences in geology, soils, forest communities, and previous land-use are some of the factors that may account for variation in sensitivity. Research has shown that high-elevation forests receive the highest levels of sulfate and nitrate deposition and have the greatest risk of long-term impacts from acid rain.

The most effective acid rain control strategies focus on reducing human-caused emissions of sulfur dioxide and nitrogen oxides. However, because of the complex chemical and meteorological processes involved in the production and distribution of acid rain, changes in human-caused emissions are not necessarily proportionally reflected in local or regional acid rain measurements. The Tennessee Valley region provides a good example. Over the past 24 years

Figure 20. Precipitation Sulfate Concentration Trends 1979 - 2002 in the East-Central U.S.
(Milligrams per liter, Source: NADP/NTN).



High Deposition in High Places

Global nitrogen deposition, often in the form of acid deposition, has increased dramatically in the past century as a result of human-made nitrogen oxides (NO_x) emissions from fossil-fuel combustion and use of nitrogen fertilizer. Usually nitrogen is the nutrient that limits forest growth. High-elevation southern Appalachian forests receive among the highest loadings of atmospheric nitrogen in North America and show high nitrate levels in soil and stream waters, indicating that nitrogen is so plentiful that it is “leaking” from the system.

A cooperative long-term nitrogen study has been initiated at the Noland Divide Watershed, located in the high elevations of the Great Smoky Mountains National Park. Cooperators include the National Park Service, the Tennessee Valley Authority, the Department of Agriculture, the Geological Survey, the Department of Energy, EPRI (Electric Power Research Institute), and several universities. This long-term study measures the different factors that control nitrogen in a forested ecosystem, including atmospheric inputs, soil properties, and vegetation characteristics. It will provide important information to assess differing NO_x emission reduction strategies and help determine whether regional NO_x emission reductions will significantly reduce regional environmental nitrogen.

(1979-2002), annual average sulfur dioxide (Figure 6) and rainfall sulfate (Figure 20) concentrations have declined by about half, while rainfall acidity has declined by about one-third (Figure 17).

Visibility

When people go to the mountains, they often head to high places for a good view. "Visibility" is a very important value in appreciating wilderness. Historically, "visibility" is defined as the greatest distance at which an observer can "just" see a black object viewed against the horizon sky. However, visibility is more than just a measurement of how far an object can be seen; it is related to the conditions that allow appreciation of the inherent beauty of landscape features. Unfortunately, regional visibility has been estimated to have declined by as much as 60 percent over the past 50 years in the eastern US, with the poorest visibility conditions occurring during summer months.

The deterioration in visibility is linked to an increase in regional haze, a type of visibility impairment resulting from widely dispersed and intermixed pollutants from many sources. Atmospheric particles and gases that reduce visual contrast and visual range by absorbing and scattering light have their origins in both natural and human-produced processes. For example, the bluish "smoky mountain" haze characteristic of southern Appalachia originates from organic (i.e., carbon-based) aerosols emitted by the lush mountain forests. Much of the light extinction in our regional haze that reduces visibility is due to fine sulfate particles. Sulfates can originate from natural sources such as volcanoes and oceans but these are of minor importance in the east-central US. Instead, our light extinction is mostly due to sulfates that originate from human-produced sources of emissions including fossil-fuel combustion and industrial processes.

In 1999 EPA issued new regional haze regulations with a goal of restoring visibility in National Parks and Wilderness Areas to natural conditions by 2064. As a first step toward this goal, states are encouraged to control sources where it can be reasonably determined that the source is impairing visibility in Class I National

Great Smoky Mountains National Park Air Quality Cooperative Research

The Great Smoky Mountains National Park is a national treasure. It is the most visited National Park in the country; an International Biosphere Reserve; a tourist destination that significantly contributes to North Carolina and Tennessee economies; and has possibly the world's highest species diversity of any temperate forest region. The Park faces numerous environmental threats including over-visitation, invasion by numerous exotic species, and air quality impacts. There are three critical issues related to air quality:

Visibility – Regional haze reduces visibility and over the past 50 years, average regional visibility has decreased by as much as 60 percent. Coal and oil combustion plants are a significant source of SO_2, which provides one significant component of regional haze.

Ozone – On occasion summertime ground-level ozone exposures in the Park are among the highest in the eastern US. The Park issues health warnings to visitors during high ozone days and there is documentation of visible ozone injury to some plant species. Sources which contribute to the Park ozone include volatile organic compounds (from mostly natural sources such as vegetation) and NO_x (from motor vehicles, coal and oil combustion plants, industry, and non-road engines).

Acid deposition – The peaks of the Great Smoky Mountains experience the highest levels of total nitrogen deposition in North America and the second highest levels of total sulfur deposition. High deposition levels are hypothesized to have long-term, secondary ecological impacts. Both SO_2 and NO_x contribute to acid deposition.

TVA collaborates with a number of research partners including the National Park Service, Environmental Protection Agency, National Oceanographic and Atmospheric Administration, US Geological Survey, Department of Energy, the Electric Power Research Institute, and numerous universities and state and local air programs to conduct research and demonstration projects. The goal of this cooperative research program is to better understand the air quality issues affecting the Park and other Class I areas and to ensure that the solutions that we undertake result in effective, beneficial improvements.

Look Rock Air Quality Station

It's been more than 23 years since TVA, the EPA, and the National Park Service (NPS) established the first, fully instrumented air quality and visibility monitoring station in the eastern US at Look Rock. Located on the high western edge of the Great Smoky Mountains National Park, this station is ideally suited to measure visibility changes. After the initial three-year study in the early 1980s, this air quality monitoring station was managed by Tennessee. Then, starting in the late 1980s, it was adopted by the NPS as one of its permanent air quality monitoring stations. Since 1988, NPS and TVA have used the Look Rock station to address visibility, ozone, fine particles and other important regional air quality issues.

In 2000, partnership support of the Department of Energy, the Electric Power Research Institute, and TVA added high-sensitivity sulfur dioxide, nitrogen oxides, and carbon monoxide gas monitoring instruments and several continuous particle measuring instruments. Beginning in July 2002, Look Rock has served as a fine particle measurement "supersite" to help further refine national understanding of rural fine particles and their relationship to visibility impairment. While there are several urban "supersites," Look Rock was the first rural supersite and, as such, provides a measurement baseline by which all other information will be compared.

In 2003, TVA and NPS are using Look Rock to participate in the Visibility Improvement State and Tribal Association of the Southeast (VISTAS) project. VISTAS is a collaborative effort of state governments, tribal governments, and various federal agencies established to initiate and coordinate activities associated with the management of regional haze, visibility, and other air quality issues in the southeastern US.

Parks and Wilderness Areas. States are also required to develop 10-year plans to achieve reasonable progress toward this goal and are encouraged to collaborate with neighboring states to develop regional strategies to improve visibility.

Toxic Air Pollutants

Toxic air pollutants are any of more than 650 chemicals identified by the EPA which, with significant exposure, may potentially cause health problems. The Surgeon General's Office suggests that our collective exposure to "toxic chemicals are adding to the disease burden of the United States in a significant, although as yet not precisely defined way." Examples of toxic air pollutants include those defined as "hazardous" compounds in the Clean Air Act (asbestos, beryllium, mercury, vinyl-chloride, benzene, arsenic, and radionuclides); heavy metals (such as chromium, cadmium, and nickel); and persistent bioaccumulating compounds (such as polychlorinated biphenyls (i.e., PCBs), dioxin, and pesticides).

The sources of toxic air pollutants are many. They include very large industrial plants using or producing plastics, pesticides, solvents, fossil fuels, petrochemical fuels, and agrochemicals; waste treatment facilities such as incinerators, sewage treatment plants, and landfills; small sources such as the corner dry cleaners, gas stations, and print shops; and common household products. While the amount of toxic emissions is important, our personal exposure to toxic pollutants is dominated by small, nearby sources. For example, a large petroleum refinery may emit thousands of pounds of benzene but our personal exposure may be dominated by our pumping self-serve gasoline.

Concern about hazardous chemicals in general and toxic air pollutants in particular has increased for a number of reasons:

- Heightened public awareness of health concerns related to cancer, birth defects, and neurological disorders that have been associated with exposures to some chemicals.
- Improvements in measurement technology which

allow detection of extremely low levels of toxic chemicals throughout the environment.

- Catastrophic, unintentional releases of toxic chemicals, such as in Bhopal, India, and Valdez, Alaska.
- Increased awareness of the production, use, and release of toxic chemicals around the world.

Efforts to reduce toxic pollutant exposure have focused on identifying potentially harmful compounds, protecting workers from on-the-job exposures, and protecting the public by controlling significant sources. Evaluation and control of emissions can be a lengthy process. In 1990, Congress amended the Clean Air Act to accelerate the control of toxic air pollutants.

Indoor Air Quality

It's a game of sums. Our personal exposure to air pollution is determined by the various pollution levels we encounter as we move from place to place and the amount of time we spend in these places. It shouldn't surprise anyone to know that most of us spend more than 95 percent of our time inside. This translates to, on average, about one and one quarter hours a day outdoors. This means, from a public health perspective, that indoor air quality is, in many ways, the preeminent air quality issue.

Under most circumstances, indoor environments offer some protection from outdoor air pollution. Air pollution advisories, issued when outdoor pollution levels become unhealthy, admonish us to "restrict physical activity and stay indoors." However, the same doors, windows, roofs, and walls that help keep outdoor pollution "out" also serve to trap indoor pollution "in."

Risk Assessment—Taking Extra Steps to Insure Public Safety

On Earth Day 1997, EPA added coal- and oil-fired electric generating plants to the list of facilities required to report annual air, water, and land releases of potentially toxic substances to the EPA-maintained, public-access Toxics Release Inventory (TRI) database.

TVA, one of the nation's largest power producers, issued its first TRI release reports (for calendar year 1998) on July 1, 1999. These plant-specific reports estimated the land, air, and water releases of more than 20 potentially toxic substances including antimony, arsenic, barium, beryllium, chromium, cobalt, copper, hydrochloric acid, hydrogen fluoride, lead, manganese, nickel, selenium, sulfuric acid, thallium, zinc, n-hexane, and 1,2,4-trimethylbenzene.

While the total amount of TVA's TRI releases can be substantial, quantity alone does not provide a meaningful picture of associated health risks. To gain this perspective, it is necessary to estimate human exposure. Beginning in 1999, TVA conducted plant-specific, inhalation risk assessments based on annual air TRI emissions estimates for each of its plants. These risk assessments combine environmental exposure estimates with evolving health effects guidelines developed by EPA and others. The risk estimates provided by these annual assessments help TVA gauge the health significance of its TRI releases.

The results from TVA's inhalation health risk assessments indicate that airborne emissions of TRI substances from TVA plants do not pose a significant health risk to either TVA employees or the general public. These findings are consistent with independent assessments by EPA and others.

TVA's TRI risk assessments continues to yield important and informative results. It is, however, only one step in a continuing process of better understanding the possible fate and effects of TRI emissions. As the science of risk assessment evolves, TVA is committed to remain on the leading edge of health risk assessment for its facilities.

For those air pollutants with indoor sources, indoor pollution levels are much higher than those outdoors. Let's face it; we're still more likely to open our windows to "let in some fresh air" than we are to consciously prevent outdoor pollution from getting in.

There are many kinds and sources of indoor air pollution:

- Combustion gases such as carbon monoxide, carbon dioxide, and nitrogen oxides from indoor combustion appliances such as unvented kerosene and gas space heaters or improperly installed or operated gas appliances.
- Small particles from smoking, fireplaces, wood stoves, and cooking.
- Volatile organic compounds from aerosols, insecticides, cleaning solvents, stored fuels, paint, vinyl, plastic, adhesives, stain repellents, and building materials.
- Biological contaminants such as allergens from pets, insects, and plants; molds and fungi from damp surfaces; and viruses and bacteria from people and pets.
- Radioactive gases such as radon from the soil beneath the building.
- Air "purifiers" which generate ozone to help destroy odors and keep excess mold and mildew in check can also yield unacceptably high ozone concentrations that pose a threat to health as well as prematurely aging carpets, drapes, wall coverings, and painted surfaces.

Health complaints associated with poor indoor air quality, sometimes referred to as "sick building syndrome," are as many and as varied as the kinds of indoor pollutants. These complaints can include dizziness, headache, nausea, irritation of the eyes and airways, impaired learning ability, allergies, sleepiness, rashes, abdominal and chest pains, respiratory illness, infectious diseases, and cancer.

Although modern heating, ventilating, and air conditioning systems can provide healthful and energy-efficient living spaces, indoor air pollution problems are sometimes aggravated by well-intentioned weatherization efforts. In many cases, we do not adequately address the need for ventilation when we "tighten up" our buildings and homes. Reduced ventilation coupled with the existing burden of indoor pollution, and use of alternative heating sources—such as wood stoves and unvented heaters—can lead to significant indoor air pollution problems. In fact, if indoor pollution were routinely measured and subjected to the same regulatory standards as those for outdoor pollution, indoor air quality health advisories would be commonplace. The EPA, California Air Resources Board and others suggest that typical indoor air pollution exposure is associated with much greater health risk than outdoor air pollution.

Even as we learn more about indoor air pollution, it is appropriate to minimize our own exposure. Here are some common sense ways to reduce exposure to indoor air pollution:

- Install and operate all combustion appliances according to manufacturer's specifications. Yearly maintenance checks are recommended.
- Consider additional ventilation as part of home and office weatherization efforts.
- Read the labels on household products such as cleansers, polishes, drain cleaners, and stove cleaners to ensure proper use and storage.
- Ventilate kitchens and bathrooms during use to remove smoke, excess moisture, and odors.

- Store paints, household cleaning products, and fuels in approved containers in well-ventilated areas.
- Don't smoke and avoid smoke-filled rooms.
- If you live in an area with known radon problems, test your home or workplace.

Global Climate Change

Lately, it seems like both summers and winters have been warmer than they used to be. Whether or not this is true, the earth's climate is always changing, it always has. It was much warmer when dinosaurs roamed millions of years ago and much colder during the last ice age, some 10,000 years ago. Some scientists think the earth's climate may be changing more rapidly than ever before because of the "greenhouse effect." Natural variation or not, the earth's average temperature has gotten a little warmer—about one degree Celsius in the past 120 years (Figure 21). One degree doesn't sound like much, but even small changes can lead to significant environmental changes. Most climate change scenarios suggest that continuing changes in the composition of the earth's atmosphere could lead to more pronounced global warming, which, in turn, could result in melting polar and glacial ice, rising sea levels, and altered rainfall patterns.

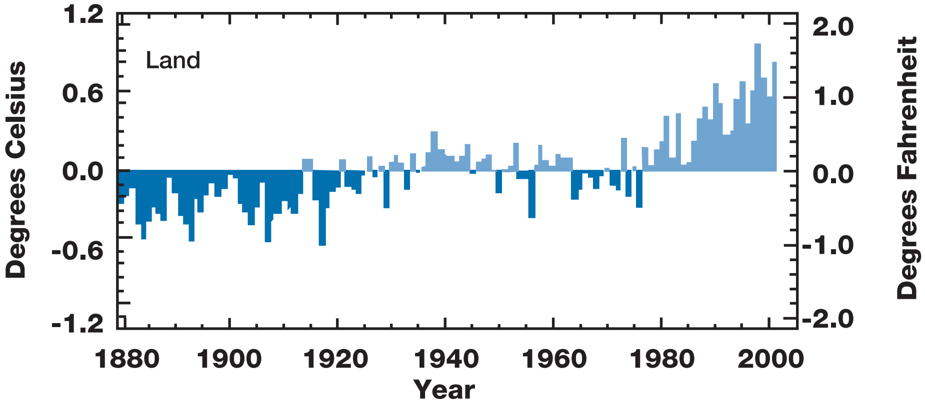
There's no question about it, the earth's atmosphere plays a primary role in determining global temperature. Just like a greenhouse, the atmosphere allows some of the sun's energy in and lets only part of it back out. The remainder stays behind to warm the environment and power the giant heat-transfer machine that we know as the "weather." Basically, there are at least two ways that human activities can influence the earth's "greenhouse."

First, humans influence the amount of solar energy coming through the atmosphere. This is where the "ozone holes" come in. In the upper atmosphere, the stratosphere, naturally formed ozone intercepts incoming solar energy and limits the amount of ultraviolet radiation reaching the earth's surface. Long-lived chlorofluorocarbons (CFCs) used in air conditioners, refrigerators, industrial solvents, aerosol sprays, and in manufacturing foam food containers can reduce stratospheric ozone and allow more ultraviolet radiation in. Although it is not apparent that increased ultraviolet radiation has occurred here in the mid-latitudes, a global increase may lead to several adverse environmental effects including higher rates of skin cancer and eye cataracts and additional global warming.

Second, humans influence the amount of energy retained in the lower atmosphere—the troposphere. Upon reaching the lower atmosphere, incoming solar radiation is absorbed and much of it re-released as infrared radiation. Much of this infrared radiation is lost to space but some is trapped by clouds and so-called "greenhouse gases." This trapped energy warms the atmosphere. Levels of one of the principal greenhouse gases, carbon dioxide, a product of plant and animal respiration and fossil-fuel combustion, have risen by 30 percent over the past two centuries. Other important greenhouse gases on the rise include methane (from landfills, livestock, and other sources) and nitrous oxide.

Recent projections suggest that global temperatures may rise an additional 1 to 2 degrees Celsius during the next 50 years. However, these projections are based on a limited understanding of the complex processes that

Figure 21. Changes in Global Temperature Since 1880.
(Source: NOAA National Climatic Data Center)



What's so Green about Green Power?

The "green" in green power is its renewability. You use the fuel today; it comes back tomorrow, like a growing plant. And the whole process of use and renewal helps sustain our environment. Green power is electricity generated by renewable resources, like wind, solar energy, landfill gas, small hydropower sources, and geothermal energy. Renewable sources of electricity are some of the cleanest available.

TVA and some of its distributors are now offering their customers the choice of green power from wind, solar energy, and gas from landfill and sewage treatment plants, three sources with some availability in the Tennessee Valley. By choosing Green Power Switch and paying a premium for green power, consumers can encourage the use of cleaner renewable energy in the Valley.

Wind — Wind turbines can generate electricity anywhere the wind blows steady and strong (at least 9 miles an hour), but wind power remains expensive compared with conventional energy sources in the Tennessee Valley. Wind turbines produce no pollution and can be placed on some sites without disrupting the way the land is used.

Solar — Photovoltaic (PV) panels can be used to convert sunlight directly into electricity. The price of PV cells has dropped steadily over the last 25 years, but solar power remains one of the most expensive energy sources; and more expensive than either wind or conventional power. Because PV panels burn no fuel and have no moving parts, they are clean and easy to maintain.

Landfill and Sewage Treatment Plant Gas — Landfills and sewage treatment plants emit gases as organic material decays, and those gases can be collected for use as fuel. Methane, a gas that contributes to the greenhouse effect, is a major component, and it is 20 times more harmful as a greenhouse gas than carbon dioxide. Proven technology shows that methane can be captured before it escapes into the atmosphere and used as a fuel to produce electricity at a cost comparable to that of conventional power.

Green power costs more because although the sun and the wind are free, the technology needed to convert renewable energy to usable electricity is still substantially more expensive than traditional generating technology. As more consumers buy green power and the technology matures, the cost is expected to come down.

Green Power Switch®

determine the earth's climate. Whether the current phase of global warming is due to the "greenhouse effect" or natural variation, one important point is evident: accelerated international research programs are needed to better understand global climate change and develop effective management strategies.

CONCLUSIONS

The bottom line is that the implementation of clean air legislation has resulted in substantial emission reductions and significant improvements in ambient air quality. We are moving in the right direction. It has, to be sure, required a great deal of time, effort, and resources. The route taken has not often been smooth and direct but rather one where the regulators, the regulated, and various special interests on both sides have hewn a contentious and oftentimes convoluted path. Nevertheless, outdoor air quality in and around the east-central U.S., in particular, and across the country, in general, is much better today than 24 years ago when TVA published the first "How Clean is Our Air?"

Regional levels of sulfur dioxide and particulate air pollution have improved dramatically. Where once there were many "non-attainment" areas for these pollutants, today there are none. Carbon monoxide and nitrogen dioxide continue to meet clean air standards. Localized lead and local and regional ozone pollution continue to test our resolve, and the recent stringent revisions to ozone and fine particle ($PM_{2.5}$) clean air standards will provide major new challenges.

The continuing concerns about acid rain, visibility impairment, air toxics, indoor air quality, and global climate change will be with us for years to come even though some improvements are evident.

- Acid rain levels are lessening as our industrial emissions of strong acid gases-sulfur dioxide and nitrogen oxides-continue to decline.

- Visibility problems related to regional haze continue to be a special problem for our National Parks and Wilderness Areas. These problems, too, should lessen as our emissions of sulfur dioxide and nitrogen oxides continue to decline.

- Air toxics are a growing area of concern as ever improving, ever more comprehensive environmental technology underscores the inter-relatedness and vulnerability of the global ecosystem. Quite literally, emissions from our own "backyard" affect not only our regional environment but also that of the nation and the world.

- Indoor air quality is a major concern from the public health perspective and although we often consider our homes to be our "castles," they are often a predominant source of exposure to many kinds of air pollution.

- Global climate is certainly changing and more research on this topic is definitely needed. Perhaps no single environmental issue is more related to the often asked question of "where do we go from here?"