

US EPA ARCHIVE DOCUMENT

PM-2.5 COMPOSITION AND SOURCES

**Prepared for
FACA National and Regional Strategies Workgroup**

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**Prepared by Emissions, Monitoring and Analysis Division
Office of Air Quality Planning and Standards**

COMPOSITION OF PM-2.5

- PM-2.5 is composed of a mixture of particles directly emitted into the air and particles formed in the air from the chemical transformation of gaseous pollutants (secondary particles).
- The principal types of secondary particles are ammonium sulfate and nitrate formed in the air from gaseous emissions of sulfur dioxide (SO₂) and oxides of nitrogen (NO_x), reacting with ammonia (NH₃). The main sources of SO₂ are combustion of fossil fuels in boilers and the main sources of NO_x are combustion of fossil fuel in boilers and mobile sources.
- The principal types of directly emitted particles are soil related particles and organic/elemental carbon particles from the combustion of fossil fuels and biomass materials. The main sources of soil-related particles are roads, construction and agriculture. The main sources of combustion-related particles are diesel motor vehicles, managed burning, open burning, residential wood combustion, utility and commercial boilers.
- Figures 1-3 show that the PM-2.5 soil particle component is low (generally 5-15%). The PM-2.5 combustion particle component is much higher, (35% to 60%). Sulfate particles comprise about 50% of the ambient PM-2.5 in Washington, D.C. The concentration of nitrate particles is higher in the western urban areas. Note: Figures 1-8 are based on at least one year of ambient measurements in each area.
- Figures 4-6 show that the PM-2.5 soil content is about 15-20% of the PM-10 soil content. The contribution of sulfate, nitrate and combustion particles increases dramatically relative to soil particle contributions in the PM-2.5 fraction. This has obvious implications for control strategies.
- Figure 7 is based on data from the IMPROVE air monitoring network's non urban air monitoring sites across the United States. The data show that the composition of PM-2.5 in the East is fairly uniform, consisting of roughly 50% ammonium sulfate, 9% ammonium nitrate, 35% organic/elemental carbon (combustion-related) and 6% soil-related particles. Comparison of Figures 1 and 7 shows that the composition of the PM-2.5 in Washington, D.C. is generally consistent with the non urban IMPROVE data for the eastern US.

ADDITIONAL INFORMATION ON PM-2.5 IN CENTRAL U.S.

- Table 1 summarizes available PM-2.5 air quality data at sites in the agricultural heartland of the Central U. S.

TABLE 1 - PM-2.5 AMBIENT DATA IN THE CENTRAL U. S.

Note: Data have not been compared to proposed Federal Reference Method for PM2.5

Location	Obs.	Dates	Long Term Mean Concentration ug/m ³	Maximum Observation ug/m ³	Data Reference
Wichita, KS	47	81-82	13.6	30.2	US EPA Inhalable Particulate Network
Topeka, KS	71	81-82	11.6	31.8	US EPA Inhalable Particulate Network
Topeka, KS ^a	201	79-81	12.9	NA	Journal APCA V33, #12 12/83
Clint, TX	140	79-82	13.3	33.6	US EPA Inhalable Particulate Network
Portage, WI ^b	271	79-81	12.5	NA	Journal APCA V33, #12 12/83
Bismarck, ND	85	95-96	9.7	26	David Lutz, Personal Communication

^a - Composition of PM-2.5 mass in Topeka, KS estimated from elemental composition: Soil - 9%, Ammonium Sulfate 35%.

^b - Composition of PM-2.5 mass in Portage, WI estimated from elemental composition: Soil - 4%, Ammonium Sulfate 47%.

- Table 1 suggests that widespread exceedance of a PM-2.5 NAAQS is highly unlikely in the Central U. S., America’s agricultural heartland. Moreover, limited data from Topeka, KS and Portage, WI are consistent with Figures 1-6, showing that the soil component of PM-2.5 is likely very small compared to that which would be found in PM-10.

IMPLICATIONS FOR INTERPRETATION OF INVENTORY OF DIRECT EMISSIONS AND PRECURSORS

- **Emission inventories alone are misleading.** Emission inventories provide essential information to air planners but, unfortunately, they can be very misleading if used alone. They must be used in conjunction with photochemical dispersion modeling or chemically characterized ambient data that represent the area of concern. This is especially important for PM_{2.5}, where several factors collectively contribute to the incorrect perception that soil-related particles will be abundant in PM_{2.5} ambient concentrations. As has been shown, soil is actually only a small portion of PM_{2.5} ambient concentrations. Sulfates formed from fossil fuel combustion and combustion-related particles from mobile sources and wood burning are **much** more important contributors to PM_{2.5} ambient concentrations. The factors that contribute to this misperception are discussed below.
- **Inventories don't account for secondary particles .** The inventory for directly emitted soil and combustion-related particles does not include secondary particles because they are formed in the atmosphere from gaseous precursors. Secondary particles comprise 50% of PM-2.5 ambient concentrations throughout the East and many western urban areas. Thus, direct emissions have only about ½ the impact on PM_{2.5} concentrations that they would appear to have, if one were to try to interpret the inventory of directly emitted PM_{2.5} without the benefit of modeling or chemically characterized air samples..
- **Emissions are not uniformly distributed within a region .** Ambient air monitors are generally located in highly populated areas which are usually well away from agricultural areas and unpaved roads. Moreover, they are usually in areas where combustion sources such as mobile sources and boilers are abundant. This spatial nonuniformity of emissions can only be interpreted by using a photochemical dispersion model or in conjunction with chemically characterized air samples. Either of these methods would do what an inventory alone cannot do -- show how particles are formed, dispersed and removed from the air.
- **Release height of emissions can vary .** Combustion particles are generally emitted in hot plumes that initially carry the particles higher into the air. In contrast, soil particles are emitted at a very low height and at ambient temperatures. Thus, soil and combustion particles disperse differently in the ambient air and inference of their relative contributions to ambient concentrations from the inventory alone can be misleading.
- **Emission estimation methods constantly being reviewed and improved .** The emission factors and inventory for both soil and combustion-related source emissions undergo periodic review. Some source emissions can be overstated and some can be understated. For example, secondary organic particles are likely to form from condensation or through chemical reaction of gaseous VOC precursors, but their amount is unknown and, like sulfates and nitrates, they are not included in the

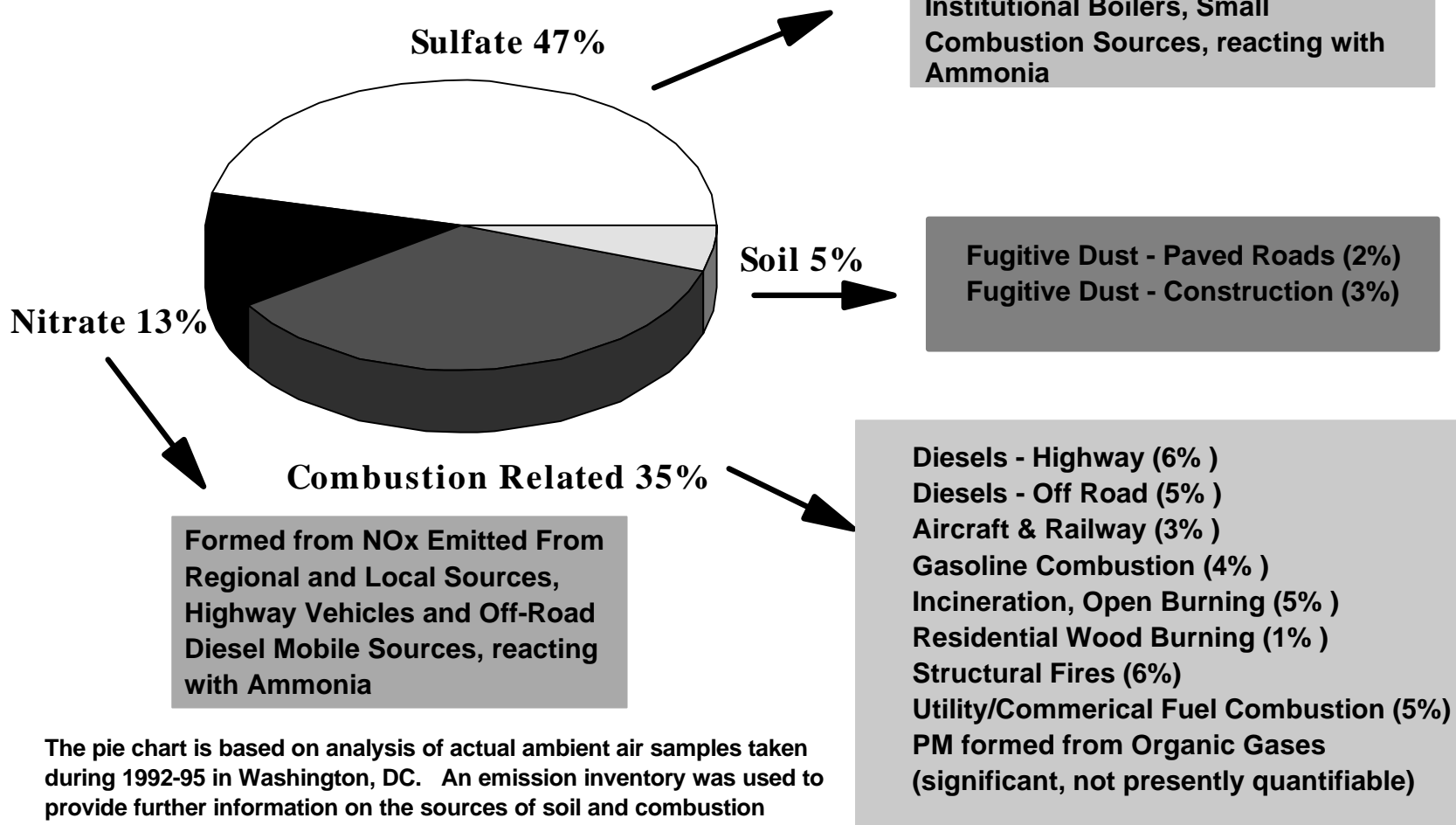
inventory of directly emitted particles. These would account for some of the differences found in comparing the ambient data and emission inventory.

- **Chemically characterized ambient measurements (or photochemical dispersion modeling) are key to properly interpreting the PM-2.5 emissions inventory.**

Washington DC (PM-2.5)

(Typical Eastern Urban Complex)

Figure 1



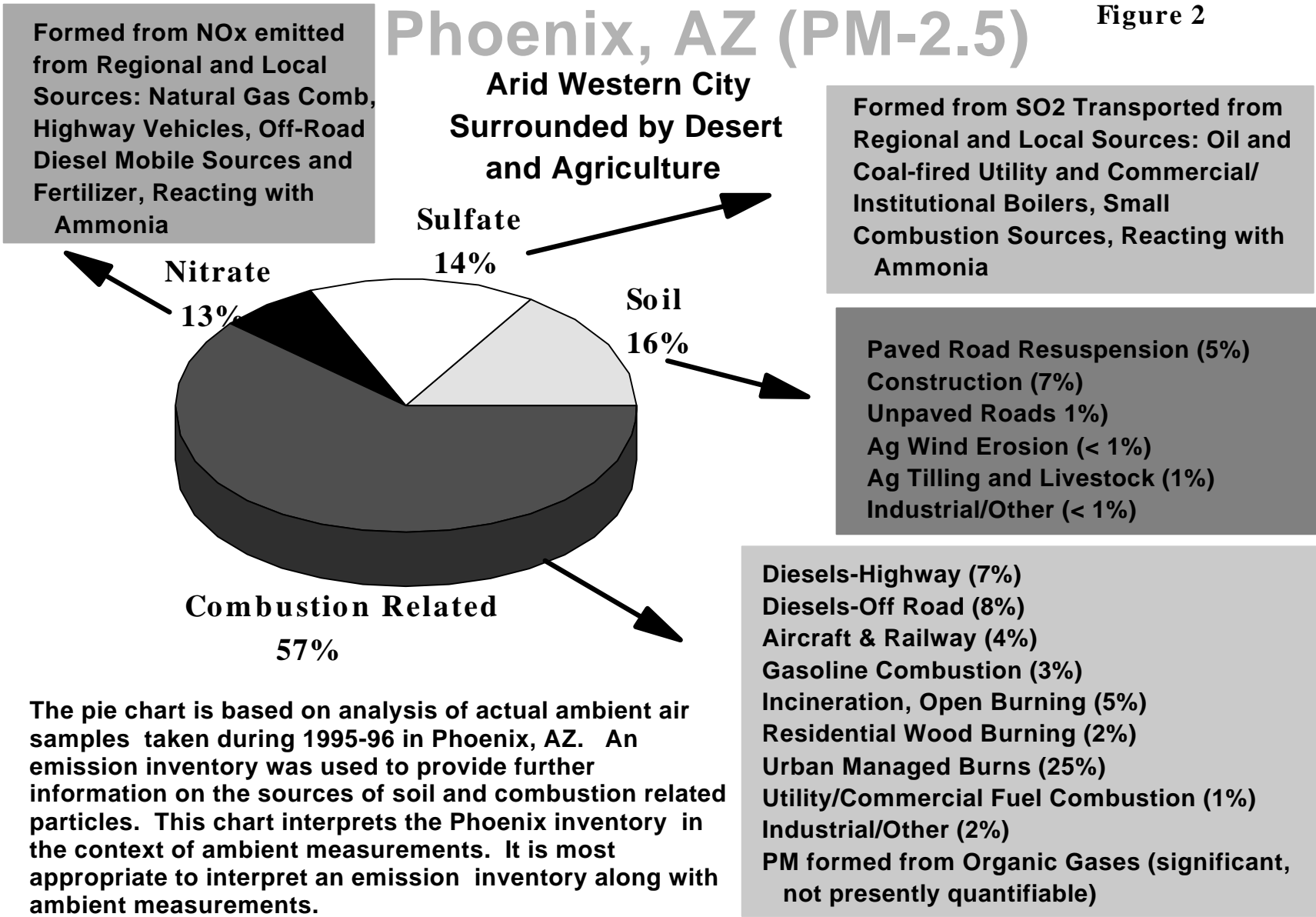
The pie chart is based on analysis of actual ambient air samples taken during 1992-95 in Washington, DC. An emission inventory was used to provide further information on the sources of soil and combustion related particles. This chart interprets the Washington inventory in the context of ambient measurements. It is most appropriate to interpret an emission inventory along with ambient measurements.

Ref: Adapted from IMPROVE, Cooperative Center for Research in the Atmosphere, CSU, Ft. Collins, CO, July 1996
6/5/97 DRAFT

Phoenix, AZ (PM-2.5)

Figure 2

**Arid Western City
Surrounded by Desert
and Agriculture**



The pie chart is based on analysis of actual ambient air samples taken during 1995-96 in Phoenix, AZ. An emission inventory was used to provide further information on the sources of soil and combustion related particles. This chart interprets the Phoenix inventory in the context of ambient measurements. It is most appropriate to interpret an emission inventory along with ambient measurements.

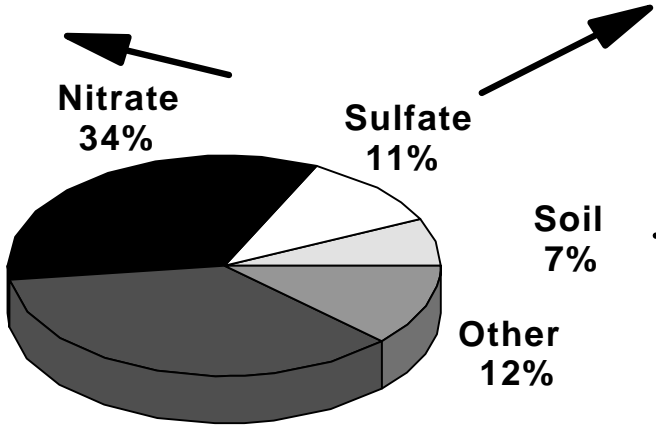
San Joaquin Valley (PM-2.5)

(Stockton, Fresno, Bakersfield and Crow's Landing)

(Agricultural/Industrial Communities)

Figure 3

Formed from NOx Emitted from Regional and Local Sources: Highway Vehicles Off-Road Diesel Mobile Sources and Fertilizer, Reacting with Ammonia



Formed from SO2 Transported from Regional and Local Sources: Oil and Gas-fired Utility and Commercial/Institutional Boilers, Small Combustion Sources, Reacting with Ammonia

Paved Road Resuspension (1%)
 Construction (2%)
 Unpaved Roads (< 1%)
 Ag Wind Erosion (1%)
 Ag Tilling & Livestock (2%)
 Industrial/Other (< 1%)

Combustion Related
 36%

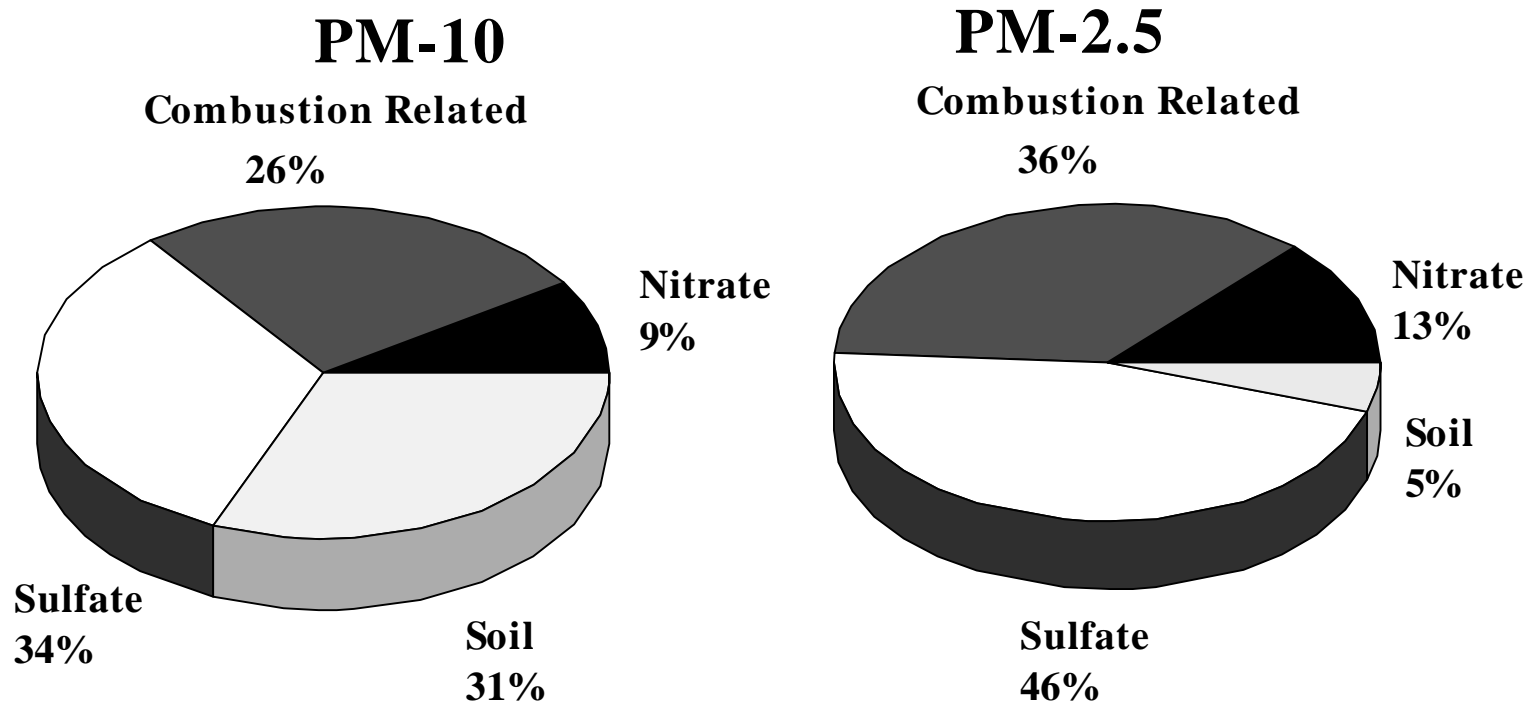
- Diesels - Highway (4%)
- Diesels - Off Road (1%)
- Aircraft & Railway (1%)
- Gasoline Combustion (1%)
- Incineration, Open Burning (1%)
- Residential Wood Burning (7%)
- Managed burns, Wildfires (14%)
- Utility / Commercial Fuel Combustion (1%)
- Industrial/Other (6%)
- PM formed from Organic Gases (significant, not presently quantifiable)

The pie chart is based on analysis of actual ambient air samples taken during 1988-89 in the San Joaquin Valley of CA. An emission inventory was used to provide further information on the sources of soil and combustion related particles. This chart interprets the inventory in the context of ambient measurements. It is most appropriate to interpret an emission inventory along with ambient measurements.

Figure 4

Washington, DC

Comparison of PM-10 and PM-2.5 Sources (Based on Ambient Measurements)

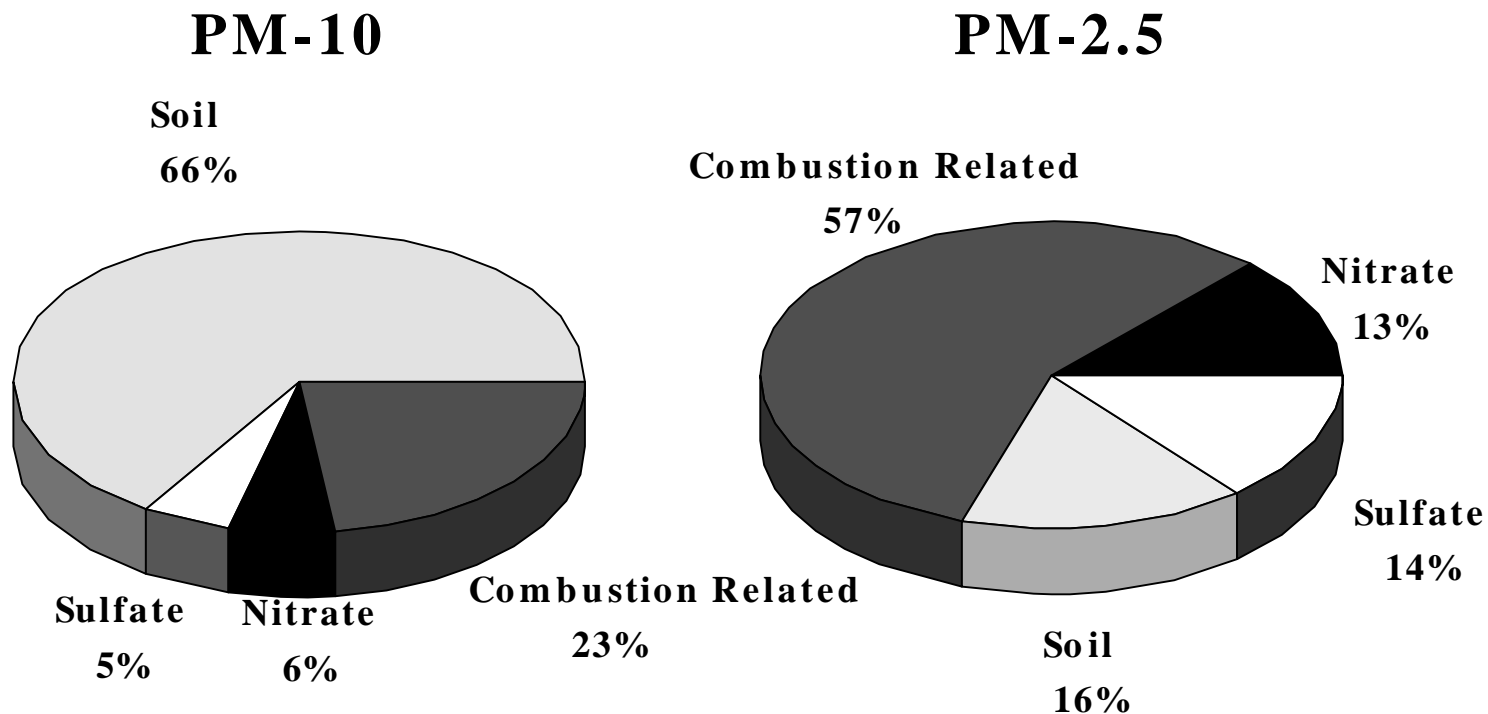


Ref: Adapted from IMPROVE, Cooperative Center for Research in the Atmosphere CSU, Ft. Collins, CO, July 1996

Figure 5

Phoenix

Comparison of PM-10 and PM-2.5 Sources (Based on Ambient Measurements)

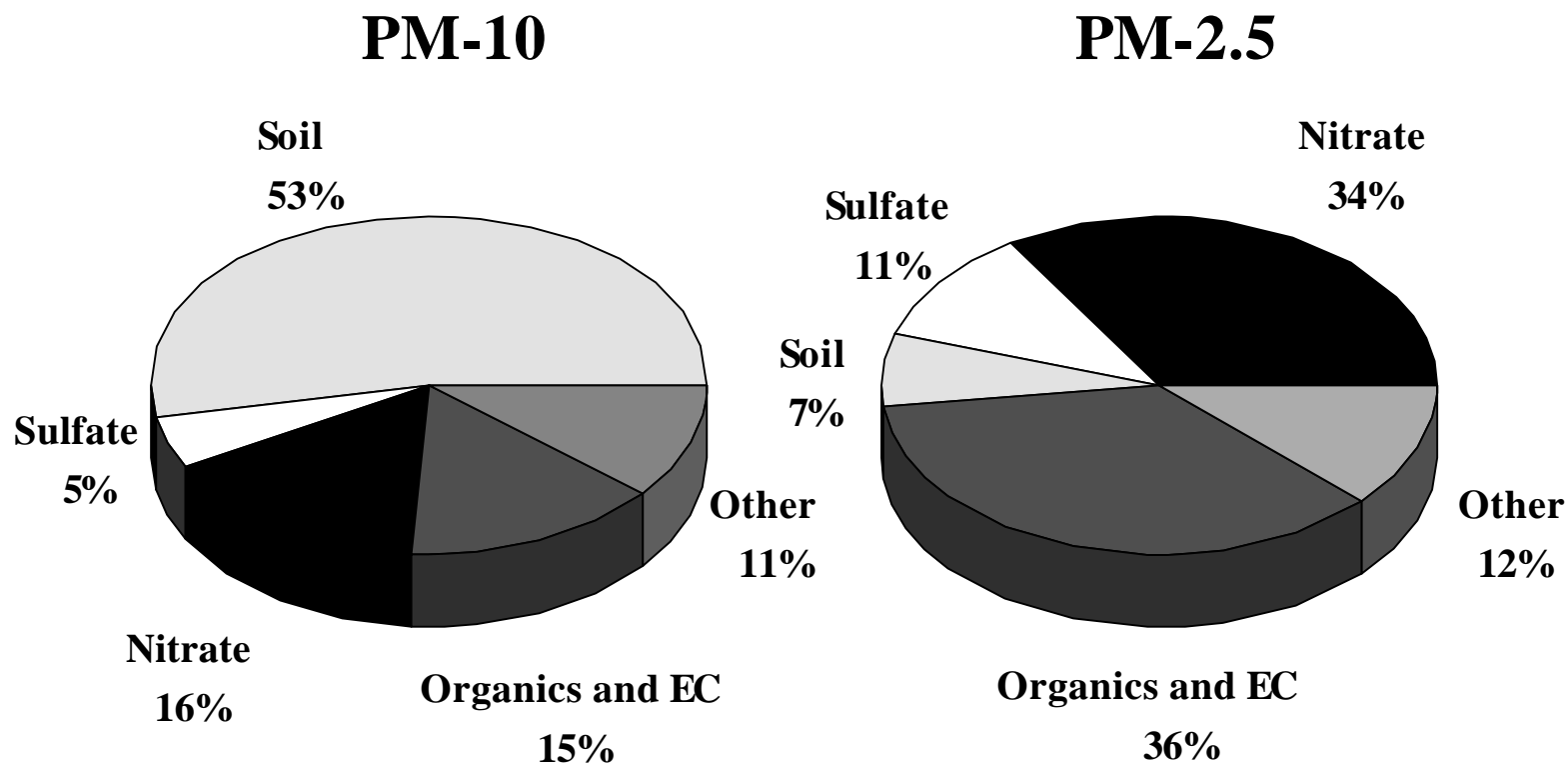


Ref: Adapted from Heloemmen, H., Purdue, L. and J. Bowser, in *Proceedings of Health Effects in Ambient Air-AWMA Symposium*, Prague, CZ, 23-25 April, 1997;
 Personal communication John G. Watson, Desert Research Institute, Reno, NV, May, 1997

Figure 6

San Joaquin Valley

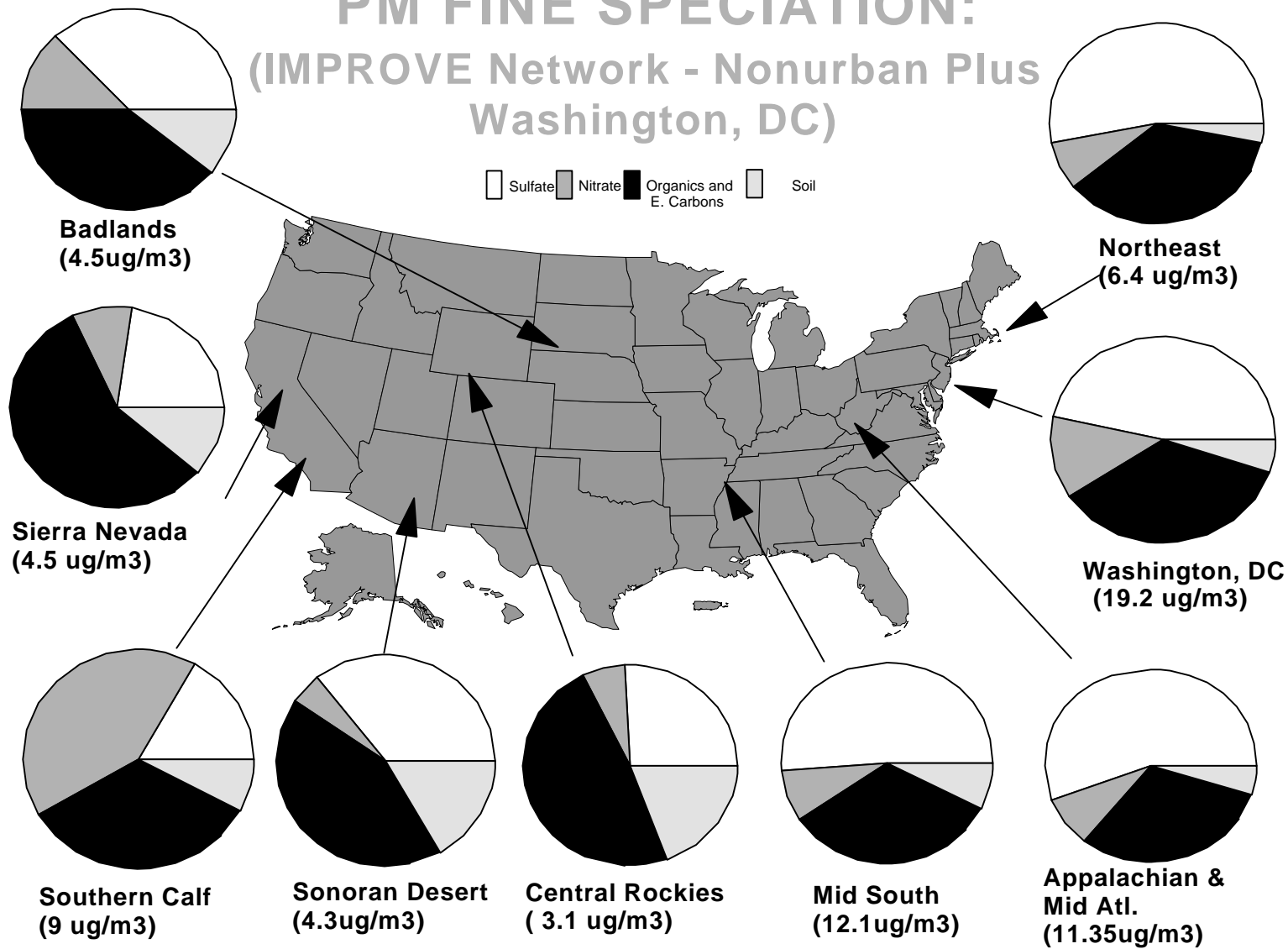
Comparison of PM-10 and PM-2.5 Sources (Based on Ambient Measurements)



Ref: Adapted from PM-10 and PM-2.5 Variations in Time and Space, Desert Research Institute, Reno, NV, Oct 1995

Figure 7

PM FINE SPECIATION: (IMPROVE Network - Nonurban Plus Washington, DC)



Data from the IMPROVE network (July 1996, ISSN:0737-5352-32)