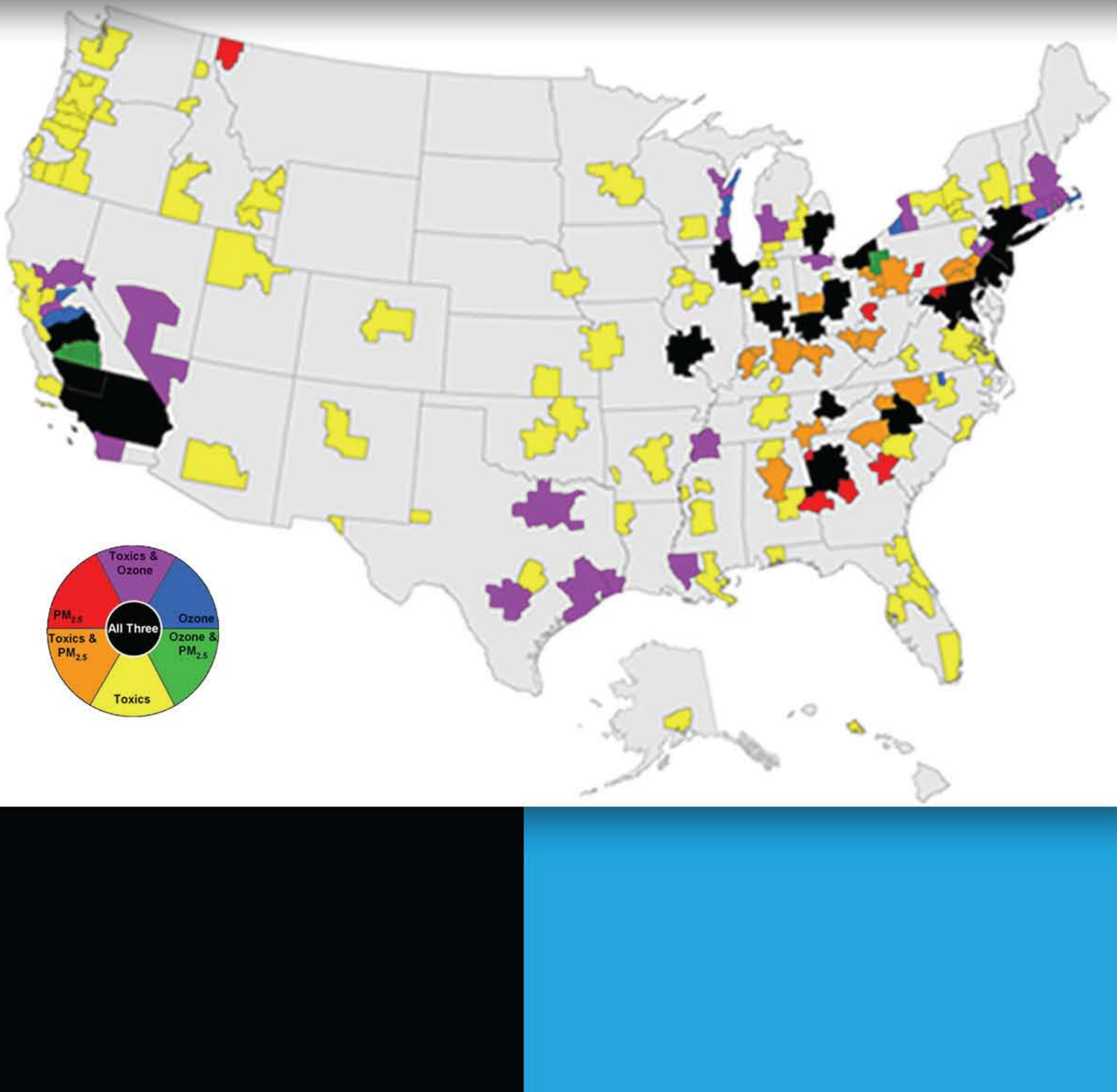
The Multi-pollutant Report:

Technical Concepts & Examples



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Introduction

The U.S. Environmental Protection Agency's (EPA) Office of Air Quality Planning and Standards (OAQPS) is responsible for a broad set of air quality management activities including setting standards, developing cost-effective control strategies, and evaluating air quality. To date, OAQPS has approached air quality management one pollutant at a time based largely on the legislative directions of the 1990 Clean Air Act Amendments (CAAA). The 1990 CAAA established a mix of emissions, technology, and ambient air quality goals focused on reducing criteria air pollutants (CAPs) and hazardous air pollutants (HAPs). The 1990 CAAA also include programs to reduce acid deposition and protect the stratospheric ozone layer. Air quality management responsibilities are shared among federal, state, local, and tribal governments. Major current components of this air quality management system include the following:

- National Ambient Air Quality Standards (NAAQS) for six criteria pollutants
- State Implementation Plans (SIPs) for criteria pollutants including regional haze
- Federal regulations such as the NO_x SIP Call, Clean Air Interstate Rule (CAIR), Clean Air Mercury Rule (CAMR), Clean Air Visibility Rule, and Heavy-Duty Diesel and Nonroad Diesel Rules
- An air toxics (HAPs) program to develop technology-based Maximum Achievable Control Technology (MACT) standards and residual risk standards for HAPs

The technical infrastructure to support the implementation of the 1990 CAAA includes research, monitoring networks, emission inventory development, modeling, exposure and risk assessment, and cost/benefit analysis.

The current system has resulted in significant reductions in emissions and pollutant concentrations during a period of strong economic growth. Acknowledging the past successes, the 2004 National Academy of Sciences (NAS) study "Air Quality Management in the United States" (National Research Council, 2004) called for modifying current air quality management practices to integrate assessment, planning, and implementation efforts across all air quality and environmental issues—that is, a multi-pollutant (and multimedia) focus. The NAS study has catalyzed reorganization activities and new research themes throughout EPA's air quality management program. Using NAS's report as a blueprint, OAQPS has begun to transition toward a comprehensive, multi-pollutant treatment of our nation's air quality problems.

Managing air quality with a multi-pollutant approach is a challenge for our evolving air quality management system. The adoption of this type of approach to environmental decision-making requires an improved understanding and appreciation of the scientific complexities of co-pollutant interactions. In a discussion of the air quality management of fine particles, the North American Research Strategy for Tropospheric Ozone (NARSTO, 2004) stated

> "The current understanding of atmospheric processes shows that $PM_{2.5}$ problems are related to ground-level ozone, acid rain, and climate issues and share many of the same sources. This recognition provides the impetus for integrated and optimized management strategies that accommodate different atmospheric responses for each pollutant."

Continuing to improve the air quality management system requires the addition of a multi-pollutant component to the existing framework (shown in **Figure I-1**). Technical concepts that need to be addressed include shared emissions sources, multi-pollutant effects from control technologies, common receptors and shared atmospheric chemistry, transport, deposition, and exposure pathways.

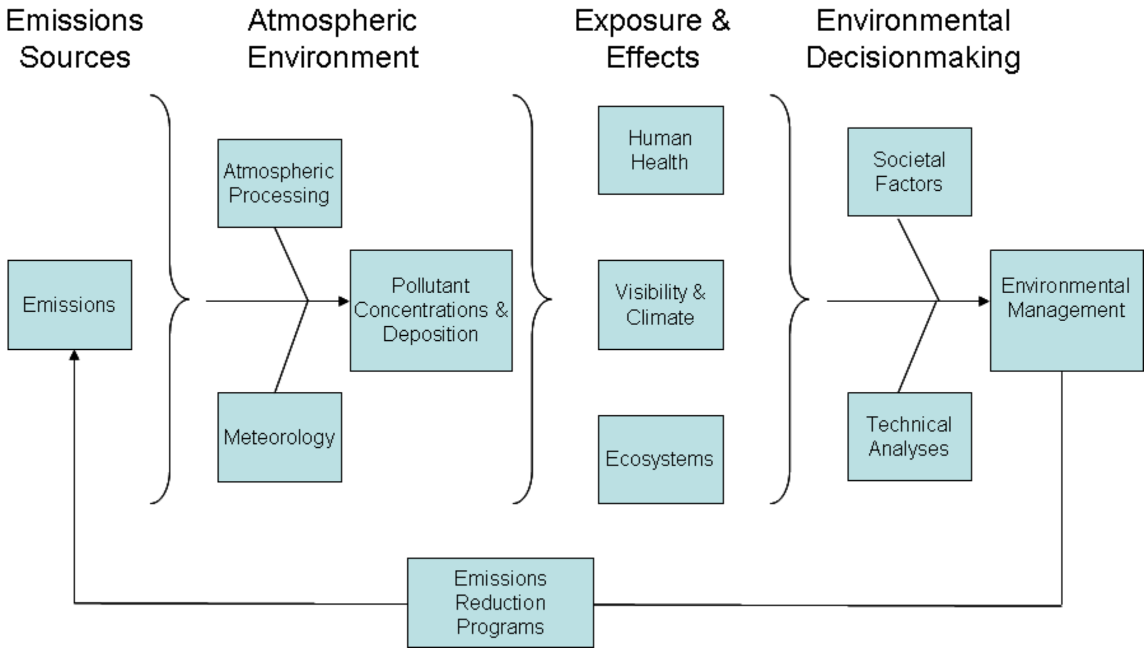

Figure I-1. Framework for informing air quality management.

SOURCE: Adapted from NARSTO (2004).

This report focuses on multi-pollutant concepts as they relate to our air quality management system. We focus on ozone, fine particles, and air toxics because these pollutants remain among the most persistent air quality problems affecting human health. However, we recognize that a multi-pollutant definition is far broader and should include coarse particles, sulfur dioxide (SO_2), nitrogen oxide (NO_x), and environmental concerns such as regional haze, deposition to ecosystems, stratospheric ozone protection, and climate change. With this report, we hope to facilitate a common understanding of multi-pollutant concepts to foster collaboration within and across the technical and policy disciplines throughout OAQPS; explore multi-pollutant analytic issues; and illustrate the initial development and implementation of a technical infrastructure to support a multi-pollutant approach to our programs.

This report is divided into the following chapters:

1. **Multi-pollutant Concepts for Air Quality Management**. This chapter explores the science behind the multi-pollutant approach including the links among emissions sources, control technologies, atmospheric processes, and environmental exposure.

2. **Multi-pollutant Air Quality Issues at the National Level**. This chapter explores the spatial and statistical correlations among ozone, fine particles, and HAPs across the continental US.
3. **Multi-pollutant Air Quality at the Local Level, an Example**. This chapter features a local assessment of multi-pollutant air quality in Detroit, MI.
4. **Current Trends and Projected Improvements in Air Quality at the National Level**. This chapter provides current trends in CAPs and HAPs and projected changes to future air quality.
5. **Multi-pollutant Analytical Products and Capabilities**. This chapter outlines current efforts to develop technical infrastructure including a multi-pollutant emissions inventory, monitoring, and modeling capabilities.

Chapter 1: Multi-pollutant Concepts for Air Quality Management

A starting point for discussion of a multi-pollutant approach to air quality management is to recognize the numerous interactions that occur within the atmosphere and across environmental media. **Figure 1-1** illustrates the relationships among pollutant sources (e.g., transportation and industry), atmospheric processes (e.g., photochemistry and dispersion), and effects on human health and ecosystems (e.g., acidification and eutrophication) from exposure to air pollution. A multi-pollutant perspective requires an understanding of these interactions and an ability to account for them in analytical assessments to inform the development of programs and policies within our air quality management system. The relationships among pollutants, sources, transport transformation pathways, and environmental effects are complex. This chapter provides details of these interactions and their relevance for air quality management.

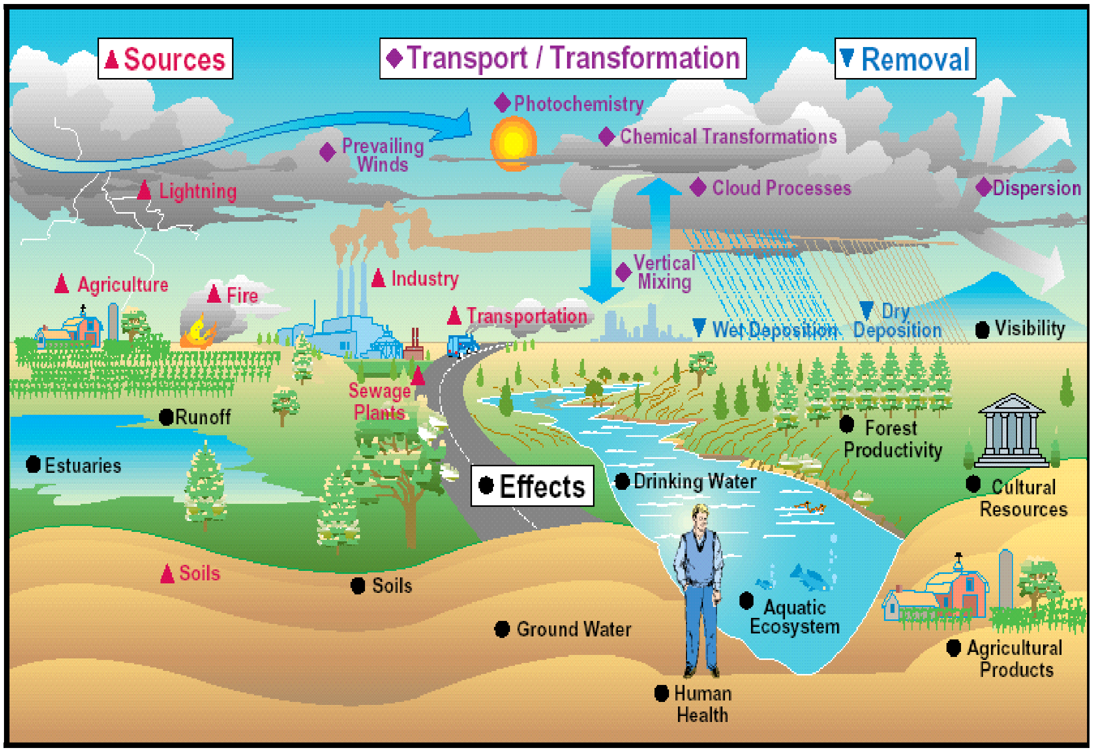

Figure 1-1. Conceptualized depiction of pollution sources, atmospheric processes, and effects on human health and ecosystems from exposure to air pollution.

Source: Adapted from the National Science and Technology Council Committee on Environment and Natural Resources, Air Quality Research Subcommittee, 1999.

Technical Elements for a Multi-pollutant Perspective

It is important that environmental policymakers understand the following technical elements that form the basis of a multi-pollutant approach:

- Pollutants may have common emissions sources.
- Control technologies can affect multiple pollutants.
- Similar atmospheric processes create, remove, or transform many pollutants.
- Exposure pathways and risks are affected by multiple pollutants (and may be enhanced by pollutant interactions).
- Pollutants affect ecosystems and other atmospheric concerns in addition to human health.

Each technical element is described in more detail below.

Pollutants May Have Common Emissions Sources

Many human activities emit a variety of air pollutants. **Figure 1-2** shows the national-level contributions of major source categories to emissions of specific criteria and air toxic pollutants. These air pollutants include primary emissions of stable pollutants (i.e., those that do not react—or react very slowly—in the atmosphere) and emissions of precursor pollutants (i.e., those that react and contribute to secondary formation of pollutants such as ozone or formaldehyde). For example, emissions from combustion-based sources (e.g., electricity generation, motor vehicles) include directly emitted criteria pollutants (e.g., carbon monoxide [CO], primary fine particles, and SO_2), air toxics (e.g., benzene, lead, some volatile organic compounds [VOCs], trace metals including mercury), precursor emissions (e.g., NO_x, SO_2, some VOCs, and ammonia [NH_3]), and greenhouse gases (GHGs) (e.g., carbon dioxide [CO_2]).

The contributions of source categories vary across pollutants. For example, SO_2 emissions are dominated by electric generating units (EGUs), other fossil fuel combustion industrial sources (e.g., boilers), and industrial processes (e.g., petroleum refineries), whereas the major contributors to primary fine particles are EGUs, fires, road dust (part of “miscellaneous” in Figure 1-2), and residential wood combustion. It is important to note that the relative contribution of sources, shown in Figure 1-2 at the national level, will differ across regions of the country and within local areas, both urban and rural. Recognizing the multi-pollutant nature of emissions sources enables consistent emission estimation procedures, and regulatory reporting requirements across sources and activities, leading to better informed decisions within EPA’s air quality management system.

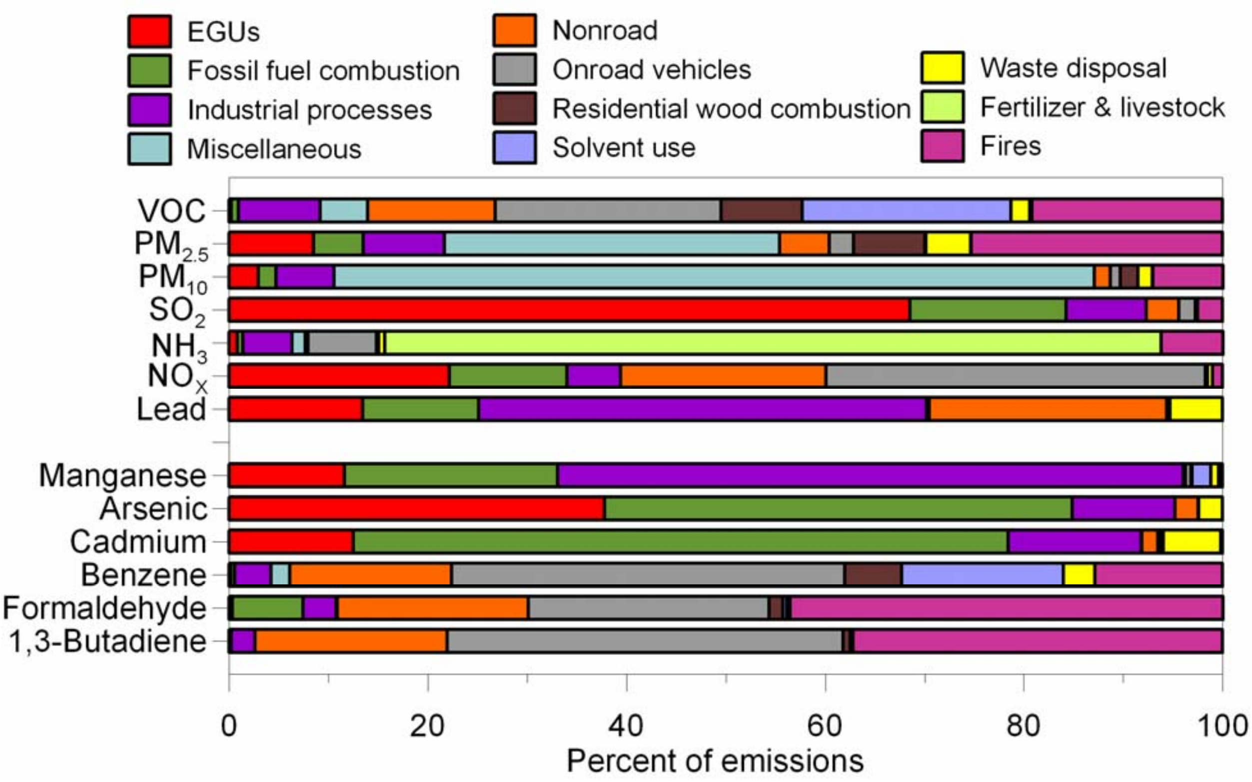

Figure 1-2. National-level source contributions to CAPs and HAPs by source sector for 2002.

Source: U.S. Environmental Protection Agency, 2007a

Control Technologies Can Affect Multiple Pollutants

Because sources emit more than one pollutant (as shown in Figure 1-2), control technologies or other approaches to reduce emissions (e.g., reduced demand) have the potential to affect multiple pollutants. **Figure 1-3** shows examples of multi-pollutant controls available at power plants:

1. Selective catalytic reduction (SCR) – ammonia reacts with NO_x on a catalyst to reduce NO_x to nitrogen and can enhance removal of mercury through oxidation downstream in the process for bituminous-fired units.
2. Electrostatic precipitator (ESP) – electrical discharge charges fly ash particles in the flue gas; charged particles are collected on a surface. The collected particles also include heavy metal HAPs such as lead, cadmium, arsenic, and nickel.
3. Fabric filter (FF) – flue gas passes through tightly woven fabric, resulting in the collection of particles including heavy metal HAPs on the fabric. In general, an FF is interchangeable with the ESP. In some units, an FF is placed downstream of the ESP (in which case it is referred to as a "COHPAC" unit). For example, a COHPAC unit would be used if an existing plant cannot meet particle levels with the ESP alone; the added FF downstream in a COHPAC unit would provide additional particle removal.

4. Wet scrubber – flue gas desulfurization (FGD) occurs as flue gas comes in contact with limestone or lime slurry in the scrubber; SO_2 reacts to form calcium sulfate/calcium sulfite salts, which are removed along with acid gases such as hydrocholoric acid (HCl), hydrofluoric acid (HF), and sulfur trioxide (SO_3); this process also captures soluble, or ionic, mercury.

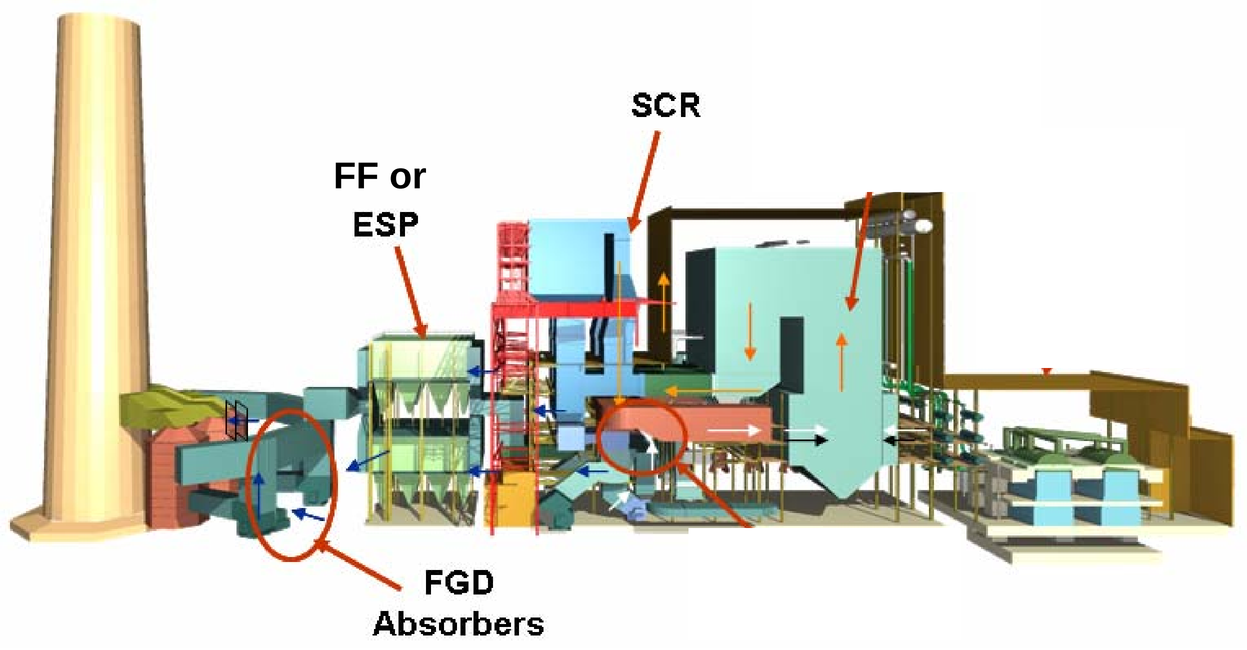

Figure 1-3. Examples of multi-pollutant controls at power plants.

Automobile emissions controls cover all the technologies employed to reduce air pollution-causing emissions produced by automobiles. The major pollutants emitted from a vehicle are shown in **Figure 1-4**. These emissions fall into three basic categories: tailpipe (or exhaust), evaporative, and life cycle. As shown in Figure 1-4, both exhaust (NO_x, CO, CO_2, fine particles, and air toxics) and evaporative emissions (hydrocarbons and air toxics) are multi-pollutant in nature.

When people think of air pollution caused by vehicles, most think of exhaust emissions, i.e, the products of burning fuel in the engine emitted from the exhaust system. Exhaust emissions controls fall into three areas:

1. Increasing engine efficiency – has been gradually improved with progress in the following technologies:
   - electronic ignition
   - fuel injection systems
   - electronic control units

2. Increasing vehicle efficiency – has come from reducing fuel consumption and related emissions:

    - lightweight vehicle design
    - minimized air resistance
    - reduced rolling resistance
    - improved powertrain efficiency
    - increased spark to the spark plug
    - regenerative braking

3. Cleaning up emissions – advances in engine and vehicle technology continually reduce the amount of pollutants generated, but this is generally considered insufficient to meet emissions goals. Therefore, technologies to react with and clean up the remaining emissions have long been an essential part of emissions control; some of these include

    - air injection
    - exhaust gas recirculation
    - use of catalytic converters

4. Reducing Vehicle Miles Traveled (VMT)—use of public transportation, flexiplace, and other innovative voluntary programs can reduced to decreased emissions.

More recent efforts to reduce evaporative emissions include capturing vented vapors from within the vehicle using carbon canisters and reducing refueling losses through the use of tank filler necks that capture some of these evaporative emissions.

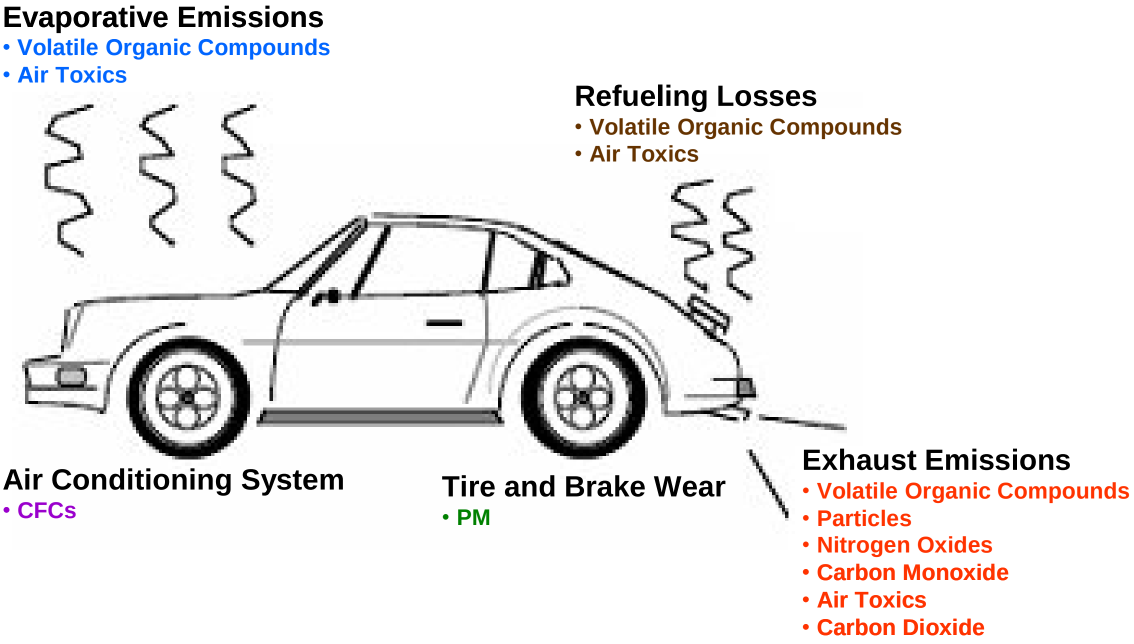

Figure 1-4. Schematic of multi-pollutant emissions from a vehicle.[1]

Life-cycle emissions (not shown in Figure 1-4) are produced in activities associated with the manufacturing, maintenance, and disposal of the automobile and include such items as emissions from manufacturing plant power requirements, volatile solvents used in the manufacturing process, and outgassing of synthetic materials used to reduce weight and simplify manufacturing.

Emissions controls often result in "co-control" across pollutants emitted by the source; however, emissions of some pollutants may actually increase as a result of controlling another pollutant. For example, reformulated gasoline was introduced in the mid-1990s to reduce ozone concentrations by targeting reductions in emissions of VOCs from vehicles. HAPs such as benzene and 1,3-butadiene were also reduced in ambient air by reformulated gasoline, but formaldehyde likely increased. Furthermore, some control measures reduce GHGs and traditional air pollutants, including leak detection and fuel switching. However, some measures for controlling traditional air pollutants may increase GHGs to some extent, and some measures for controlling GHGs may increase traditional air pollutants. For example, controls to decrease SO2 emissions from industrial sources require energy to operate and result in reduced process efficiencies and increases in GHGs, and changing the composition of transportation fuels to reduce GHGs may affect traditional air pollutant emissions. Recognizing multi-pollutant benefits and disbenefits from specific control technologies or programs allows a more complete characterization of pollutant releases to the environment and the potential human health and ecosystem impacts. Therefore, EPA's programs and policies can be developed to result in a

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[1] Note that chlorofluorocarbons (CFCs) in air conditioning systems only exist in automobiles manufactured prior to 1994. CFCs have been phased out since 1995 and replaced by hydrochlorofluorocarbons that do less damage to stratospheric ozone.

potentially more effective and efficient overall set of controls that address multiple air quality objectives.

Atmospheric Processes Create, Remove, and Transform Pollutants

After being released to the atmosphere, all primary and precursor emissions become part of a common chemical and physical system. Pollutants in a single air mass experience the same meteorological conditions. Some react chemically with one another, some may be acted upon by common oxidants, some may be removed by common physical processes such as rain, and some subsequently arrive at sensitive receptors as a mixture. Because of these shared processes, changes in one pollutant can lead to changes in other pollutants.

Figure 1-5 is a simplified diagram that shows the potential interactions among emissions that lead to ozone, fine particles, air toxics, regional haze, deposition to ecosystems, and climate change. Source emissions are characterized as either directly emitted, such as benzene or primary particles, or as precursors, such as NO_x and VOC emissions that combine with sunlight to form ozone. Particles are multi-pollutant in composition because they contain both direct (e.g., carbon, metals) and secondarily formed components (e.g., sulfates, nitrates, carbon). In some regions, organic compounds, including secondary organic aerosols, are important contributors to ambient fine particle concentrations. Some air toxics are primarily gaseous, some are particles, and others are semi-volatile. Some gaseous air toxics (e.g., benzene, 1,3-butadiene) react in the atmosphere and are precursors to ozone formation.

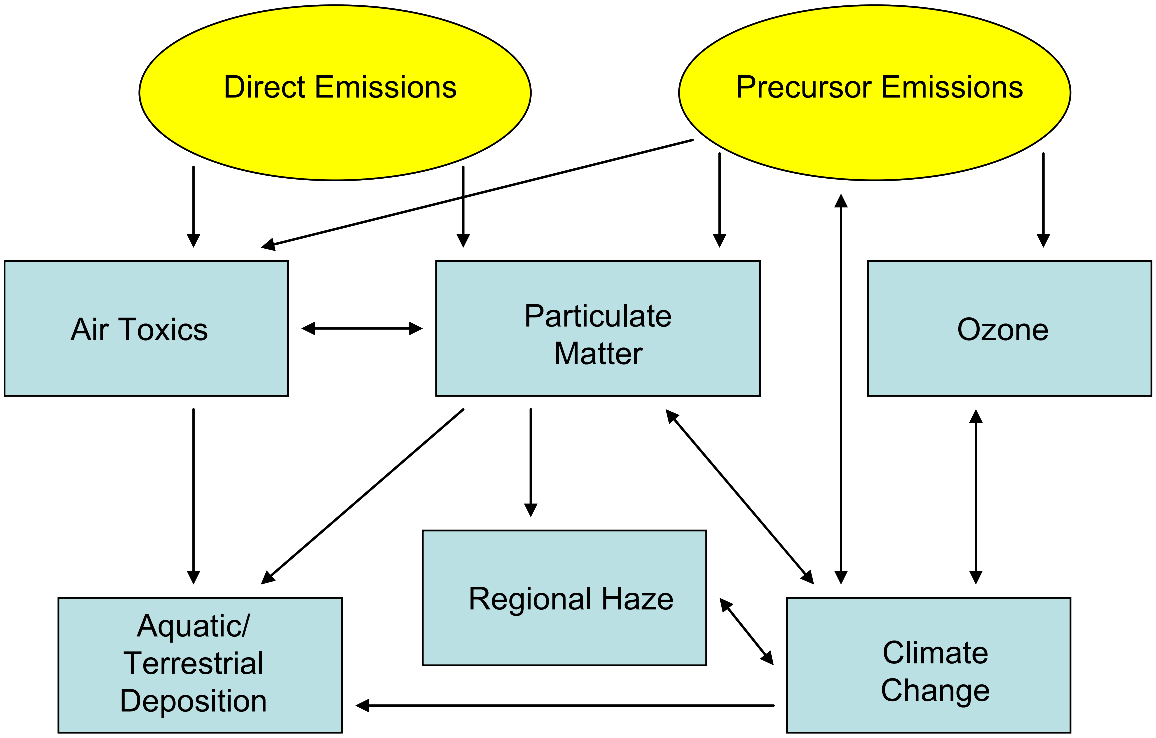

Figure 1-5. Simplified diagram illustrating relationships among direct and precursor emissions that lead to ozone, fine particles, and air toxics formation.

Figure 1-6 also illustrates some of the relationships among direct and precursor emissions in more detail than the simplified diagram in Figure 1-5. Primary emissions (in blue) are distinguished from those formed secondarily (in red) via atmospheric reactions. The hydroxyl radical (OH) and ozone play key roles in many of the reaction pathways. Further information on these atmospheric relationships can be found in textbooks (e.g., Seinfeld and Pandis, 1998). Atmospheric model development continues to improve the treatment of meteorology, emissions, atmospheric chemistry processes, and relationships across pollutants to better evaluate emission reduction programs (Community Modeling & Analysis System Center, 2007a, b).

Exposure Pathways and Risks Are Affected by Multiple Pollutants

Exposure to airborne pollutants through inhalation, dermal, and ingestion pathways is largely a multi-pollutant process because air parcels contain mixtures of pollutants. Not only do these pollutants interact in the atmosphere (as described earlier), these interactions also affect human health and ecosystems. Each breath of air contains a mixture of fine particles and gases that penetrate the lungs. The epidemiological and toxicological studies showing the effects of these pollutants typically attempt to isolate the effects of specific pollutants such as fine particles or ozone to determine direct associations of specific health effects and to account for the correlation between pollutants in the overall mixture.

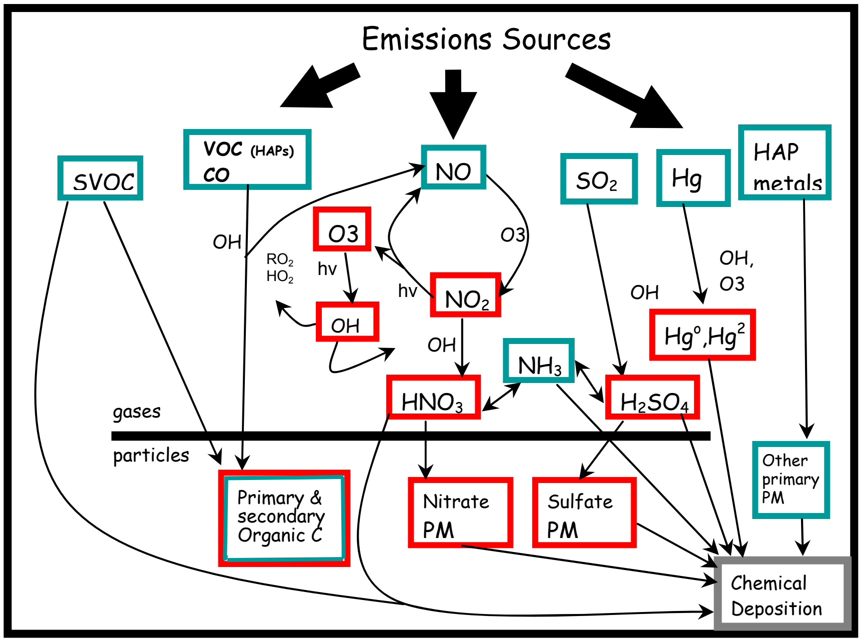

Figure 1-6. Links illustrating chemical relationships among CAPs and HAPs including mercury, as well as connections across sources, secondarily formed species, gases, primary particles, and deposition.

Note: hv represents sunlight , HO_2 = hydroperoxyl radical, and RO_2 = organic peroxyl radicals, where R symbolizes any number of organic chemical groups

Scientific studies have shown that an increase in fine particle pollution leads to an increase in respiratory problems such as asthma attacks (in asthma sufferers) and bronchitis, as well as emergency room admissions and hospitalization for respiratory diseases. Increased mortality has also been linked to higher particle concentrations; furthermore, people who breathe high concentrations of fine particles for long periods are more likely to die prematurely. These health impacts depend on the size and, potentially, the composition of particles; size determines a particle's ability to penetrate the lungs, and composition determines a particle's toxicity once deposited in the lungs.

Ozone can affect human health in similar ways. Ozone (and other oxidants) can penetrate the lungs and cause a number of respiratory problems including increases in asthma attacks, respiratory symptoms, and emergency room and hospital admissions. When ozone concentrations are elevated, similar to particle concentrations, mortality rates increase.

Additional research is needed to understand possible synergistic or antagonistic effects between pollutants in the mixture and the role of pollutants in the mixture as catalysts or carriers for other pollutants. For example, sulfate particles tend to absorb water and can thus "carry" other types of particles in the overall mixture (e.g., metals and polycyclic aromatic hydrocarbons [PAHs]), potentially providing a larger dose of these metals and PAHs into the lungs than previously thought.

Pollutants Affect Ecosystems and Other Environmental Concerns

The ambient mix and chemical/physical properties of pollutants can affect ecosystems and other environmental concerns. For example, ozone attacks biological molecules such as terpenes from biogenic emissions. As plant leaves absorb ozone, cells within the plants that control photosynthesis are damaged, potentially leading to reduced plant growth and root development. Airborne pollutants can also deposit on surfaces, and some pollutants cause eutrophication in water bodies.

The ability to quantify pollutant interactions depends on whether their effects are additive, synergistic, or antagonistic. As shown in **Table 1-1**, a single air pollutant category (e.g., NO_x) can interact with other pollutants in the atmosphere (e.g., ozone, fine particles) and consequently have multiple effects on health, the environment, and climate.

Table 1-1. Common emissions precursors and their ability to impact human health and the environment (independent of relative magnitude or direction of effect).

	SO_2	NO_x	NH_3	VOC	CO	Primary PM
Health impacts						
– direct (VOC HAPs)				●		
– direct (criteria)	●	●				●
– indirect (O_3 and particle formation)	●	●	●	●	●	
Ecosystems						
– Acidification	●	●	●			
– Eutrophication		●	●			
– O_3 vegetation		●		●	●	

Acidification: the process whereby air pollution, mainly NH_3, SO_2, NO_X, is converted into acid substances. Acid deposition is best known for the damage it causes to forests and lakes, but it also damages freshwater and coastal ecosystems, soils, and historical monuments.

Eutrophication: the process whereby water bodies receive excess nutrients, such as nitrogen, that stimulate excessive plant growth.

NH_3=ammonia, CO_2=carbon dioxide, SO_2=sulfur dioxide, O_3=ozone, PM=particulate matter, CO= carbon monoxide

Using Multi-pollutant Concepts for Air Quality Management

The U.S. air quality management system involves setting goals, collecting and analyzing air quality and emissions data, developing and implementing emissions control strategies, and evaluating progress.. **Figure 1-7** shows how each major amendment to the CAA increasingly altered each of the major steps in the air quality management process as part of the continual evolution of EPA's system. As noted by Bachmann (2007), "over time, the system itself has evolved through legislation and policy to address problems in achieving results, advances in scientific and technical understanding, and changing socioeconomic and political conditions." The NAS report and the Clean Air Act Advisory Committee's (CAAAC) AQM Subcommittee Phase I and II reports identify challenges in the current air quality management system and call for innovations that will improve air quality with greater efficiency and effectiveness. Based on these recommendations, the next management challenge is to incorporate multi-pollutant environmental decision-making into this system through improved understanding of the interconnected technical and scientific elements, including environmental data and modeling tools, to appropriately inform each step in Figure 1-7. Consideration will be given to how multi-pollutant tools can be integrated into the system by identifying the limitations of the current air quality management system, acknowledging changes needed to make the process more efficient and effective, and assessing how these tools can lead to more informed decision-making. For more information, see text box on "Multi-Pollutant Air Quality Management Plan Project at OAQPS" on page 1-12 and http://epa.gov/air/caaac/aqm.html.

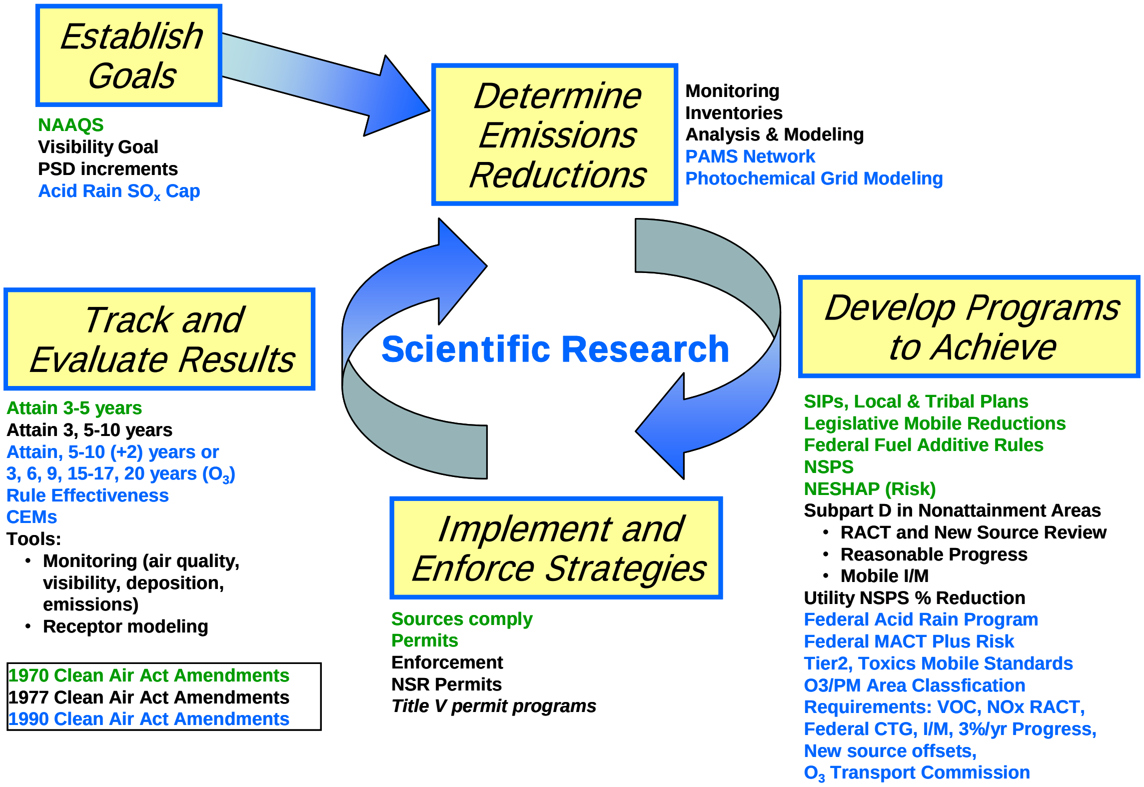

Figure 1-7. Evolution of EPA's air quality management system.

Source: Bachmann, 2007

Multi-pollutant Air Quality Management Plan Project at OAQPS

EPA is currently working with three areas (Illinois/Missouri [St. Louis], New York, and North Carolina) to integrate non-traditional planning into air quality management. Many state, local, and tribal governments are moving away from single-pollutant planning to developing multi-pollutant strategies that address future air quality needs. EPA's "Air Quality Management Plan Project" encourages state and local governments to create comprehensive air quality plans. Air Quality Management Plans (AQMPs) address air quality concerns such as attainment and maintenance of criteria pollutant standards, sector-based emission reductions, improvements in regional haze and visibility, and risk reductions of HAPs. These plans may include other air quality concerns such as land use, transportation, energy, and climate change. The goal is to integrate the requirements of the current SIP process into a more comprehensive plan for air quality in a manner consistent with the 2004 NAS report, "Air Quality Management in the United States," and the 2007 CAAAC recommendations.

To explore some of the technical challenges of implementing an AQMP, EPA is undertaking the Detroit Multi-pollutant Pilot Project. This project will investigate the methods, tools, and models available to the state, local, and tribal agencies in developing AQMPs. In particular, the project will explore the local and regional scale nature of certain criteria and toxics pollutants, and the best tools to use when considering their impacts. The project will also consider the multi-pollutant impacts of selecting control strategies that will control key air toxics, as well as ozone and fine particles. Using Detroit as the example urban area, the project seeks to demonstrate an approach for considering multiple pollutants in an integrated manner for air quality planning. A report will be provided that discusses the tools, data, and methods used, the approach implemented, and the project results and conclusions. This report will be useful in informing EPA guidance developed for consideration of multi-pollutant air quality assessments.

The interdependencies among pollutants are now being incorporated into the design of emission reduction programs. For example, a strategy focused on reducing ozone typically considers some combination of NO_x and VOC emission reductions. VOC reductions can then reduce HAP exposures of benzene, 1,3-butadiene, toluene, and xylenes and may also reduce concentrations of secondary HAPs such as formaldehyde, acetaldehyde, and acrolein. In addition, VOC reductions may also have some limited effects on reducing secondarily formed fine particle mass from the transformation of larger aromatic compounds such as toluene, xylenes, and ethylbenzene. As discussed previously, reductions in NO_x might result in reductions in secondarily formed ammonium nitrate or nitric acid.

Table 1-2 summarizes how emission reduction programs can lead to multiple changes in pollutant or atmospheric concerns. Though reductions in precursor pollutants generally lead to improvements in air quality and other atmospheric concerns, the design of a multi-pollutant strategy still requires careful consideration of multiple consequences of precursor emission controls. For example, reducing NO_x emissions can result in significant decreases in fine particles, ozone, nitrate, acid deposition, and watershed eutrophication, and improvements in visibility. However, reducing NO_x emissions can increase mercury deposition/methylation in sediment reactions. NO_x emission reductions can also cause ozone in certain places to increase due to the NO_x titration effect on ozone in VOC-limited areas of the country. Similarly, under certain conditions, reductions in VOCs, while leading to improvements in ozone, air toxics, and watershed eutrophication, can lead to particulate nitrate increases caused by the reduction of peroxyacetyl radicals that would cause more nitric acid to form and be available for atmospheric conversion to particulate nitrate.

Table 1-2. Possible pollutant/atmospheric relationships associated with emission precursor reductions (NARSTO, 2004b).

Reduction in pollutant emissions	Change in Associated Pollutant or Atmospheric Issue										
		PM Composition									
	Ozone	Sulfate	Nitrate	Organic Carbon	$PM_{2.5}$	Visibility	HAP VOCs	HAP Metals	Acid Deposition	Watershed Eutrophication	Hg – dep/ methylation
SO_2	↓$^{a, b}$	**↓**	↑^{e}		**↓**	**↓**			**↓**		↓^{g}
NO_x	**↓** ↑^{c}	↓^{d}↑^{e}	**↓**	↓^{d}	**↓**	**↓**	↓		**↓**	**↓**	↑^{g}
VOC HAPs	**↓**	↓	↑^{f}↓^{d}	**↓**	↓	↓	**↓**		--	↓	
CO	↓	↓	↓^{d}	↓^{d}	↓	↓	↓^{d}		↓^{d}		
NH_3	--	↓	**↓**		**↓**	**↓**				**↓**	↑^{g}
Primary PM-organic C				**↓**	**↓**	↓					
Primary PM-black C					**↓**	**↓**					
Primary PM-(crustal/metals)	↓^{b}				**↓**	↓		**↓**			
Mercury											**↓**

a – Arrow direction denotes relative increase ↑ or decrease ↓ of pollutant resulting from a decrease in associated emissions. Large arrow indicates either well established relationship and/or substantial magnitude of effect. Small arrow implies possible response that is likely to be of minimal magnitude.
b – Ozone reduction associated with decreased light scattering from decrease in fine particle levels.
c – NO_x titration effect on ozone largely limited to VOC-limited urban areas.
d – Associated with effect on decreasing OH and ozone levels.
e – Substitution effect in competition for NH_3 in NH_3-limited regions (and increase in hydrogen peroxide leading to increased in-cloud SO_2 production).
f – Associated with reduction of peroxyacetyl radicals leading to increased nitric acid formation.
g – Associated with nitrogen, sulfur, and mercury interactions within sediments.

Spatial and temporal patterns among pollutants must also be considered in the design of a multi-pollutant emissions reduction strategy. Spatial and temporal scales for environmental decision-making depend on the pollutant of concern and range from global (i.e., long-range transport) to local scales. For example, **Figure 1-8** illustrates the potential need to consider contributions to fine particles (and their chemical constituents) from all spatial scales when developing emission reduction strategies. As domestic concentration levels of secondarily formed pollutants decrease across the US through the reduction of precursors, the relative contribution of pollutants from international transport becomes more important. Similarly, as progress is made in "regional" air pollution levels, attention can turn to more localized pollution sources (e.g., manufacturing or near-roadway emissions). The diurnal and seasonal patterns in pollutant concentrations, which are a function of the source of pollution, meteorology, and formation and removal processes, may also need to be taken into account when designing a multi-pollutant control strategy.

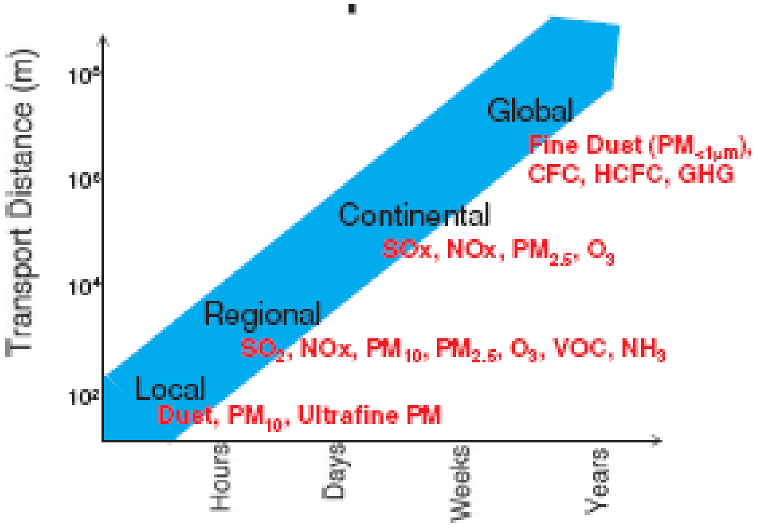

Figure 1-8. Illustrative transport scales for PM and other atmospheric pollutants.

Source: NARSTO, 2004c

Summary

The technical and scientific basis for integrating across multiple air quality issues to inform EPA's air quality management system will continue to evolve to better account for the interdependencies shown in Table 1-2. As we progress, a variety of implications arise for air program management and the direction of policy. As suggested by the NAS report (and agreed upon by CAAAC), a truly integrated air quality management framework would maximize health and environmental benefits using comprehensive emission reduction control strategies. It would streamline the various programs and their associated requirements across different source sectors, potentially reducing the cost of achieving health and environmental goals. We will need to integrate multi-pollutant concepts in the management of their air quality problems. A multi-pollutant technical infrastructure (i.e., data, tools, and models) will need to be built so that more effective and efficient environmental solutions can be achieved. More details on this infrastructure are given in Chapter 5. However, moving to a multi-pollutant air quality management approach will require changing the way we currently solve problems and interact with one another, and will take considerable time, effort, and support.

This report is a first step in exploring the nature of historical, current, and future multi-pollutant air quality issues across the US. The next chapter introduces the "current" characterization of these multi-pollutant issues by identifying areas with multiple problems, such as areas where ozone and fine particles are above the NAAQS and where air toxics pose high risks to populations.

Chapter 2: Multi-pollutant Air Quality Issues at the National Level

This chapter explores the geographic nature of multi-pollutant air quality issues across the US. The conceptual approach used here to examine multi-pollutant issues is simplified to focus only on three select pollutant types: ozone, fine particles, and air toxics. This simplification allows concise articulation and visual representation of the relationships among the three primary air quality issues affecting human health. Future assessments that extend this initial investigation to include such air quality issues as visibility impairment, nutrient and acid deposition, and secondary air quality standards will result in a broadening of the identified pollutant relationships to rural areas. In addition, further extension of this analysis to include such considerations as the recently revised 24-hour particle standard and more stringent standards for other pollutants (e.g., ozone) will bring even more urban areas into this spatial overlap of pollutants (i.e., “nexus”).

Identifying Areas with Multiple Air Quality Problems

In this section, national-level spatial relationships between ozone and fine particles are examined first. Air toxics concentrations at the national level are then examined using NATA 1999 results (U.S. Environmental Protection Agency, 2006a). Finally, the nexus of air toxics, ozone, and particles is shown at the national level, and the correlations among these multi-pollutant issues are discussed.

Ozone and Particle Pollution

The counties in which ozone and $PM_{2.5}$ levels exceed current air quality standards are shown in **Figure 2-1**. Counties that exceed the ozone standard are outlined in blue; counties that exceed the $PM_{2.5}$ standard are outlined in red; and counties that exceed standards of both pollutants are outlined in purple. The areas with the highest ozone and/or particle pollution concentrations are primarily in, or downwind of, heavily populated urban areas in California, Texas, the industrial Midwest, the Southeast, and the Northeast. Counties with high concentrations of ozone or fine particles are more likely to be adjacent to counties with similar problems.

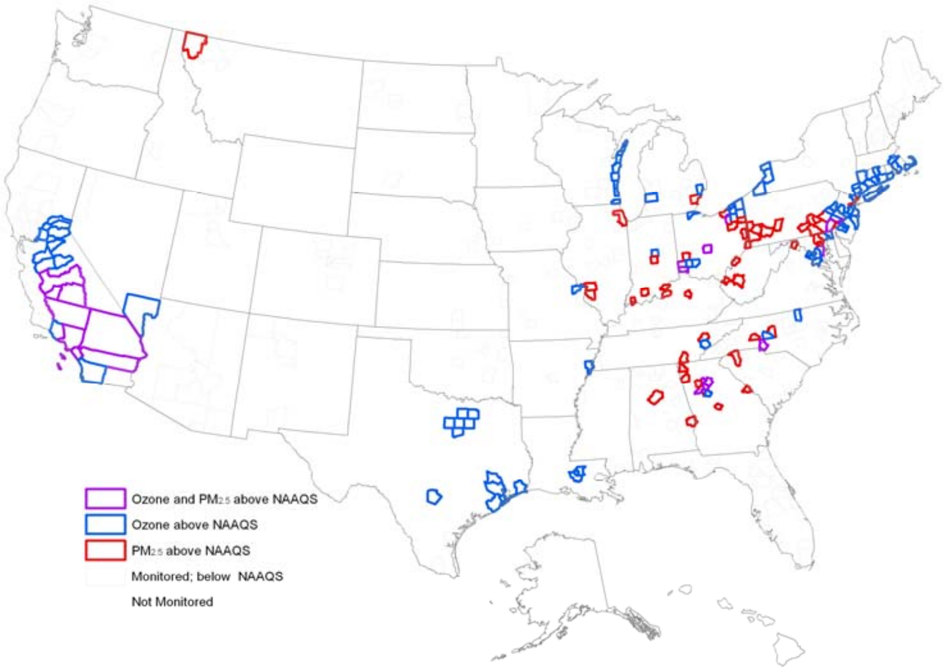

Figure 2-1. Counties with ozone and/or fine particle design-value concentrations above the NAAQS for 2003-2005.

Air Toxics Pollution

The ambient air quality monitoring network for air toxics is sparse compared with the ozone and fine particle networks and does not provide sufficient measurement data to comprehensively estimate toxics risk nationwide. The best currently available characterization of the national air toxics picture is the National Air Toxics Assessment (NATA), which is the source of cancer risk estimates in this report.[2] Released in February 2006, the 1999 NATA results offer a snapshot of air quality and the health risks from air toxics resulting from estimated 1999 emissions (U.S. Environmental Protection Agency, 2006a). This assessment covers 177 of the 187 listed air toxics plus diesel particulate matter (DPM). The risks estimated in the assessment are associated with inhaling the pollutants, which is the most significant route of exposure for the majority of air toxics. **Figure 2-2** shows county-level nationwide health risk estimates for air toxics for 1999. In most of the country, the lifetime cancer risk from air toxics is less than 25 in a million. This means that out of one million people, fewer than 25 are likely to develop cancer as a result of inhaling air toxics from outdoor sources if they are exposed to 1999 levels over the course of their lifetime. Most urban locations have an air toxics lifetime cancer risk greater than 25 in a million, while a few counties are greater than 50 in a million.

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[2] Although the 1999 NATA includes estimates for respiratory and neurological non-cancer effects from air toxics, these results are not used in this report's characterization of air toxics for purposes of comparing problem areas for toxics with those for ozone and particles. Future multi-pollutant assessments may include these non-cancer impacts.

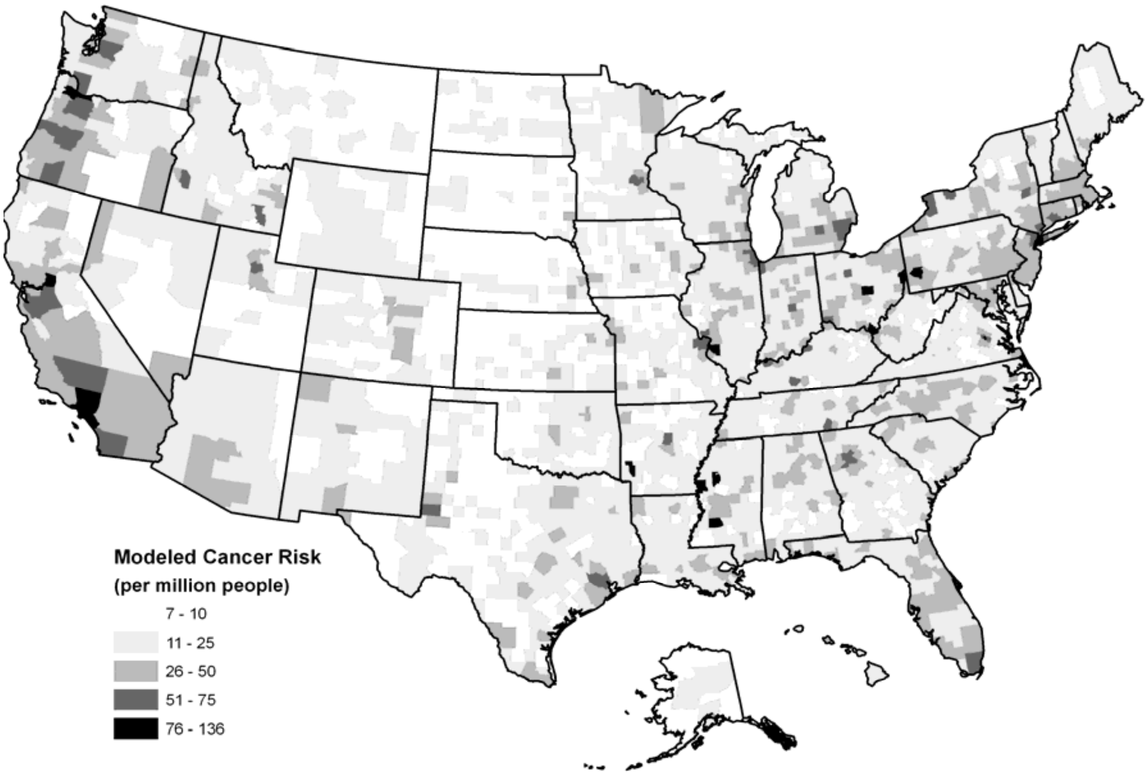

Figure 2-2. Modeled cancer risk per million people by county from the 1999 National Air Toxics Assessment.

Where Multi-pollutant Air Quality Issues Occur

Figure 2-3 demonstrates the nexus of health-related air quality issues by mapping the spatial relationships of ozone, fine particles, and air toxics. The figure is based on the model results for cancer risk from the 1999 NATA study in combination with ambient ozone and fine particle air quality concentration data. As in Figure 2-1, high ozone and fine particle pollution areas are defined as those experiencing concentrations greater than their respective NAAQS for the period 2003-2005. Areas with air toxics problems are defined as those with estimated cancer risks higher than the 90th percentile of the 1999 NATA model results for all counties (i.e., greater than 35 in a million), representing counties that include 55 percent (approximately 163 million people) of the total population. The map aggregates county-level data to the metropolitan level, i.e., the combined statistical area (CSA) level or core-based statistical area (CBSA) level where possible, based on the maximum county-level values in each area. County-level data are shown where aggregation to CSA or CBSA levels is not possible (i.e., where a county is not in a CSA or CBSA).

Figure 2-3 shows that some metropolitan areas experience high ozone, particle pollution, and air toxics cancer risk. These areas include southern and central California, urban areas in the industrial Midwest and the Northeast corridor, as well as some parts of the Southeast (e.g., Atlanta, Charlotte). The nexus of high ozone, particle pollution, and air toxics typically occurs in urban areas. Notably, a number of areas where residents are predicted to have relatively high cancer risk associated with air toxics do not have ozone or particle pollution problems. While urban areas are most likely to have all three issues, some rural areas have high concentrations of at least one of the three air quality issues.

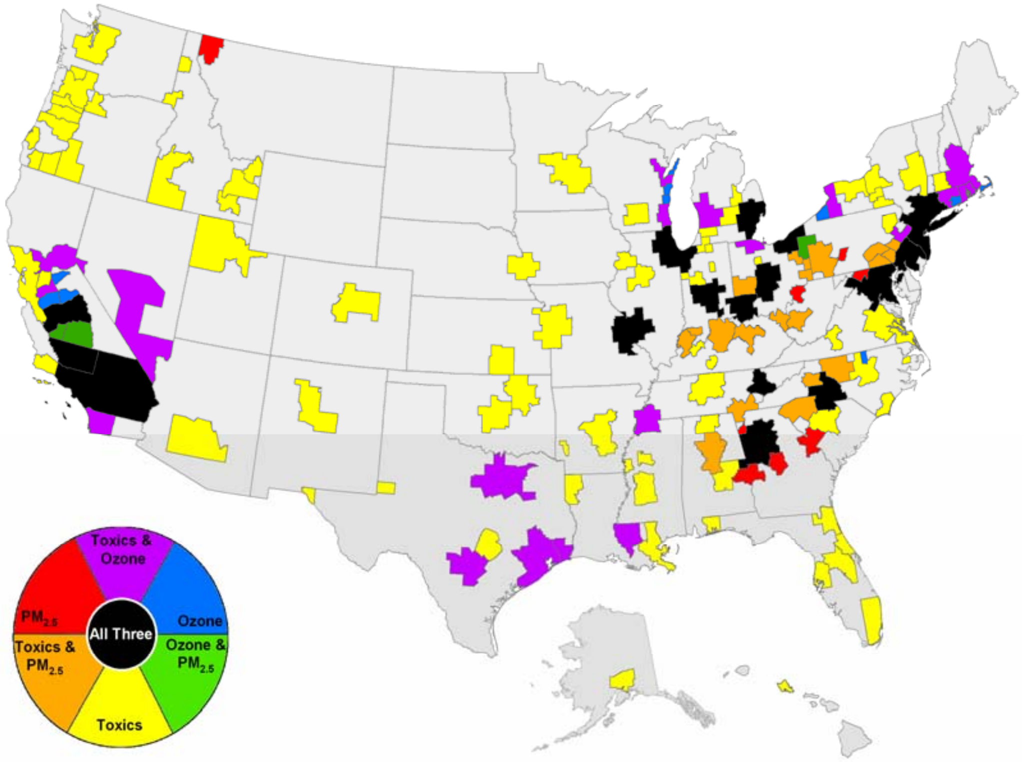

Figure 2-3. Nexus of fine particles, ozone, and air toxics.

Note: Areas with ozone and/or fine particle concentrations above the NAAQS for 2003-2005 and/or with modeled county-level cancer risk estimates from NATA 1999 in the top 10 percent for all counties. Data are aggregated to the CSA or CBSA levels where possible based on the maximum county-level values; otherwise, county-level data are shown.

Correlations Among Multi-pollutant Issues

Figure 2-4 shows the distribution of air toxics cancer risk by the presence or absence of ozone and particle pollution by county. Overall, people living in counties with high ozone and particle pollution levels have higher average cancer risk from air toxics than people living in counties with lower ozone or particle pollution concentrations. However, the highest estimated cancer risks from 1999 NATA (i.e., average county excess cancer risk levels at or above 35 in a million) can occur across any categories of ozone and particle combinations.

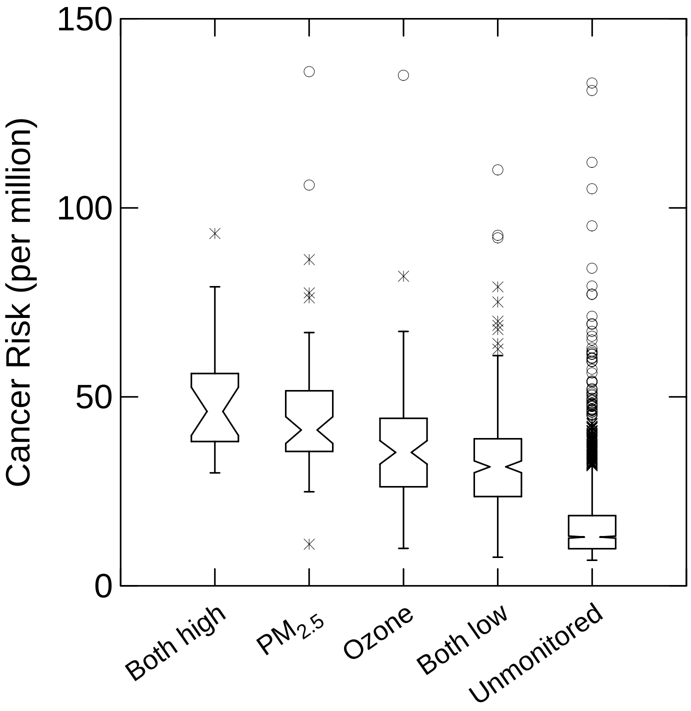

Figure 2-4. Distribution of air toxics cancer risk as a function of ozone and particle problems.

*Note: Counties with ozone and fine particle problems (as defined in Figure 2-3) are more likely to have air toxics problems as well. The plot shows modeled cancer risk distributions for residents of counties with different types of air quality problems. The box shows the extent of the 25th and 75th percentiles, the notch is the median, the whiskers extend to 1.5*interquartile range (IQR), and individual outliers beyond this are shown as asterisks or circles.*

As shown in **Figure 2-5**, many counties experience concentrations very close to (above or below) both the ozone and fine particle standards. Pollutant concentrations exist along a continuum, ranging from relatively clean air in the bottom left quadrant to relatively polluted air in the upper right quadrant. Differences in county concentrations are due to variations in population, emissions, meteorology, topography, and transport. For example, many counties downwind of large urban areas are seen in the bottom right quadrant, while those near the Pacific Ocean and those isolated from emissions are located in the bottom left quadrant. Southern and central California have some of the highest concentrations because of high emissions, mountains that trap air, and meteorological conditions conducive to ozone and particle formation. In addition, this figure also reflects the degree of the air toxics problem in those counties that measure ozone and particles. Higher air toxics risk values are associated with areas in which ozone and particle concentrations are also high, consistent with the results shown in Figure 2-4, although risk values vary significantly among counties in each of the four quadrants.

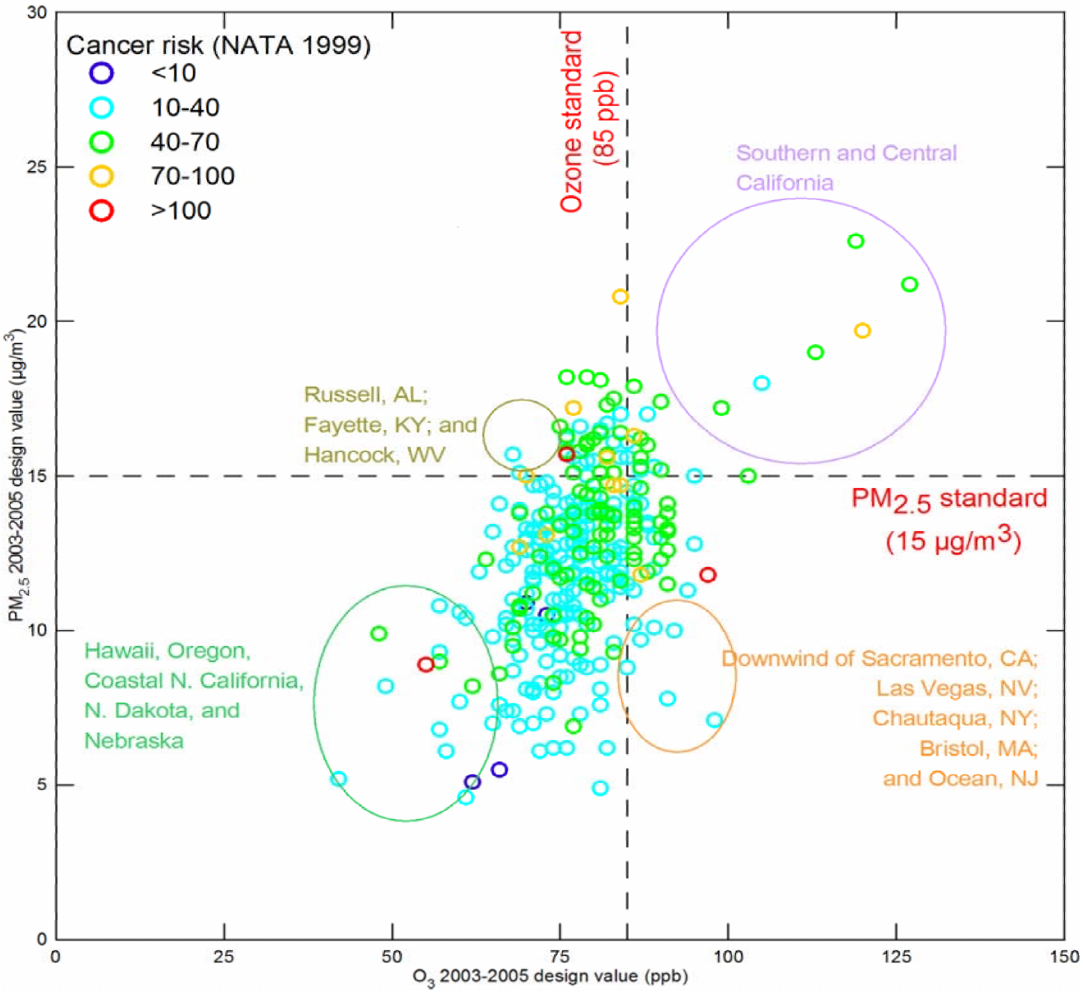

Figure 2-5. Scatter plot of county-level maximum 8-hour ozone and $PM_{2.5}$ concentrations from 2003 to 2005 color-coded by cancer risk level estimates from NATA 1999.

Summary

In this chapter, the development of a spatial nexus of particle pollution, ozone, and air toxics was discussed. Particle and ozone problems were defined based on their NAAQS, and for particles, the focus was only on the annual NAAQS. Air toxics were represented at the national level by the upper end of cancer risk estimates from NATA 1999. The development of this nexus revealed some interesting correlations between measured particle and ozone concentrations and modeled air toxics risk. While this chapter focused on a national summary, the next chapter will look more closely at Detroit, MI an area that has a nexus of PM, ozone, and air toxics problems.

Chapter 3: Multi-pollutant Air Quality at the Local Level, an Example

As discussed in the previous chapter and shown in **Figure 3-1**, one metropolitan area that has a nexus of fine particle, ozone, and air toxics air quality issues is Detroit, MI. An essential first step in developing a comprehensive plan to address such multi-pollutant air quality issues is to establish a conceptual model for the area of interest. A conceptual model is informed by available technical data and analyses for an area, and assists air quality planners in determining which control programs would be most beneficial for reducing the pollutants of most concern (see textbox "Value of Conceptual Models for Multi-pollutant Air Quality Management"). Detroit is rich in technical data; several special studies have been conducted for this area.[3] This chapter discusses the technical data and analyses that outline a conceptual model that could be used to inform the development of effective multi-pollutant control strategies for the Detroit area.

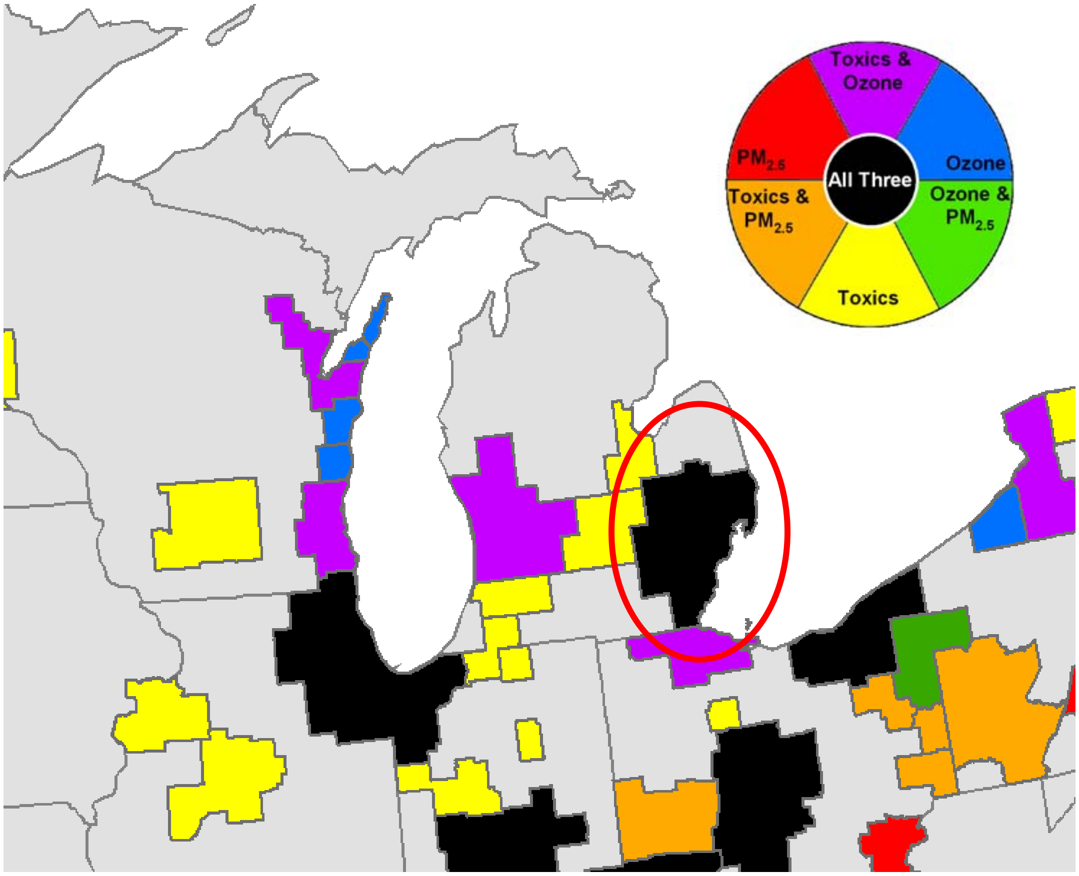

Figure 3-1. Multi-pollutant nexus of air quality issues for southeastern Michigan.

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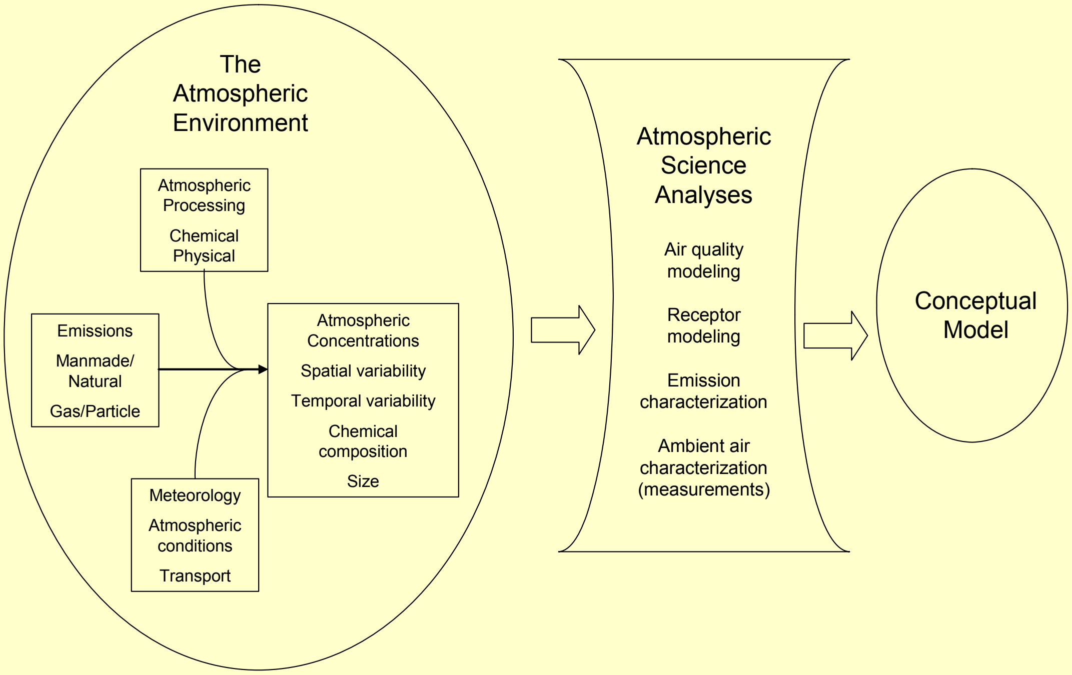
[3] These studies include, but are not limited to, the Detroit Air Toxics Initiative (Michigan Department of Environmental Quality, 2007a), the Detroit Exposure and Risk Assessment Study (U.S. Environmental Protection Agency, 2007b), LADCO technical analyses (LADCO, 2007a, b), and recent literature studies ((Rizzo, 2005; Trepat et al., 2007).

Value of Conceptual Models for Multi-pollutant Air Quality Management

The conceptual model for an area is based on the application of technical data, tools, and models that reflect our best understanding of that area's atmospheric environment (as shown in the figure below). It compiles and summarizes the most advanced science to inform the development of control strategies to meet an area's air quality goals. In fact, areas are expected to develop a conceptual model as part of their State Implementation Plan (SIP) demonstration for criteria pollutants such as ozone and fine particles. Chapter 11 of EPA's *Guidance on the Use of Models and other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone,* $PM_{2.5}$*, and Regional Haze* is devoted to conceptual models and walks through questions that an area should address to have a full understanding of their air quality problems and thereby determine the best approach for developing and evaluating control strategies to achieve attainment. For more detail on conceptual models in practice, Chapter 10 of the 2004 NARSTO report on fine particles provides conceptual model descriptions for nine North American regions including the upper Midwest/Great Lakes region.

Air quality management efforts that extend the current single-pollutant conceptual models to reflect multiple pollutants can be a challenge. However, as illustrated in this chapter, it is feasible to do by integrating multiple technical data sets, tools, and models reflecting knowledge of the region's atmospheric environment and sources. These technical components are essential to the development of conceptual models, which in turn guide the selection of air quality models and technical assessments needed to design and implement effective control strategies for multi-pollutant air quality planning.



Development of a conceptual model is based on technical data and analysis reflecting the best understanding of the nature of an area's air quality issues

Source: NARSTO, 2004

Ambient Air Characterization

Development of a conceptual model for Detroit begins with a characterization of the existing ambient monitoring data. **Figure 3-2** shows the monitoring network for southeastern Michigan for multiple pollutants. **Table 3-1** summarizes the highest monitored values of criteria air pollutants in the Detroit area for 2005 as outlined in the Michigan Department of Environmental Quality (MDEQ) annual report (MDEQ, 2007b) and indicates the average cancer risk for Wayne County as predicted by 1999 NATA. Note that 8-hour ozone and both the annual and daily fine particle concentrations exceed the NAAQS, and the overall cancer risk of 63.2 is in the top 90th percentile of risk across US counties.

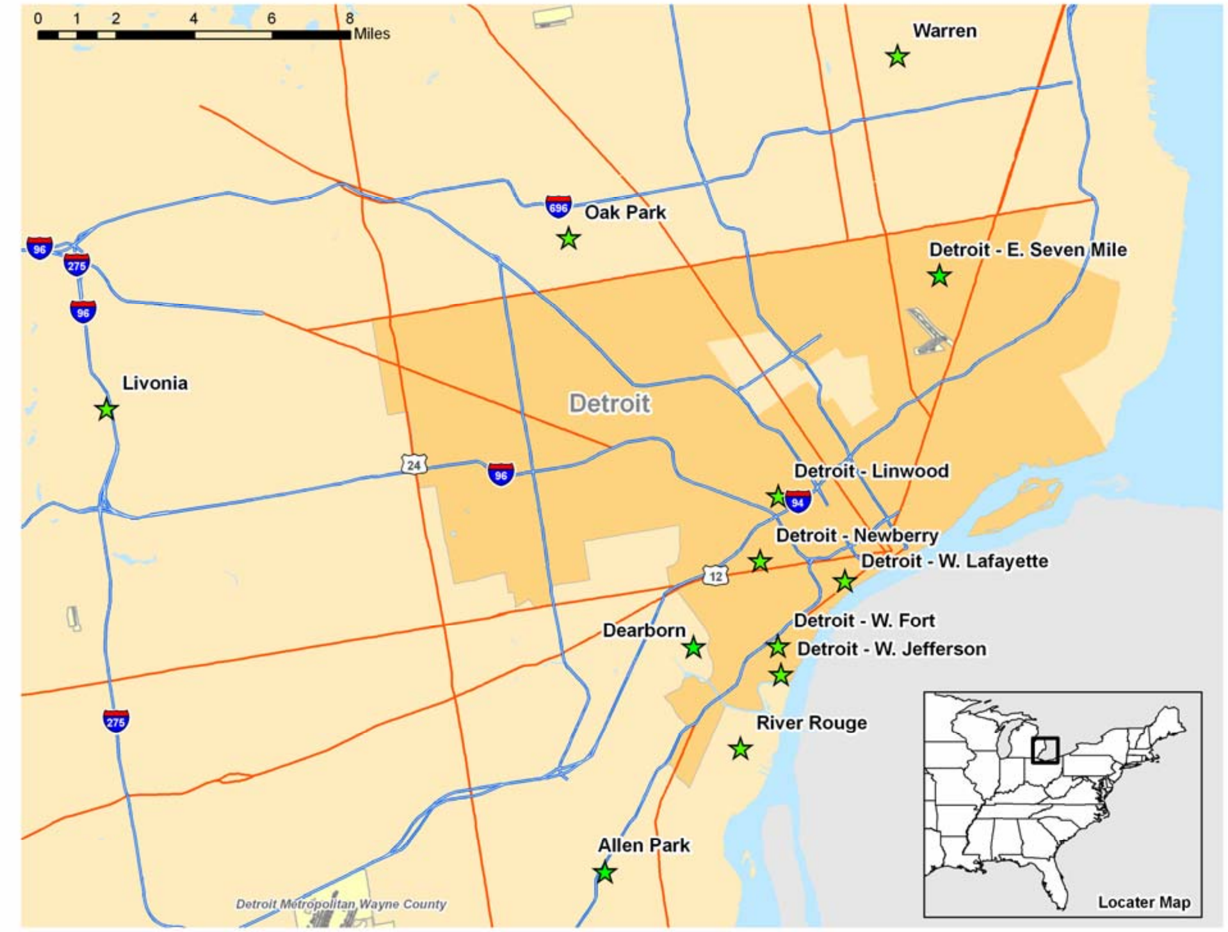


Figure 3-2. Michigan Air Sampling Network for southeastern Michigan for 2005.

Table 3-1. Summary of maximum pollutant levels in the Detroit urban area in 2005.

Pollutant	Duration and Unit	Highest Value	NAAQS
CO	8-hour (ppm)	2.6	9.0
Lead	24-hour (µg/m^3)	0.117	NA
NO_2	Annual (ppm)	0.017	0.053
Ozone	1-hour (ppm)	0.118	0.12
	8-hour (ppm)	0.103	0.08
$PM_{2.5}$	Annual (µg/m^3)	18.6	15
	24-hour (µg/m^3)	79	35
PM_{10}	Annual (µg/m^3)	40	revoked
	24-hour (µg/m^3)	95	150
SO_2	Annual (ppm)	0.007	0.03
	24-hour (ppm)	0.045	0.14
Air Toxics	NATA 1999 Model (cancer risk per million)	63.2	NA

NA = not applicable

Criteria Pollutants

As shown in Figure 3-2 and Table 3-1, several monitoring sites in the Detroit area measure pollutants for which NAAQS exist, such as CO, ozone, lead, NO_x, SO_2, and particles. While the Detroit area did not exceed the NAAQS standard for several pollutants (e.g. CO, NO_2, SO_2), there were measured exceedences of the 8-hour ozone NAAQS and the 24-hour and annual fine particle NAAQS.

Fine Particles

To understand more about the sources of the high fine particle values, speciation-monitored data, at the Allen Park and Dearborn monitoring site are explored. Fine particles consist of multiple chemical constituents and are usually speciated into sulfate, nitrate, ammonium, organic carbon, elemental carbon, and crustal components. While sulfate, nitrate, and ammonium are mostly secondarily formed, elemental carbon and the crustal components are primary species usually deposited directly from the source. In **Figure 3-3**, annual average concentrations for 2005 of the major chemical components of fine particles are shown for the Allen Park and Dearborn sites as percentage of fine particle mass. The annual average fine particle mass in 2005 measured at Allen Park was about 15 $\mu g/m^3$, while at Dearborn it was about 18 $\mu g/m^3$. When comparing the chemical species contributions with the mass between these two sites, the amount of sulfates, nitrates, and even carbon is reasonably consistent on a percentage basis. However, the amount of crustal material at the Dearborn site is a much higher contributor to mass (about 11 percent compared with less than 0.6 percent at Allen Park). The relatively high amount of crustal material indicates very local contributions of crustal material to the Dearborn monitoring site. Causes of site-to-site differences in species components of fine particles for any area should be taken into account when considering sources to include as part of potential control strategies.

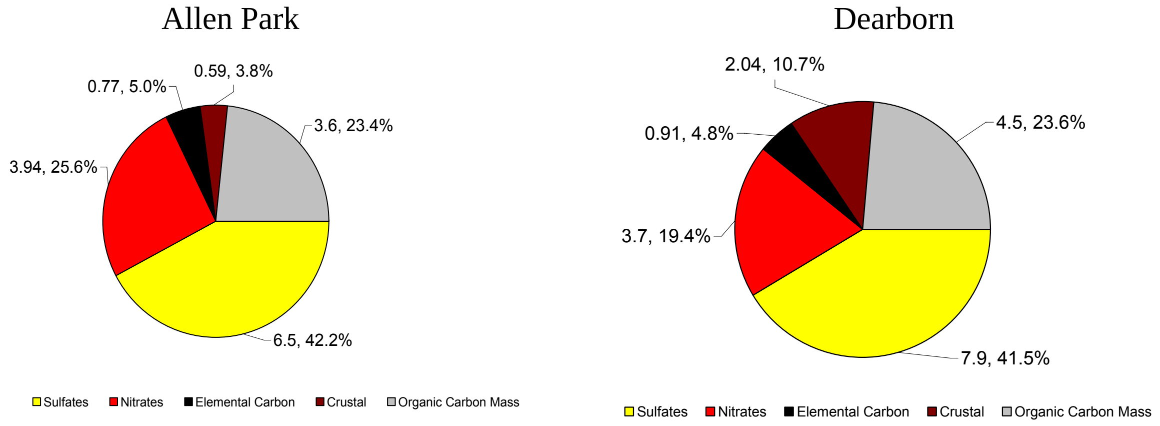


Figure 3-3. 2005 annual average concentrations ($\mu g/m^3$) of fine particle chemical constituents at Allen Park and Dearborn sites.

Ozone

Of the seven monitors in the Detroit area, only Warren and New Haven have ozone levels averaged over 2003-2005 that continue to exceed the ozone NAAQS of 0.085 ppm **(Figure 3-4)**. Because ozone is not emitted but is formed from the chemical interactions of other pollutants, it is called a "regional" pollutant. Because of this, it becomes important to understand the atmosphere's responsiveness to the reduction of ozone precursors, such as NO_x and VOCs. This is usually done through sensitivity analyses with atmospheric models. An area is called "NO_x-limited" when reducing NO_x will lead to decreases in ozone. In such an environment, the most effective control strategy will focus on controlling NO_x emissions. When the opposite is true, the area is called "VOC-limited." Detroit is a "VOC-limited" area, with the limiting factor in ozone production being VOC concentrations. In the Detroit urban area, the most effective control strategy would focus on VOC reductions.

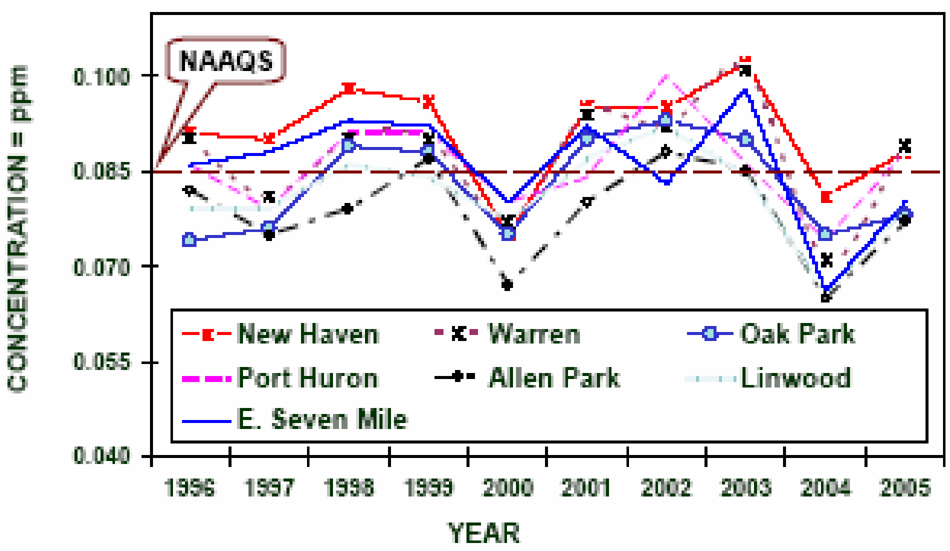


Figure 3-4. Trends in ozone levels for monitoring sites in southeast Michigan for 1996-2005.

Source: Michigan Department of Environmental Quality, 2007b

Air Toxics

While there is a great deal of air quality monitoring data in Detroit for NAAQS pollutants, the amount of air toxics measurements are limited. To address this issue, the MDEQ undertook an intensive air quality sampling program to measure levels of over 200 air toxics in the Detroit area. This study, called the Detroit Air Toxics Initiative (DATI) Study, was conducted from April 2001 to April 2002 at six locations within Wayne County and one location in Southfield. The location of these monitors is shown in **Figure 3-5**. A monitor was also placed in Ypsilanti for comparison purposes.

Based on the measurements taken during the DATI , MDEQ released the DATI Report that detailed the study and summarized the findings. In this report, the air toxics found to be risk drivers for both cancer and non-cancer in Detroit are shown in **Figures 3-6 and 3-7**. Thirteen air toxics were identified as contributing the most to risks in the Detroit area. These were 1,4-dichlorobenzene, acrylonitrile, arsenic, benzene, formaldehyde, methylene chloride, naphthalene, manganese, nickel, cadmium, carbon tetrachloride, acetaldehyde, and 1,3-butadiene (not in order of priority). Two other pollutants, acrolein[4] and DPM, were also added to the list as important toxics based on additional data.

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[4] Acrolein information based on actual monitored data in Detroit as part of EPA's Detroit Exposure Aerosol Research Study (DEARS).

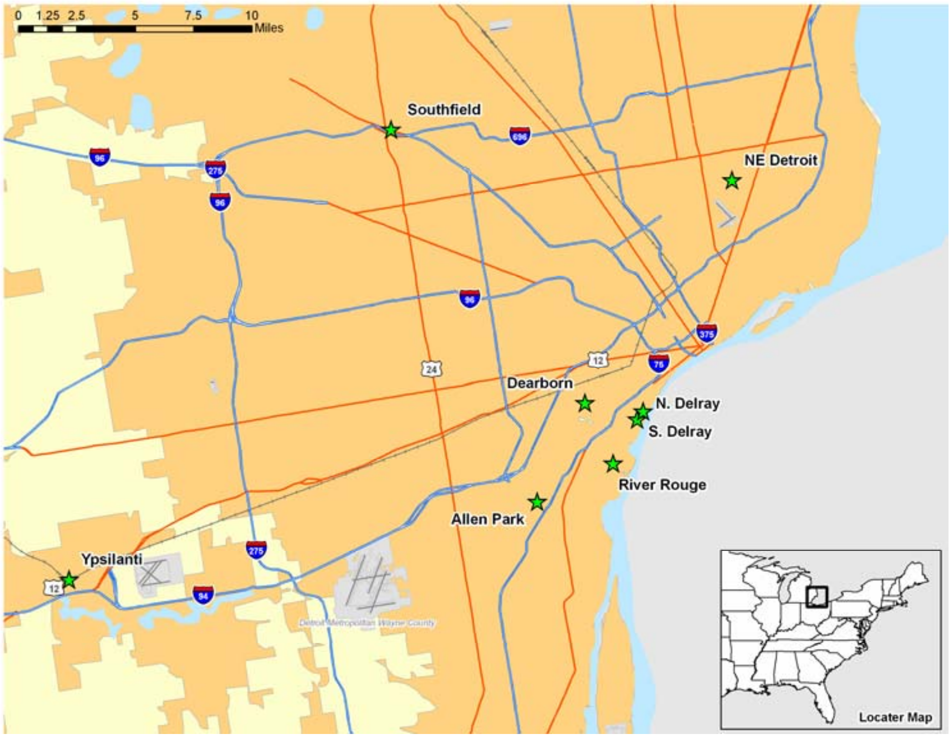

Figure 3-5. DATI monitoring sites for air toxics in the Detroit area.

Source: MDEQ DATI Report, 2005

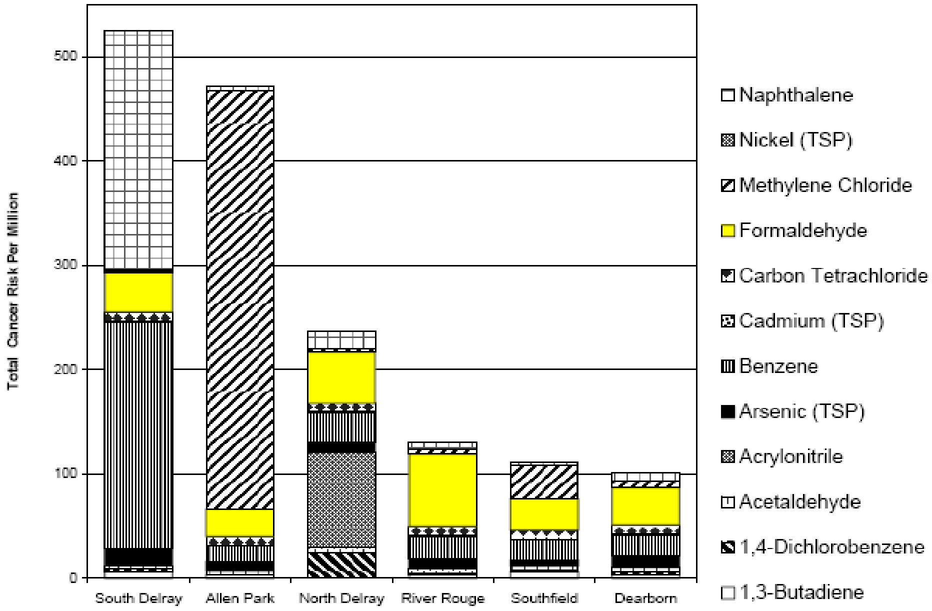

Figure 3-6. Additive cancer risk by monitoring site in the Detroit area for 2002.

Source: MDEQ DATI Report, 2005

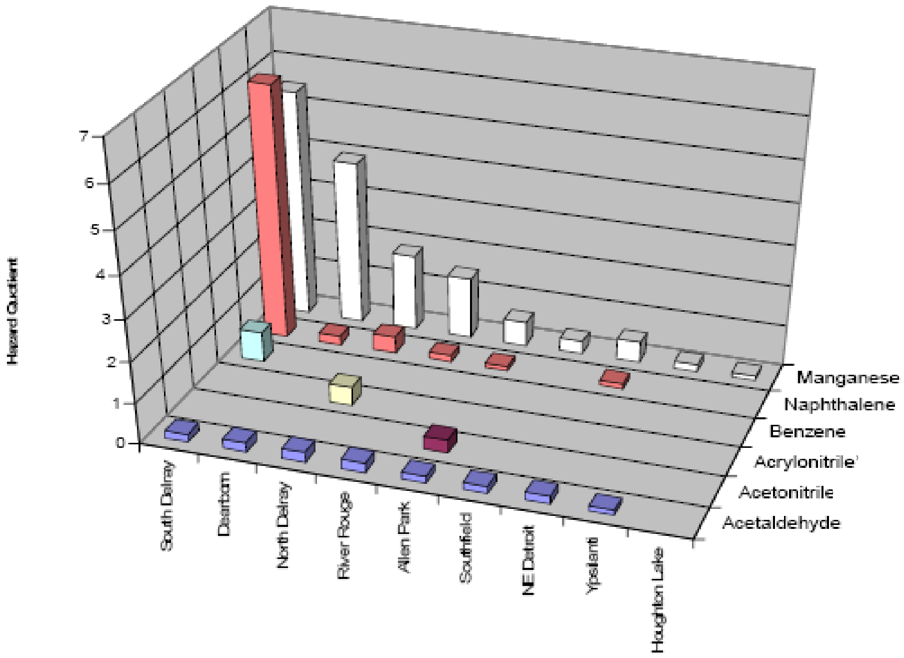

Figure 3-7. Non-cancer hazard quotient by site and chemical in the Detroit area for 2002.

Source: MDEQ DATI Report, 2005

Figure 3-6 shows that additive risks for the 12 carcinogens designated as having an individual risk greater than $1x10^{-6}$ varied among the sites.[5] Within the Detroit area, there is about a five-fold difference between sites with the highest and lowest risk from these carcinogens. If consideration is given to the fact that methylene chloride at Allen Park and naphthalene and benzene at South Delray may have been isolated occurrences, then formaldehyde seems to be one of the more important carcinogens across the Detroit area.

In Figure 3-7, the non-cancer benchmark is shown via hazard quotient (HQ) across monitoring sites in the Detroit area. Monitored levels of six compounds were found to be present at levels greater than one-tenth of the chronic health protective benchmark value, indicating an HQ greater than 0.1. These six compounds were acetaldehyde, acetonitrile, acrylonitrile, benzene, manganese, and naphthalene. Only two of these compounds, manganese and naphthalene, exceeded their hazard quotient (HQ>1) at any of the sites.

While most of these air toxics were found at levels similar to those in other large, industrialized urban areas of the US, a few air toxics were particularly high at some sites in the Detroit area. These include methylene chloride at Allen Park, benzene and naphthalene at South Delray, and manganese at South Delray, North Delray, Dearborn, and River Rouge. It is interesting to note the unusually high concentrations of manganese, a metal HAP and a directly emitted particle. Relating this information to the high crustal component in the speciated fine particle data shown in Figure 3-3 suggests that a source of directly emitted fine particles could

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[5] The IRIS cancer benchmark for formaldehyde used by MDEQ is not the one currently recommended by OAQPS.

also be emitting manganese. Targeting such a source could provide multi-pollutant benefits by reducing fine particle concentrations as well as reducing the risk from this air toxic.

Source Contributions to Air Quality Problems

The relationship between ambient measured concentrations of pollutants and the sources of these pollutants is important to understand when the release or control of one pollutant will affect the release or chemical formation of another pollutant. Therefore, in developing an effective multi-pollutant control strategy, the nature of these source-receptor relationships must be understood. **Figure 3-8** shows the location of monitoring sites in the Detroit metropolitan area relative to local point and mobile emission sources. Point source (i.e., large facility) emissions of NH_3, NO_x, SO_2, and VOCs all contribute to fine particle concentrations, while emissions of NO_x and VOCs contribute to ozone, and many of the VOCs are also HAPs. The annual average daily traffic volumes represent motor vehicle emissions (e.g., higher traffic volume indicates higher emissions) and help to show the spatial distribution of motor vehicle emissions of VOCs, NO_x, and fine particles.

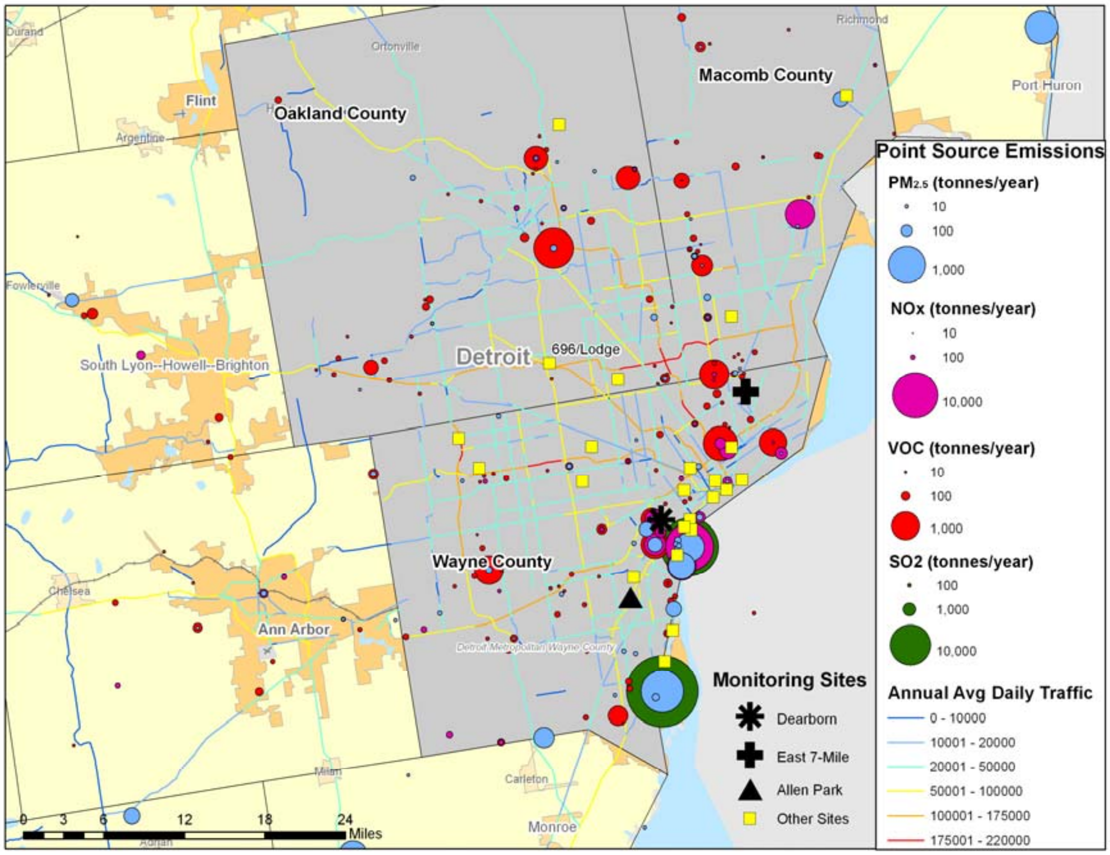

Figure 3-8. Map of monitoring sites and pollutant emissions in the Detroit vicinity for 2001.

From MDEQ's DATI report, **Table 3-2** describes all emission sources, including point, area, and mobile sources within four miles of each monitoring site. As shown, a variety of sources are in the Detroit area and more than one monitor could be impacted by the same source category. **Figure 3-9** shows the break down of several major pollutants among primary source categories from the 2002 NEI (U.S. Environmental Protection Agency, 2007b). These data indicate that large industrial sources in Detroit emit SO_2, fine particles (including manganese), NO_x, and VOCs. This figure also indicates that mobile sources are a significant source of VOCs, especially benzene, formaldehyde, and 1,3-butadiene. If VOCs emitted by mobile sources in Detroit were controlled to lower ozone, such a strategy could provide multi-pollutant benefits by also reducing the high cancer risk from benzene, formaldehyde, and 1,3-butadiene. Selecting multi-pollutant control strategies that result in benefits across both CAPs and HAPs are important in an area such as Detroit.

Table 3-2. Significant emission sources within four miles of each monitoring site in the Detroit area.

Source: MDEQ DATI Report, 2005

Site (AIRS ID)	Point and Area Sources	Mobile Sources
Houghton Lake (261130001)	Fireplaces/wood stoves, Christmas tree farming, oil and gas production	US-127, boating, snowmobiling
Southfield (261250010)	Paint manufacturing, metal heat treating, machine stop, auto paint shop, asphalt, ready-mixed concrete	I-696, Telegraph, and Lodge
Ypsilanti (261610008)	Equipment manufacturing, waste water treatment plant (WWTP), commercial printing, plastic products, power generation plants	I-94
Allen Park (261630001)	Bulk petroleum stations, refuse services, quarry, metal fabrication, chemical manufacturing/processing, power generation plants, plastic resin manufacturing	I-75
River Rouge (261630005)	Steel plant, drywall manufacturing, WWTP, sewerage incinerator, asphalt plant, oil refinery, coke batteries, coke by-product production facility, power generation plants, coal-and oil-fired combustion, paint shops, assembly plants (heavy industrial)	I-75
N. Delray (261630015)	2 steel mills, used oil reclamation plant, asphalt plant, oil refinery, coke batteries, coke by-product production facility, WWTP, sunroof manufacturer, power generation plants (heavy industrial)	I-75
N.E. Detroit (261630019)	Automotive manufacturing and stamping, chemical preparations, power generation plants, foundry, metal coating, refuse systems	I-94
S. Delray (261630027)	Coke battery, asphalt plant, oil refinery, coke by-product production facility, steel mill, power generation plants (heavy industrial)	I-75
Dearborn (261630033)	Auto and steel manufacturing, power generation plants, asphalt plant, oil refinery, coke batteries, coke by-product production facility (heavy industrial)	Between I-75 & I-94

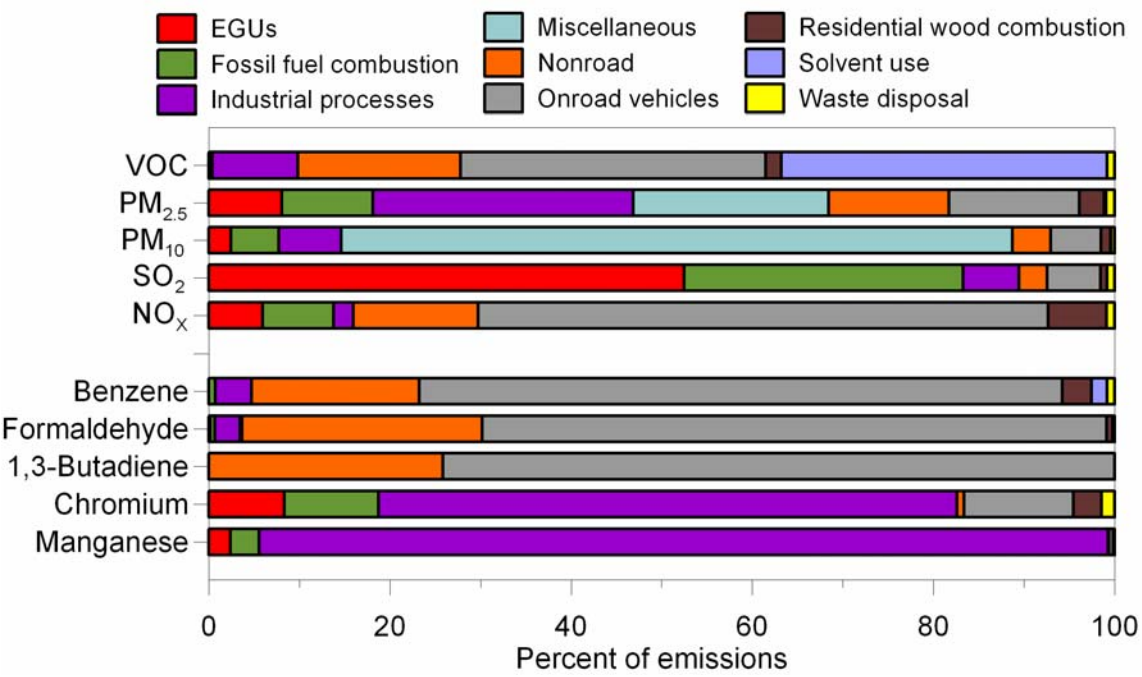

Figure 3-9. Emissions of criteria pollutants, their precursors, and key HAPs in the Detroit Area for 2002.

Source: U.S. Environmental Protection Agency, 2007b

Though the ambient monitoring data alone can give some indication of source emissions causing these multi-pollutant air quality problems, these data can also be used in conjunction with receptor models to estimate individual source contributions to pollutants at a monitoring site. Receptor models are statistical tools that identify the covariance in concentrations across species to isolate "factors" that correspond to emissions sources or transported pollution. Currently, two established receptor models are widely used for source apportionment: chemical mass balance (CMB) and positive matrix factorization (PMF). Both have been used to characterize source contributions to ambient fine particle levels (e.g., NARSTO, 2004; Lee and Hopke, 2006; Brown et al., 2007).

Table 3-3 shows the use of PMF as applied to 2004 fine particle chemical constituent data from the Allen Park and Dearborn sites. These data indicate that mobile emissions are significant contributors to fine particle concentrations at both sites. This conclusion is also supported by a recent study that the Lake Michigan Air Directors Consortium (LADCO) undertook to investigate the organic carbon portion of fine particles in the Detroit area using chemical markers that are identifiers for specific source categories. While the LADCO work is still under development, early results also indicate that mobile sources (gas and diesel) contribute heavily to ambient organic carbon in the Detroit area. It is interesting to note that recent EPA modeling has shown that mobile sources (both non-road and on-road) also play a large role in ozone formation. These findings suggest the use of a multi-pollutant control strategy for the Detroit local area that would allow reduction of fine particles and ozone through mobile source controls.

In Table 3-3, source contributions from vehicles, “secondary ammonium nitrate,” and “secondary ammonium sulfate,” are similar at the two sites. However, larger contributions of sources such as “steel” and “industrial” to the Dearborn monitor suggest a significant local source contribution. This is in agreement with the monitoring data discussed earlier in this chapter, for which the amounts of ambient crustal material and manganese (a pollutant know to be emitted from steel mills) were much higher at the Dearborn site. In this way, a receptor model can help identify sources of fine particles in a local area and enable a better understanding of the sources that contribute to the urban gradients seen in fine particles. This information allows informed decisions on potential control strategy selections at a given site and aids in the implementation of an air quality management plan.

Table 3-3. PMF-based source contributions to the Dearborn and Allen Park sites in Detroit for 2004.

Source: Rizzo, 2005

Source	Contribution in μg/m^3 (Percent of total fine particles in parentheses)	
	Dearborn Site	Allen Park Site
Vehicles	5.3 (25%)	5.9 (35%)
Secondary Ammonium Nitrate[6]	3.7 (18%)	3.5 (21%)
Secondary Ammonium Sulfate[6]	4.6 (22%)	5.0 (30%)
Vegetative Burning	0.9 (4%)	0.9 (5%)
Road Salt	0.8 (4%)	0.4 (2%)
Steel (Metals Processing)	1.1 (5%)	0.3 (2%)
Soil	1.4 (7%)	0
Diesel source	1.3 (6%)	0.2 (1.1%)
Industrial (Utility and Petroleum Refineries)	1.7 (8%)	0.7 (4%)
Total Fine Particle Mass	20.8	16.9

Receptor modeling can also be applied to identify and quantify sources that contribute to multiple pollutant issues. **Figure 3-10** illustrates a multi-pollutant PMF analysis at the Allen Park site using collocated ambient toxics and fine particle data. This figure shows that mobile sources contribute both to fine particles and air toxics at the Allen Park site. Factors identified in this work included direct emissions from diesel, mobile sources, a steel facility, an industrial facility emitting carbonaceous aerosols, and crustal material. Other factors represent transported and chemically aged pollutants, including the aged mobile sources factor, and two regional transport factors representing winter and summer seasons, respectively. This type of application of multi-pollutant receptor modeling in a local area may prove valuable in assessing source contributions to multiple pollutant problems, and aiding policy makers to determine the most effective control strategies that can be applied to improve air quality.

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[6] Pollutants such as ammonium nitrate and ammonium sulfate are formed in the atmosphere from chemical reactions of precursor species NH_3, NO_x, and SO_2. Sources of these precursor pollutants include mobile sources and EGUs.

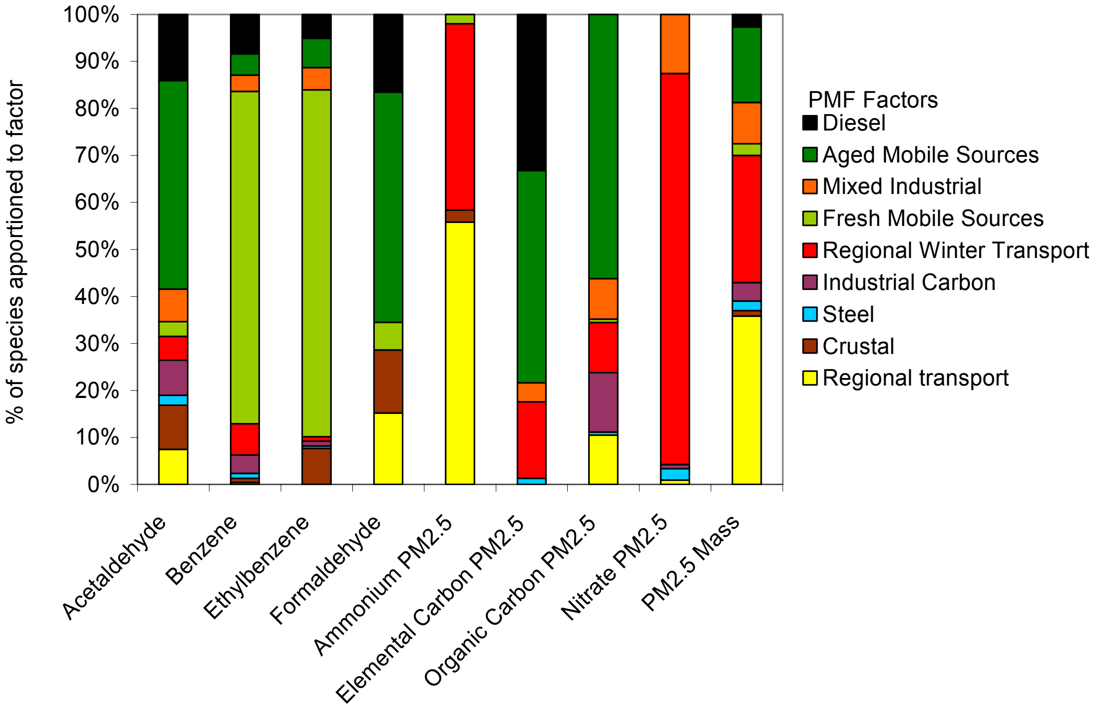


Figure 3-10. Apportionment of selected air toxics and Speciation Trends Network (STN) fine particle species by PMF factor at Allen Park for 2001-2005.

Source: Brown et al., 2007

Summary

Some air quality issues in Detroit are multi-pollutant in nature. The pollutants are linked by similar sources of emissions and by chemical and physical formation processes in the atmosphere. We explored the nature of the air quality problems in the Detroit area as part of the development of a conceptual model for informing air quality management decisions. We showed how ambient monitoring data and receptor modeling tools could be used to identify sources of importance. In identifying these sources, it became evident that controlling certain source types could provide multi-pollutant benefits by reducing both criteria pollutants and air toxics. Additional information should be considered to formulate specific control options for this area including results from past and current air quality modeling that provide insights on control responsiveness, as well as details on potential controls for the sources of most importance.

Chapter 4: Current Trends and Future Projections of Air Quality at the National Level

The 2004 NAS study acknowledged the air quality improvements brought about by EPA's implementation of the CAA, but additional changes are needed to continue to improve air quality for multiple pollutants. The NAS report also indicated that devising solutions to future air quality issues will benefit from a multi-pollutant, airshed-based approach. This chapter illustrates the reductions in criteria and air toxic pollutant concentrations based on ambient measurements. It also shows the expected improvements in particles, ozone, air toxics (including mercury), visibility, and nitrogen/sulfur deposition resulting from "on-the-books" federal programs based on projections from air quality modeling.

Decreasing Trends in Multi-pollutant Concentrations

Under the CAA, EPA established the NAAQS to protect public health and welfare (visibility impairment and damage to crops, vegetation, and buildings). Over the past three decades, EPA has partnered with state, local, and tribal agencies to implement programs aimed at reducing emissions of those pollutants that contribute to poor air quality. The national-level trends in CAPs and selected HAPs shown in **Figure 4-1** indicate the progress resulting from these programs.

Figure 4-1 shows the average national picture of criteria pollutant concentrations relative to the standard for each CAP and for HAP concentrations relative to species-specific cancer benchmarks recommended by OAQPS. Since at least the mid-1990s, average PM_{10}, NO_2, CO, SO_2, and Pb concentrations have been less than 60 percent of their standards. We have data for some pollutants for 26 years but for some others we have only 7 years worth of ambient measurements. The changes observed between first and last years are dramatically different among the pollutants, ranging from 1 to 4 percent reductions per year among the CAPs, while HAPs range from a 2 percent increase per year for acetaldehyde to a 6 percent reduction per year for benzene. Of the six pollutants for which EPA establishes national ambient standards, only two—ozone and fine particles—remain persistent, widespread problems with average concentrations above, or close to, the NAAQS. In contrast, multiple HAPs, including benzene, carbon tetrachloride, 1,3-butadiene, acetaldehyde, acrolein, and arsenic are above levels of concern nationally.

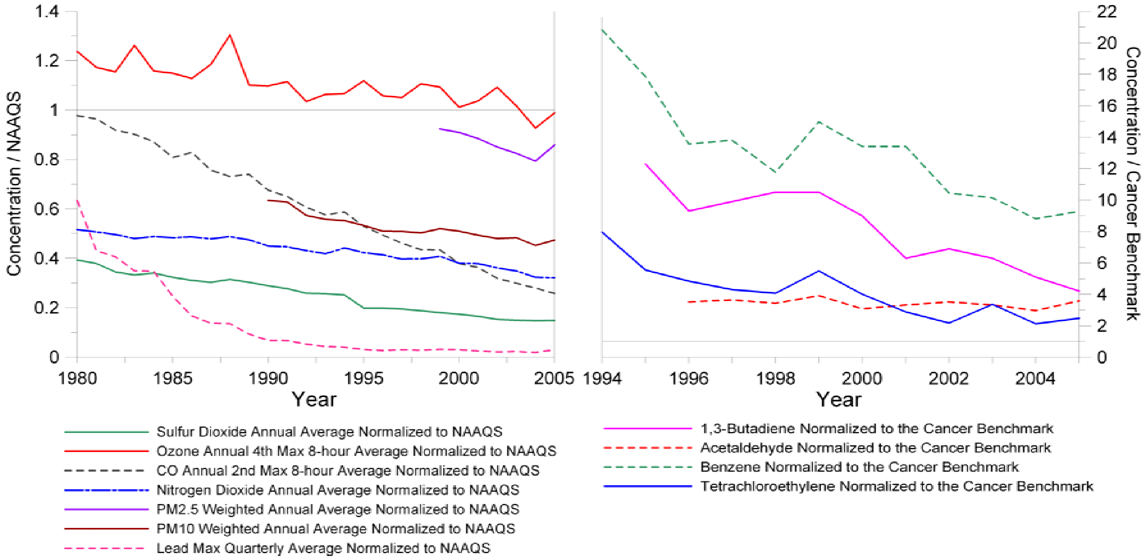


Figure 4-1. National-level trends in CAPs (left) and selected HAPs (right) relative to the NAAQS and cancer benchmarks.

Note: the difference in trend periods for the toxics compared with the criteria pollutants. These few species were selected as illustrations for air toxics because they have some of the longest trend records, highest data quality, and most monitoring sites among air toxics species. Currently, ozone or particle pollution trends are better understood than trends in air toxics.

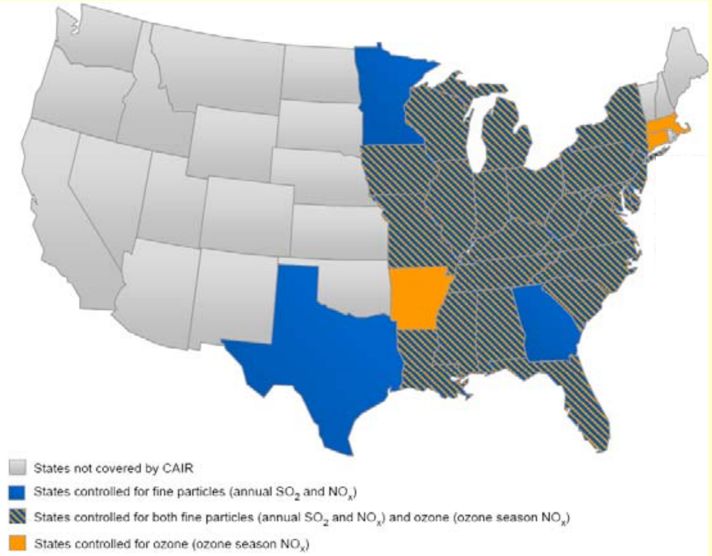
Clean Air Rules Will Further Improve Air Quality

EPA recently promulgated a number of federal regulations to reduce multiple air pollutants. In 2006, EPA implemented the “Clean Air Rules”, which included the Clean Air Interstate Rule (CAIR), the Clean Air Mercury Rule (CAMR), and the Clean Air Visibility Rule (CAVR). These rules target emissions of NO_x, SO_2, and mercury from power plants (see the following text box for more information). Reductions in these pollutants will help improve multiple air quality problems such as ozone, particle pollution, air toxics, atmospheric deposition of mercury to waterways, acid rain, and visibility at Class I areas. In addition, EPA promulgated the Clean Air Nonroad Diesel Rule in 2004 aimed at reducing air pollution from construction, agricultural, and industrial diesel-powered equipment. These Clean Air Rules will reduce emissions across a range of pollutants of concern and thus provide a good example of how the multi-pollutant approach can improve air quality across the US. The results in the rest of this chapter illustrate how these and other existing CAA programs will simultaneously reduce individual pollutants based on modeling results.

EPA's Clean Air Rules: www.epa.gov/cleanair2004/

Clean Air Interstate Rule (CAIR). This rule provides states with a solution to the problem of power plant pollution that drifts from one state to another. This rule mandates that power plants in the eastern half of the country reduce SO_2 and NO_x emissions, which will reduce ozone and particle pollution concentrations and decrease haze. The rule uses a cap-and-trade system to reduce the target pollutants by 70 percent.

States Covered by CAIR



Clean Air Mercury Rule (CAMR). This rule builds on CAIR to significantly reduce mercury emissions from coal-fired power plants, the largest remaining domestic source of human-caused mercury emissions. When fully implemented, these rules, using a cap-and-trade system, will reduce utility emissions of mercury from 48 tons to 15 tons a year, a reduction of nearly 70 percent.

Clean Air Visibility Rule (CAVR). This rule targets SO_2 and NO_x and requires emission controls known as best available retrofit technology, or BART, for selected industrial facilities built between 1962 and 1977 emitting air pollutants that reduce visibility by causing or contributing to regional haze.

Clean Air Nonroad Diesel Rule. This rule will reduce emission levels from construction, agricultural, and industrial diesel-powered equipment by more than 90 percent and will also remove 99 percent of the sulfur in diesel fuel by 2010. This rule specifically targets DPM emissions and may also reduce SO_2.

Source: U.S. Environmental Protection Agency, 2007c

Figure 4-2 shows the projected changes in pollutant emissions between 2001 and 2020 including the reductions resulting from implementation of the Clean Air Rules. As shown, with the exception of ammonia, all pollutants are expected to decline over this timeframe with significant reductions between 30 and 50 percent for NO_x, SO_2, and VOCs. These declines demonstrate the effectiveness of CAA programs; however, Figure 4-2 also shows the large remaining emissions across the eastern and western US in 2020. Our projections indicate increases in ammonia emissions of 20 percent in the 12 western-most states and 7.5 percent in the 38 eastern-most states from agriculture and related sources over this time period.

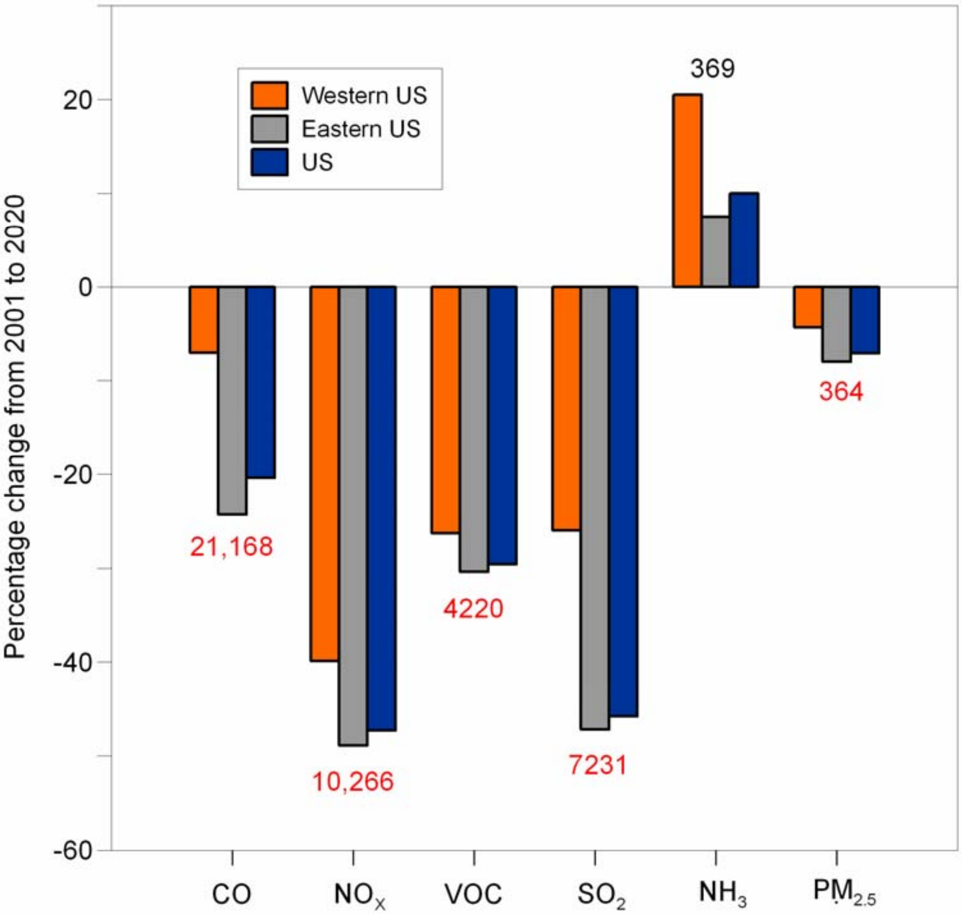


Figure 4-2. Projected percentage changes in pollutant emissions between 2001 and 2020 resulting from the Clean Air Act Programs. The numbers below (above) each set of bars is the reduction (increase) for the whole US in thousands of tons.

Ozone and Particle Pollution

Figure 4-3 shows where ozone and particle pollution problems have occurred over time and the projected benefits resulting from the CAA Programs. We see significant improvements in ozone and fine particle concentrations based on ambient data between the 1999-2001 period and the 2003-2005 period primarily due to the Acid Rain Program, NO_X SIP Call, and mobile source control programs implemented prior to and during this time. The number of counties exceeding the 8-hour ozone standard declined from 303 to 107, or by 65 percent, while those counties exceeding the annual fine particle standard declined from 167 to 74, or by 56 percent. Based on recent air quality modeling, the pollutant emission reductions expected by 2020 will result in even further reductions in nonattainment areas for ozone and fine particles. For 2020, we project 19 violating counties for fine particles and 31 violating counties for ozone under the existing NAAQS. Ozone and fine particle violations are projected to continue in southern and central California. Ozone is a persistent issue for the Northeast corridor and Houston area, while fine particle issues will continue in midwestern cities such as Chicago, Detroit, and Cleveland, OH; as well as Birmingham, AL.

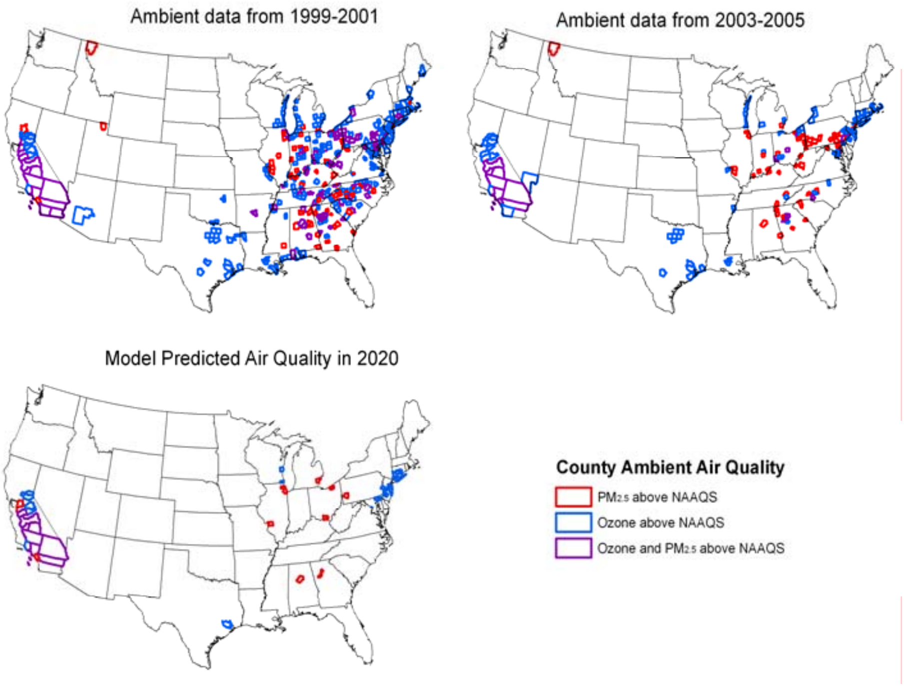


Figure 4-3. Past, current, and projected improvements in ozone and fine particle air quality for 1999-2001, 2003-2005, and 2020.

Note: Air quality has improved substantially in the past five years and is predicted to improve even more in the future as a result of the recently promulgated Clean Air Rules and other existing CAA programs.

Source: U.S. Environmental Protection Agency, 2006b

Figure 4-4 shows the results of projecting toxicity-weighted HAP emissions from 1990 through 2020 (Strum et al., 2005). Overall, total HAP emissions are projected to decline by about 48 percent in 2020 from 1990 levels. As shown, all source sectors except for "Area & Other" (i.e., stationary sources that do not meet the major source threshold, non-industrial sources such as residential heating and use of consumer solvents, and fires) decrease between 1990 and 2020.[7] These results suggest that the "Area & Other" source sector will contribute as much as the "Major" sources category in the future. The emerging prominence of the "Area & Other" source category for air toxics may indicate that it is the most promising sector for future multi-pollutant reduction efforts. It is also important to note that the on-road and non-road mobile source categories emissions will see reductions in the future at the national level but may still be significant contributors to cumulative risk in urban and local areas.

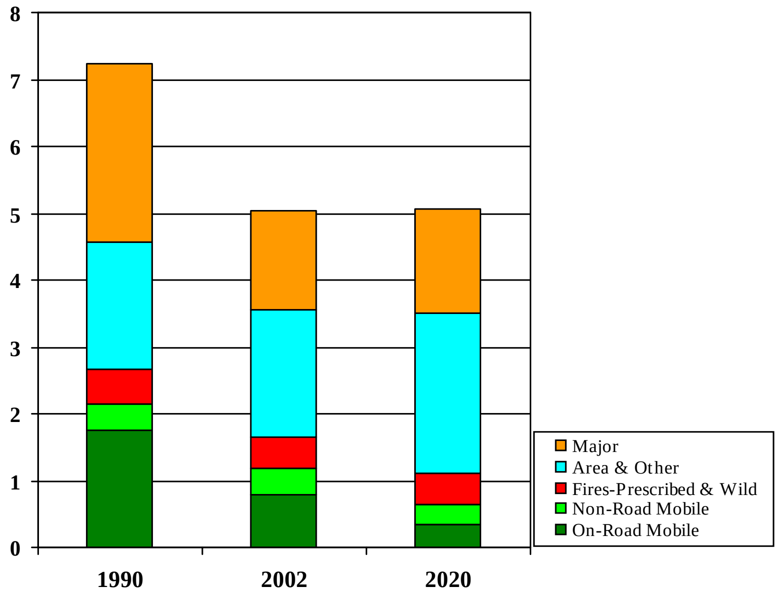


Figure 4-4. Projections of risk-weighted air toxics emissions (scaled toxicity weighted emissions) for 1990, 2002, and 2020.

Figure 4-5 shows the significant reductions in projected mercury deposition across the US from 2001 to 2020 as a result of implementation of the Clean Air Rules: CAIR and CAMR.

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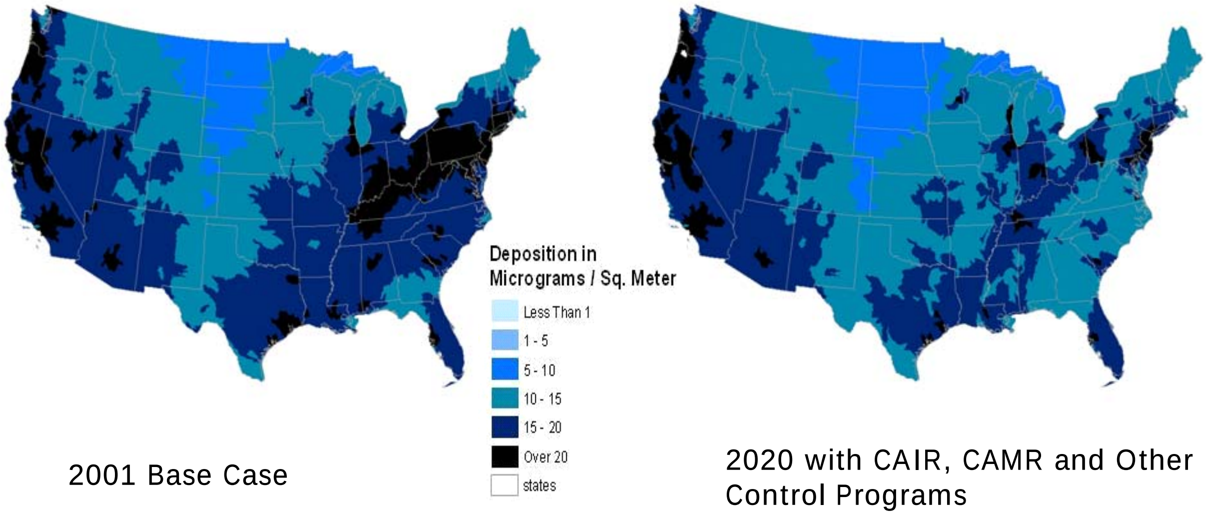
[7] Some important caveats of these projections are important to understand. Because the MACT program compliance dates are prior to 2010 and the impact of the residual risk program is not included in these projections, the emissions from major sources decline from 1990 to 2010 but begin to increase again in 2010. In addition, this study did not include the impact of area source standards that had not yet been proposed by 2004 and therefore future emissions from the "Area & Other" sector may be lower than reflected in these projections. Finally, future-year mobile source emissions are also expected to decrease even more than reported as a result of future programs that had not been accounted for at the time of this analysis, including the Mobile Source Air Toxics Rule, additional standards for small non-road gasoline engines, and standards for commercial marine vessels and locomotives.

Almost 115 tons of mercury were emitted by all sources in 2001 with EGUs emitting 42 percent of the total. Total mercury emissions in 2020 are projected at roughly 77 tons, reflecting a net reduction of almost 38 tons (32 percent) from 2001 levels. EGU reductions account for 24 tons (62 percent) of the total reduction.



2001 Base Case

2020 with CAIR, CAMR and Other Control Programs

Figure 4-5. Projected improvements in mercury deposition from 2001 to 2020.

Note: Deposition of mercury will decrease significantly as a result of implementing CAIR and CAMR.

Visibility

In **Figure 4-6**, the difference in estimated visual range between measurements taken in 2001 and projected visual ranges based on Community Multiscale Air Quality (CMAQ) model predictions in 2020 is shown for a subset of 114 IMPROVE sites. On the map, circle size corresponds to the amount of improvement in visual range (i.e., larger circles correspond to more improvement). All 114 sites show improvement in visual range. Sites in the eastern US and the Pacific Northwest show the most improvement. Improvement in the east can be attributed to a combination of CAIR and mobile source regulations that are projected to reduce particle pollution in this region. Control measures implemented to achieve compliance with the NAAQS, the Acid Rain Program, and the Regional Haze Rule also contribute to reductions in particle pollution and improvements in visual range at Class I sites.

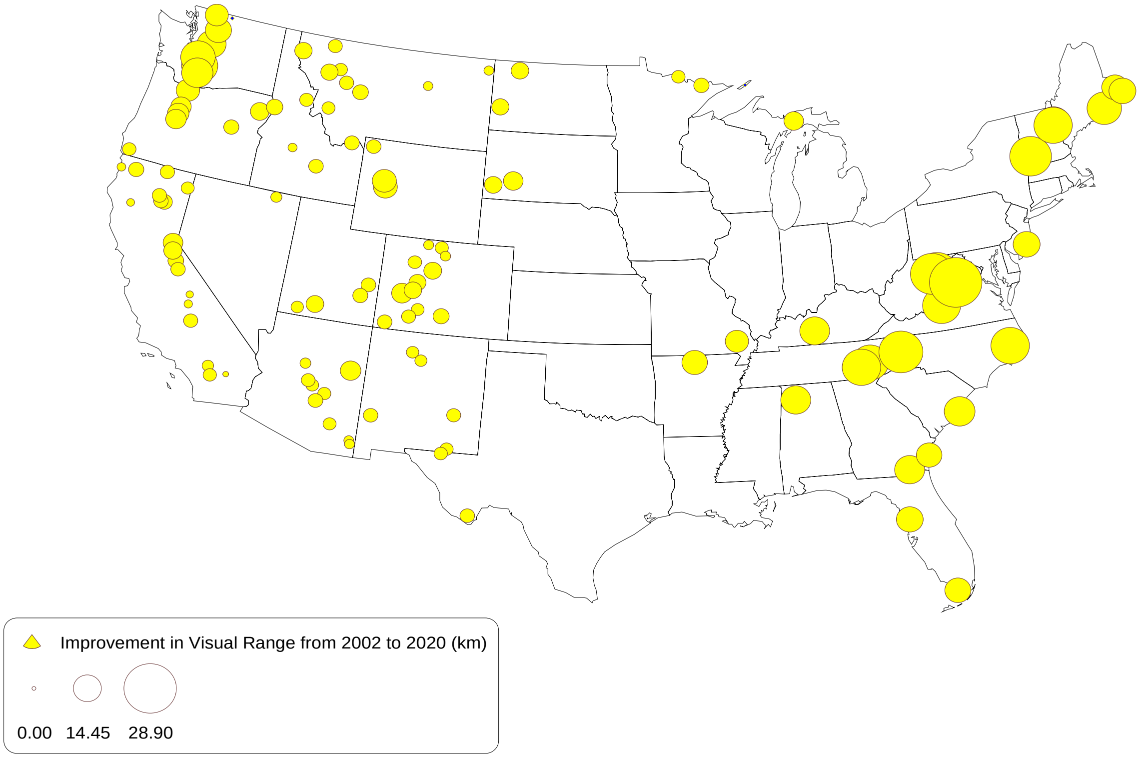
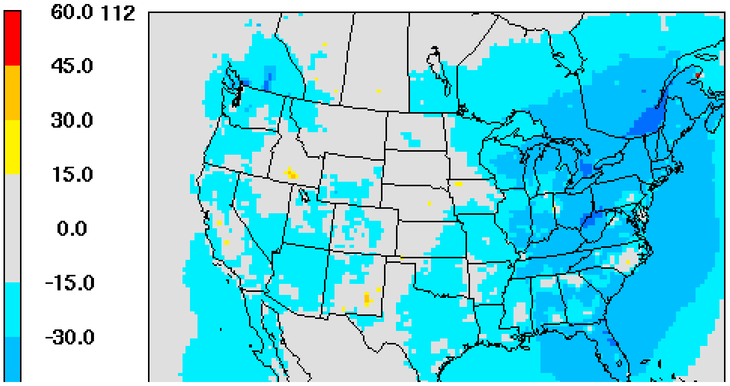


Figure 4-6. Projected improvement in visual range (km) from 2001 to 2020.

Nitrogen and Sulfur Deposition

Figure 4-7 illustrates the spatial distribution of CMAQ-predicted changes in nitrogen and sulfur deposition nationwide from 2001 to 2020 (U.S. Environmental Protection Agency, 2006b). These maps show both wet and dry deposition. In addition, both oxidized and reduced-form nitrogen deposition are included in the total. From 2001 to 2020, control measures that are part of Title IV (Acid Rain Program) and several mobile source rules (including Tier I and Tier II vehicle controls, heavy-duty diesel and non-road engine standards, and lower volatility and low-sulfur fuels) are expected to provide dramatic reductions nationwide in SO_2 and NO_x emissions that are principal contributors to sulfur and nitrogen deposition. In addition, the NO_x SIP Call and CAIR influence significant additional emission reductions of NO_x and SO_2 in the eastern US. However, ammonia emissions (another source of nitrogen) from agriculture are expected to increase by 2020. The NO_x, SO_2, and ammonia emission changes shown led to the predicted regional reductions in nitrogen and sulfur deposition seen in these figures. Local increases in nitrogen deposition are associated with locations where increases in ammonia emissions are projected to occur.

Percent Change in Nitrogen Dep: 2001 to 2020



Percent Change in Sulfur Dep: 2001 to 2020

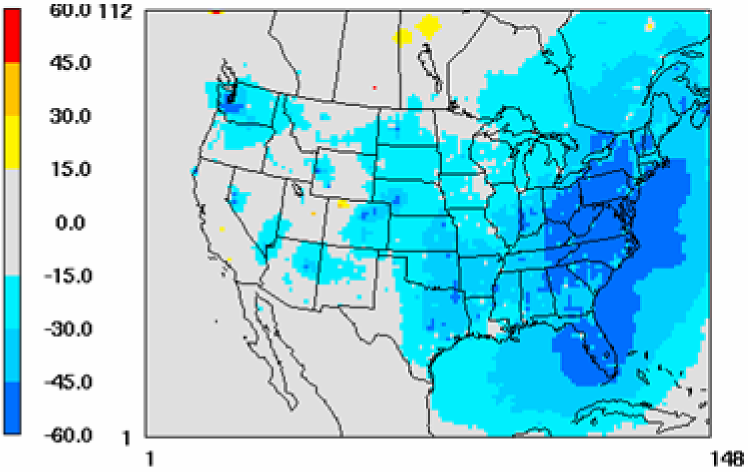


Figure 4-7. CMAQ-predicted changes in nitrogen and sulfur deposition from 2001 to 2020 (percent change).

Summary

Reductions in the concentrations of CAPs and HAPs have been shown to improve historically using ambient data. This chapter showed the expected air quality improvements in particles, ozone, and mercury resulting from “on-the-books” federal programs based on projections from air quality modeling. While air quality projections for air toxics are not yet available, projections of weighted emissions indicate that air toxics from all sources other than “Area & Other” will be reduced in the future as a result of federal programs.

Chapter 5: Multi-Pollutant Analytical Products and Capabilities

A key component of the air quality management cycle is technical information collection and analysis. Having the right tools to do the job is vital, and these tools must be able to successfully integrate across pollutants, across media, and across spatial scales. **Figure 5-1** demonstrates how technical data and tools allow those multi-pollutant concepts discussed in Chapter 1 to be considered as part of the regulatory and policy development process. Following the recommendations of the 2004 NAS study, OAQPS is emphasizing a more integrated and multi-pollutant approach for air quality management. For example, the multi-pollutant AQMP pilot projects highlighted in Chapter 1 will illustrate how these technical elements can be employed in the air quality management process to address multi-pollutant air quality issues.

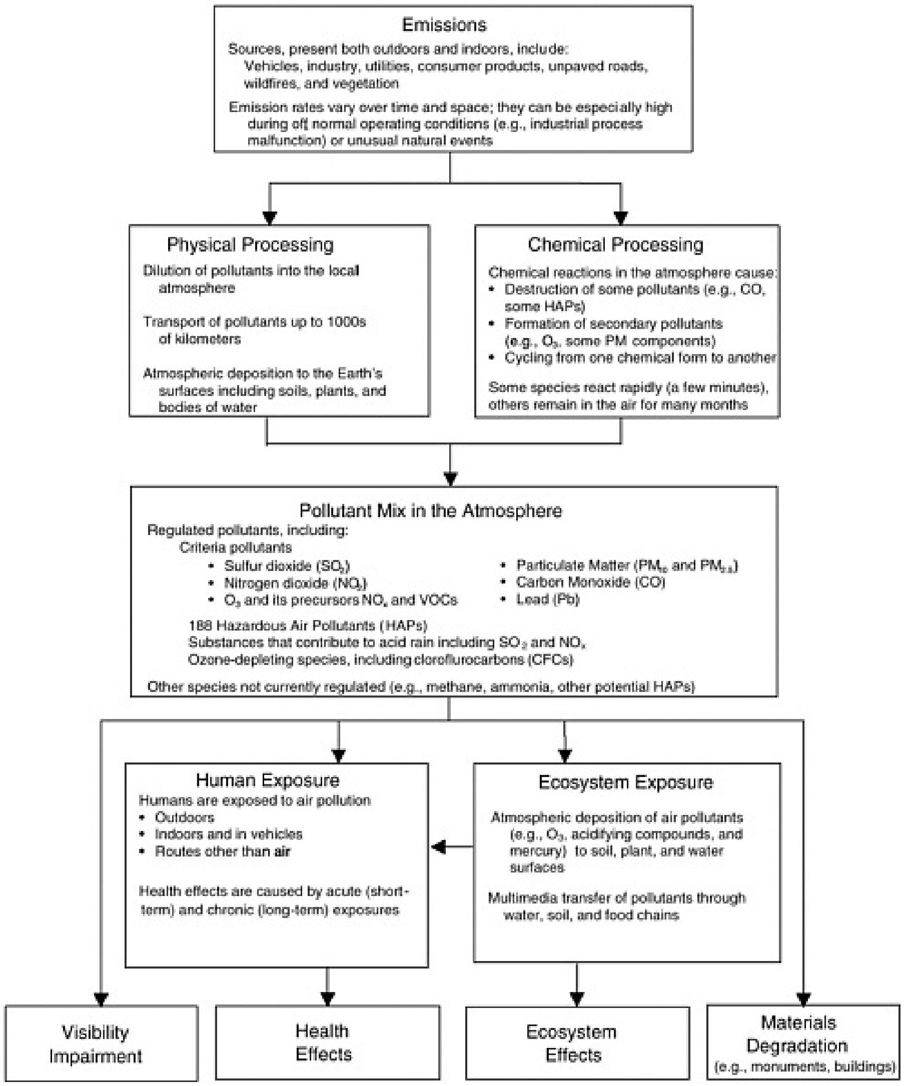


Figure 5-1. Technical elements of the air quality management system.

Source: National Research Council, 2004

OAQPS is playing a lead role in developing technical products and capabilities to inform regulatory and policy efforts that will help to identify effective multi-pollutant solutions to environmental problems. These products and capabilities include, but are not limited to, the following:

1. Integrated emissions inventory
2. Integrated monitoring network
3. “One atmosphere” air quality modeling
4. Multi-pollutant modeling platform
5. Spatial predictions of air quality data

This chapter provides details for each of these products and capabilities, some of which are available now and some of which are on the horizon. It should be noted that several of these products are already used for various EPA activities such as NAAQS designation and implementation work, regulatory impact analyses, risk assessments, monitoring network design, and source sector analyses.

Integrated Emissions Inventory – 2002, 2005 and 2008 National Emissions Inventories

In 2001, at EPA’s International Emissions Inventory Conference workshop “One Atmosphere, One Inventory, Many Challenges”, EPA proposed combining CAP and HAP inventories. Since then, EPA has taken steps toward this “one inventory” idea with its 2002 National Emissions Inventory (NEI). The 2002 NEI is EPA’s latest comprehensive national emission inventory for the entire US. It contains emission measurements and estimates for seven CAPs, their precursors, and 188 HAPs. The NEI contains emissions data for all major contributors to air pollution, including point sources, mobile sources, and non-point sources.

For point sources, the NEI includes emissions for individual processes at an industrial facility. For mobile and non-point sources, the NEI contains county-level emission estimates. The NEI is developed using the latest data and best estimation methods including data from Continuous Emissions Monitors (CEMs), data collected from all 50 states and many local and tribal air agencies, and data using EPA’s latest models such as the MOBILE and NONROAD models.

In order to ensure adequate resources to complete the NEI reengineering effort (see next paragraph), EPA developed the 2005 National Emissions Inventory (Version 1) as a reduced effort version based on the 2002 NEI (Version 3). Only the highest value-added adjustments from readily available datasets were used to make additions for the 2005 NEI, which included:

- Inclusion of 2005 electric utility data from EPA’s Clean Air Markets Division (CAMD)

- Inclusion of 2005 National Mobile Inventory Model (NMIM) results for onroad and nonroad emissions
- Information on Facility closures from state/local and tribal agencies
- Inclusion of 2005 wildfire/managed burn data

EPA is in the process of creating the 2005 NEI Version 2, which will be completed in spring 2008. The 2005 NEI Version 2 includes updates for non-EGU stationary sources with the following data:

- HAP data received from States and industry to support the MACT program, including the recent Risk and Technology Review rulemaking.
- 2005 State, local, and tribal data submitted to EPA under the CERR
- HAP data from Toxic Release Inventory (TRI) for missing facilities and pollutants
- Off-shore platform data from Mineral Management Services (MMS)

OAQPS is also undertaking a project to re-engineer the processes and systems currently used to build the NEI. The Emissions Inventory System (EIS) will come out of this project and will be used to generate the NEI beginning with the 2008 inventory cycle. The goals of this project are to (1) provide better quality assurance tools so that data can be checked before being submitted by the states; (2) implement more efficient processes so that the time it takes to develop the inventory is significantly reduced; and (3) create a central location for users to access the resources they need to develop and maintain their inventories. The 2008 NEI will be available in June 2010

Integrated Monitoring Network – NCore

EPA has proposed a new national multi-pollutant air monitoring network strategy called the National Core Monitoring Network (U.S. Environmental Protection Agency, 2007d). NCore will measure multiple pollutants in a geographically diverse network of monitoring sites. The information provided by this network should help improve our understanding of the relationships among air quality problems. These new multi-pollutant monitoring sites will anchor the current national monitoring network. The sites will measure important precursor gases, basic meteorology, as well as ozone, particles, CO, NO_x, and SO_2. Although CO, NO_x, and SO_2 are criteria pollutants, NCore is designed foremost to measure trace-level concentrations in representative, well-mixed locations to support accountability studies and exposure- and health-based assessments, and to evaluate air quality models. In addition, the sites will also measure VOCs, air toxics, and other key measurements, such as meteorlogical varaibles. By measuring multiple pollutants and other measurements at a single location, EPA and its partners can maximize the multi-pollutant information available. This approach greatly enhances the foundation for future health studies and NAAQS revisions. The sites will be placed in broadly representative urban (about 55 sites) and rural (about 20 sites) locations throughout the country to help characterize urban and regional patterns of air pollution (**Figure 5-2**).

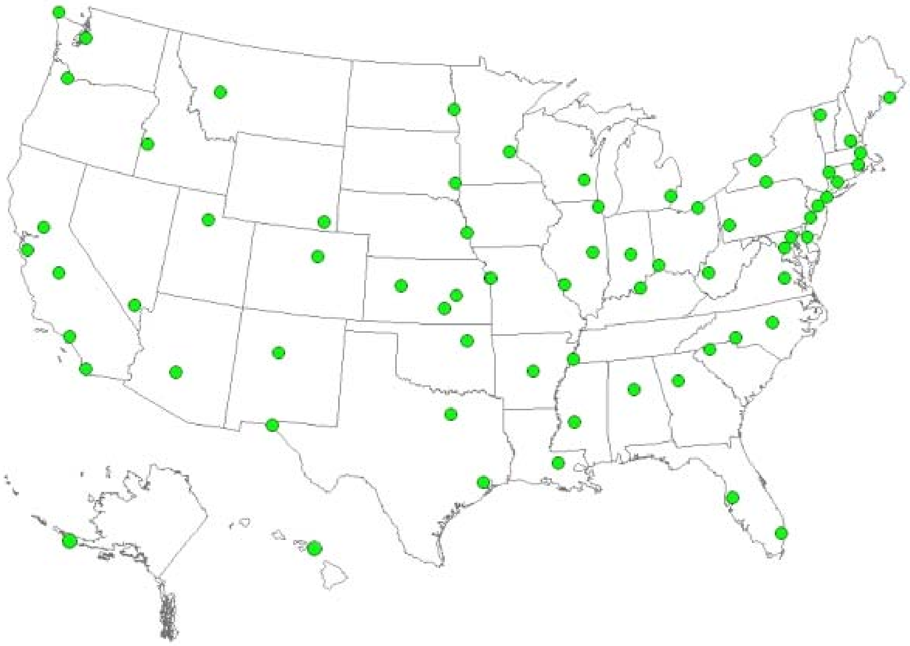


Figure 5-2. Map of candidate NCore sites.

Source: U.S. Environmental Protection Agency, 2007d

The NCore network will incorporate new instrument methods that meet the goals of (1) using automated methods that continuously monitor air quality to improve temporal resolution and (2) continuing to lower detection limits to provide information at lower concentrations. These improvements are particularly important for health-based studies because they provide scientists with more data (e.g., every hour rather than a daily average) of higher certainty (e.g., smaller bias and better precision).

“One Atmosphere” Air Quality Modeling – CMAQ Model

Atmospheric modeling of multiple pollutant issues simultaneously is important from an air quality management perspective because of the relationships among sources, transport, and transformation processes of a number of CAPs and HAPs. “One atmosphere” modeling will allow the assessment of pollutant control measures that affect more that one pollutant or issue. For example, installing scrubbers at electric utilities to remove SO_2 also can result in reduced NO_x or mercury emissions. Reducing emissions of ozone precursors (i.e., NO_x and VOCs) will not only affect ozone, but may also affect the formation of certain secondary HAP VOCs. Thus, “one atmosphere” modeling provides the ability to examine the effects of multi-pollutant control strategies and the co-benefits of programs across criteria and toxic pollutants.

The CMAQ model is designed to simulate the formation and fate of ozone, oxidant precursors, and particle concentrations over national, regional, and urban spatial scales. Key chemical and physical processes treated by CMAQ include:

- gas-phase photochemistry,

- secondary aerosol (e.g., sulfate) formation through gas-phase and in-cloud aqueous-phase processes,
- partitioning of nitrate between nitric acid gas and particle nitrate,
- horizontal and vertical transport of pollutants, and
- removal of pollutants through wet and dry deposition.

The current version of CMAQ (v4.6) has a number of scientific updates and advancements compared with earlier versions. Most notably, this version is capable of “one atmosphere” modeling in which ozone, primary and secondary particles, mercury, and other selected toxic pollutants are all treated in an integrated manner in a single model simulation. Benzene, formaldehyde, hydrazine, chloroform, chromium (III and VI), and cadmium are among the more than 30 toxic gases and metals now simulated by CMAQ. Therefore, transitioning to this version of CMAQ will allow us to simultaneously evaluate impacts across multiple pollutants as part of our regulatory and policy assessments that were previously completed individually and separately for criteria pollutants and air toxics.

CMAQ is used in regulatory and policy assessments to project future nonattainment and air quality impacts for use in cost/benefit analysis as part of Regulatory Impact Assessments (RIAs). Inputs to CMAQ include emissions from anthropogenic and biogenic sources, meteorology, and estimates of pollutant concentrations transported into the area being modeled (i.e., boundary conditions). CMAQ provides outputs of gridded concentrations and deposition on an hourly basis for the user-defined modeling domain (i.e., the area covered by the model simulation). Pollutant concentrations predicted by CMAQ are output for each of the multiple vertical layers included in the model simulation. The standard hourly CMAQ predictions can be post-processed to create gridded fields of daily, monthly, and annual average concentrations and total deposition. In addition, ozone and fine particle species predictions from CMAQ can be combined with ambient data to project ozone and fine particle design values for future years and control case emissions scenarios and associated air quality changes that can be input to BenMAP for estimating health and environmental effects and their monetary benefits.

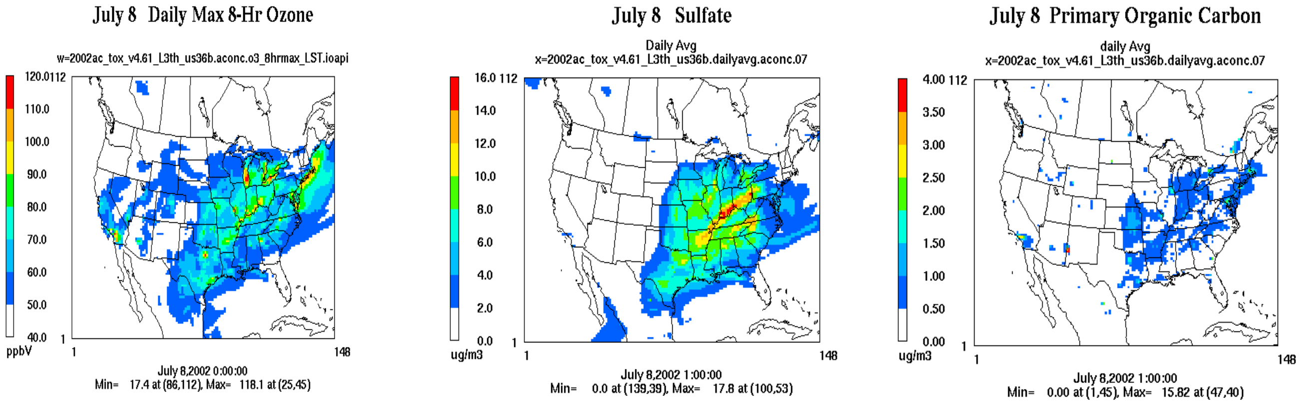
Multi-pollutant Modeling Platform – 2002 and Projected Future Years

Based on the 2002 NEI and CMAQ model, we have developed a 2002-based multi-pollutant “modeling platform”. A modeling platform is defined as a structured system of connected modeling-related tools and data that provide a consistent and transparent basis for assessing the air quality response to changes in emissions and/or meteorology. As part of this development effort, we conducted emissions inventory processing and national, regional, and local air quality modeling to produce concentration and deposition estimates for CAPs and HAPs with a detailed performance evaluation based on ambient monitoring data. The documentation reports are planned to be completed in early 2008. To meet near-term regulatory needs, the “CAP-only” version of this platform is serving as the baseline for air quality modeling of ozone and fine particles as part of the Regulatory Impact Analysis in support of EPA’s Locomotive and Commercial Marine Final Rule and the Ozone NAAQS Revisions Final Rule.

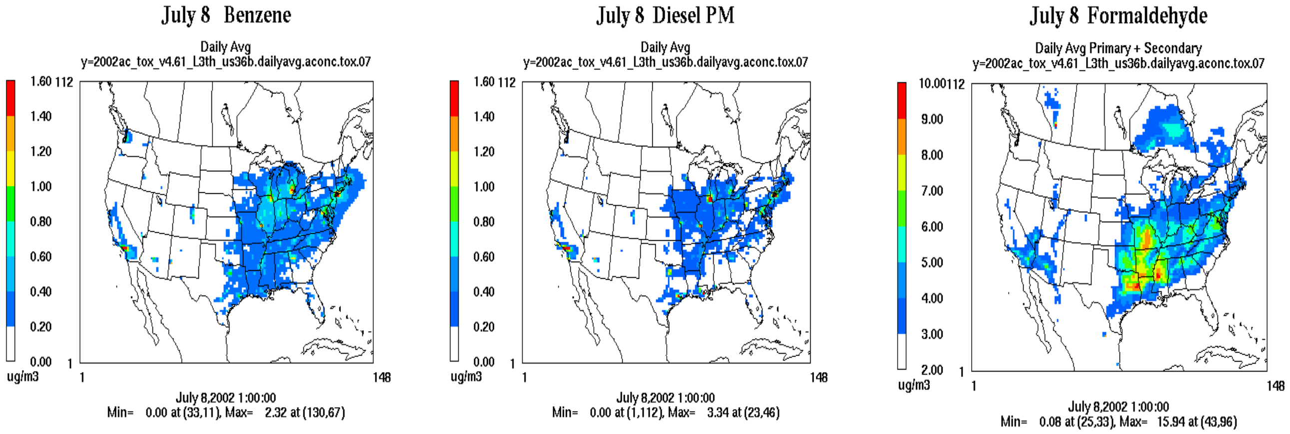
As shown in **Figure 5-3**, application of this modeling platform yields simultaneous concentration predictions for criteria pollutants (ozone and fine particle species) and toxics (e.g., formaldehyde, benzene, and DPM) as well as deposition of mercury, nitrogen, and sulfur. The maps illustrate the CMAQ model predictions for a single summer day based on a consistent set of emissions and meteorological inputs. This multi-pollutant modeling platform enables us to consider CAP/HAP interactions through both chemical interactions (e.g., VOCs, particle-related metal HAPs) and control interactions (joint emission reductions) as discussed in Chapter 1. Therefore, this modeling platform allows "co-benefit" assessments to be conducted for current and future policies or rules and informs the development of multi-pollutant control strategies.

We are conducting this type of multi-pollutant modeling as part of the technical effort for the Detroit Multi-pollutant Pilot Study that will be completed in early 2008. We expect that demonstrating this modeling capability will greatly enhance our ability to simulate and evaluate multi-pollutant control strategies and/or multi-pollutant impacts of our programs, thereby supporting our new vision of air quality management.

Ozone and PM2.5 Species



Air Toxics



Deposition

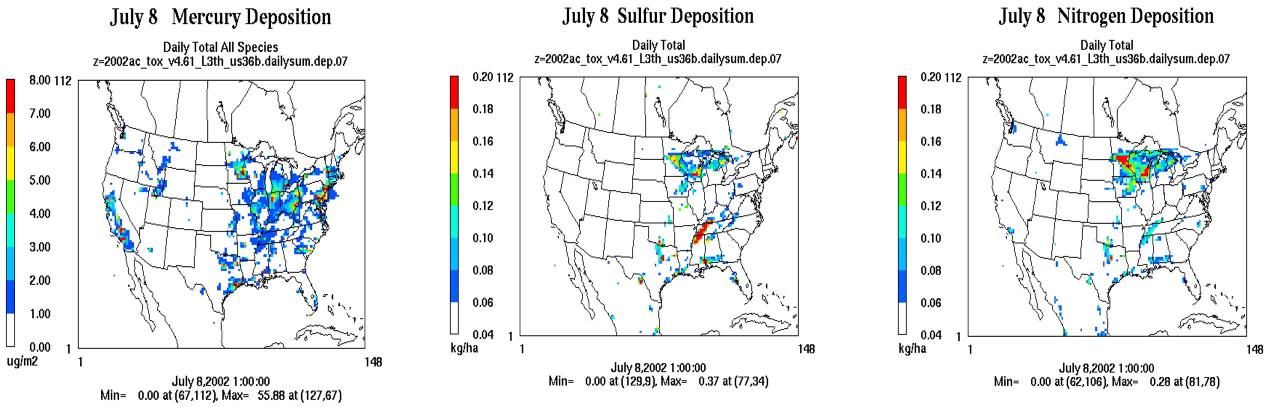


Figure 5-3. Multi-pollutant modeling outputs for CAPs, HAPs, and deposition for an example summer day in 2002.

Spatial Predictions of Air Quality Data – CDC/PHASE Project

Currently, ambient monitoring data and air quality modeling results are used separately to inform regulatory and policy assessments. However, these data and results are limited in various ways. Monitoring data are point measurements that may not be representative of air quality across a broad geographic area resulting in "unmonitored" locations for which we need information. Alternatively, air quality models provide more complete geographic coverage, but the resolution of their predictions may not be adequate for some assessments such as neighborhood scale risk assessments and may also be limited by the quality of the emissions and meteorological inputs. Therefore, to derive a more spatially complete and accurate measure of air quality across multiple pollutants, EPA is exploring how best to combine or "fuse" these disparate data sets to better inform air quality management activities.

Holland et al. (2003) provided an overview and policy motivation for developing spatial models based on ambient and predicted air quality data. A number of air quality management activities such as NAAQS risk/exposure assessments and comparisons with health outcomes data. An example in this area is the Public Health Air Surveillance Evaluation (PHASE) project, which is a multi-disciplinary collaboration between EPA, the Centers for Disease Control and Prevention (CDC) and three Environmental Public Health Tracking Network (EPHTN) state agencies. The objective of this project is to develop and evaluate the use of fused air quality predictions to associate public health tracking data with ozone and fine particles as part of the EPHTN program.

For the CDC/PHASE work, a statistical technique is being used to combine ambient monitoring data with output from photochemical models (i.e., CMAQ) to predict ambient air concentrations. These fused predictions of air quality are particularly useful in areas without monitors or for days on which monitors do not operate. This technique allows more accurate prediction where and when monitoring data are not available. Although this work currently focuses on ozone and fine particles, we are working to extend this technique to air toxics and individual fine particle species as part of the Detroit Multi-pollutant Pilot Study. Results from this modeling study will be combined with ambient monitoring data to provide improved spatial and temporal air quality characterizations as part of the risk and exposure assessments conducted for the Detroit Exposure and Aerosol Research Study (DEARS).

Summary

The tools needed to analyze multi-pollutant data are either available currently or being developed in OAQPS; they are key components of the air quality management cycle's technical information, collection, and analysis steps. As this suite of tools becomes fully available, the analyses needed to support a multi-pollutant approach for air quality management will be better realized.

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