

**Particulate Matter Concentrations,  
Compositions, and Sources in Southeast Texas:  
State of the Science and Critical Research Needs**



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## SUMMARY

Solid and liquid phase material in the atmosphere is variously referred to as particulate matter, particles, and aerosols. Unlike gas phase pollutants, such as ozone, that are distinct chemical compounds, atmospheric particulate matter (PM) is generally a mixture of many compounds, including inorganic acids, low volatility organic compounds and inorganic salts. PM can be solid or liquid. The sizes of the particles can range from nanometers (with of order 100 molecules in the particle) to dust particles that are more than 10  $\mu\text{m}$  in diameter. Atmospheric PM, depending on its size, can remain suspended in the atmosphere for days, or longer.

The human health and environmental impacts of PM are varied and include increased rates of mortality, increased rates of respiratory disease, decreased visibility, damage to materials and, if the PM is acidic, acid deposition. For all of these impacts, the extent of the impact depends on particle composition and size.

In recognition of the size dependence of the impacts, especially the human health impacts, of PM, the EPA has established multiple National Ambient Air Quality Standards for PM. In 1987, the EPA introduced National Ambient Air Quality Standards (NAAQSs) for  $\text{PM}_{10}$ , particulate matter having an aerodynamic diameter of 10  $\mu\text{m}$  or less. Since 1987, there has been growing recognition of the health impacts of particles that can penetrate very deeply into the respiratory system. Beginning in 1997, a NAAQS for  $\text{PM}_{2.5}$  (sometimes called fine particulate matter), particulate matter having an aerodynamic diameter of 2.5  $\mu\text{m}$  or less, was introduced.

All areas in Texas except El Paso meet the  $\text{PM}_{10}$  NAAQS. For the  $\text{PM}_{2.5}$  NAAQS, however, a number of regions in Texas are close to violating a proposed annual standard, including most of the State's urban areas except El Paso.

This report focuses on the concentrations, composition, size distributions, sources and possible control measures for  $\text{PM}_{2.5}$  in the eastern half of Texas, especially southeast Texas. Southeast Texas is chosen for emphasis because of the extensive data available on  $\text{PM}_{2.5}$  for this region.

Data on the mass concentrations of  $\text{PM}_{2.5}$  in southeast Texas indicate that:

- Annual average mass concentrations of  $\text{PM}_{2.5}$ , over wide regions of eastern and southeastern Texas, range from approximately 10  $\mu\text{g}/\text{m}^3$  to 15  $\mu\text{g}/\text{m}^3$ , which is close to the annual average NAAQS of 15  $\mu\text{g}/\text{m}^3$ .
- When averaged over long time periods,  $\text{PM}_{2.5}$  mass concentrations are spatially homogeneous throughout southeast Texas
- Nevertheless, localized events with high  $\text{PM}_{2.5}$  mass concentrations occur frequently at many of the monitors in the region
- Throughout the region, concentrations are slightly higher in the spring and late fall than in the summer
- A consistent and strong morning peak in  $\text{PM}_{2.5}$  mass concentrations is observed throughout the region and a weaker and slightly less consistent peak in mass concentration is observed in the late afternoon to early evening

Data on the composition of PM<sub>2.5</sub> in southeast Texas indicate that:

- Sulfate, ammonium (which neutralizes the sulfate ion), organic carbon and elemental carbon are the major constituents of PM<sub>2.5</sub> in southeast Texas and the relative concentrations of these components are, on average, spatially homogeneous.
- Nevertheless, localized events with high mass fractions of sulfate or carbon occur frequently at many monitors in the region.
- Concentrations of sulfate are slightly higher in the spring and late fall than in the summer and carbon concentrations are highest in the late fall.
- High organic to elemental carbon ratios suggest that much of the carbonaceous material is not emitted directly, but is formed in the atmosphere as the result of reactions of gas phase hydrocarbons

Data on PM<sub>2.5</sub> size distributions indicate that:

- Particle size distributions are not spatially homogeneous throughout southeast Texas
- Industrial sites, such as HRM3, have higher concentrations of small, freshly emitted, particles than more residential sites.
- Because the freshly emitted particles are small (approximately 0.1 : m) they do not have as large an impact on PM<sub>2.5</sub> mass or bulk composition as they have on the number density of fine particles

Not all of the particulate matter observed in southeast Texas is emitted or formed in southeast Texas. Examination of the spatial distributions of PM<sub>2.5</sub> mass and composition, and analysis of air parcel back trajectories indicate that:

- When high concentrations of fine particulate matter mass, sulfate and organic carbon are observed throughout southeast Texas, back trajectories suggest that high levels of background PM<sub>2.5</sub> are transported into southeast Texas from the eastern half of North America.
- But, high concentrations of fine particulate matter mass and organic carbon are observed at isolated monitors in southeast Texas, suggesting local source contributions are important on some days

The sources (both local and regional) of PM<sub>2.5</sub> can be characterized as primary (particles emitted directly to the atmosphere) or secondary (formed in the atmosphere as the result of the reactions of gas phase emissions).

Of the primary emissions (fires, geological sources, point sources and mobile sources):

- Fires are a sporadic, but significant source of PM<sub>2.5</sub> emissions in Texas. On an annual average basis, they contribute of order 1-2% of the total fine particulate matter mass in the Houston-Galveston area, but these emissions tend to be concentrated on specific days with fire events.

- Geological sources of fine particulate matter (dust) are a relatively minor contributor to total fine PM mass in the urban Houston-Galveston area.
- Primary point source emissions of fine particulate matter have not yet been estimated. Primary emissions of PM<sub>10</sub> are significant, however, so additional work should go in to characterizing the size distributions and compositions of these emissions.
- Primary mobile source emissions are significant; evidence suggests that these emissions account for approximately a quarter to a third of fine PM mass.
- Primary emissions from cooking are significant; evidence suggests that these emissions account for approximately 10-15% of fine PM mass.

For secondary sources of PM<sub>2.5</sub> (inorganic, anthropogenic organic and biogenic organic):

- Sulfate makes up approximately 30-40% of the total, annual average, fine particulate matter mass in southeast Texas. Much of the sulfate found in fine particulate matter in southeast Texas is likely the result of transport from the eastern continental U.S.
- Point sources of SO<sub>2</sub> emissions are the dominant source of locally generated sulfate
- The sulfate in fine particulate matter in southeast Texas is often not completely neutralized; ammonia emissions therefore influence total fine particulate matter mass. The dominant source of ammonia in the state is cattle and other livestock; in most of the state's urban areas, on-road sources, domestic activities (use of cleaning products, human perspiration and respiration, human wastes and pet wastes) dominate ammonia emissions.
- Organic carbon and elemental carbon make up approximately 25-30% of the total, annual average, fine particulate matter mass in southeast Texas. While some of the carbonaceous material found in fine particulate matter in southeast Texas is likely the result of transport from the eastern continental U.S., there is also evidence for significant local sources
- Ratios of organic carbon to elemental carbon suggest that much of the carbonaceous material is due to secondary organic aerosol, formed in the atmosphere as the result of the reactions of gas phase hydrocarbon emissions. Point sources and area/non-road emissions are the dominant contributors to SOA formation in the Houston urban area.
- Radiocarbon dating (<sup>14</sup>C/<sup>13</sup>C ratios) indicates that at some suburban and rural locations in southeast Texas, secondary organic aerosol formation is dominated by the reactions of biogenic emissions. These locations are primarily north and southwest of the urban core.

These findings can be used to assess the potential effectiveness of strategies for reducing PM<sub>2.5</sub> concentrations in southeast Texas.

Planned controls on primary PM emissions from mobile sources and emissions of sulfur oxides from electricity generating units will likely reduce annual average PM concentrations in southeast Texas by 2-3 µg/m<sup>3</sup>. In addition, emission reductions designed to reduce ozone concentrations are likely to reduce fine particulate matter, by at least a few tenths of a microgram per cubic meter in urban areas and potentially by much larger amounts in rural areas.

While promising, these assessments are based on semi-quantitative analyses, and are limited to southeast Texas. More rigorous analyses should be performed in certain critical areas. Specifically,

- Measurements of fine particulate matter concentrations, compositions and size distributions should be undertaken in the state's other major urban areas (outside of southeast Texas) and in selected rural areas.
- Inventories of PM<sub>2.5</sub> emissions from point sources, mobile sources and cooking are not yet available. Inventories should be assembled using currently available methods.
- Although preliminary inventories have been performed for point source emissions of SO<sub>x</sub>, ammonia emissions, and biogenic, point and area source emissions of secondary organic aerosol precursors, more detailed information on SO<sub>s</sub>/SO<sub>2</sub> ratios, spatial distribution of ammonia emissions and emissions of semi-volatiles is needed.
- Among the control strategies that will be implemented in Texas is reduction of SO<sub>x</sub> emissions. Since the SO<sub>s</sub>/SO<sub>2</sub> ratios for emissions in southeast Texas may be different than in other regions, and because experience in southern California has shown that reductions in SO<sub>x</sub> emissions may lead to increases in ammonium nitrate formation, detailed modeling of inorganic aerosol formation in southeast Texas should be performed as soon as the necessary emission inventory data have been assembled.
- Reductions in emissions that will lead to reduced ozone formation will also likely lead to reduced rates of secondary organic aerosol formation (both inorganic and organic). Detailed modeling of secondary organic aerosol formation in southeast Texas should be performed as soon as the necessary emission inventory data have been assembled.