

The Human Health Effects of Particulate Matter Air Pollution

George D. Thurston, Sc. D.

NYU School of Medicine
New York, NY USA



Introduction

- Past air pollution episodes and recent epidemiological and toxicological studies have indicated that particulate matter air pollution can cause significant adverse human health effects.
- In this presentation, I will briefly review this evidence and discuss the health effects of Particulate Matter.

Documented Effects of Ambient Air Pollution

- Reduced lung function in children and adults.
- Lung airway inflammation.
- Asthma exacerbations.
- Increased hospital ER visits and admissions.
- Increased mortality incidence.

Types of Particulate Matter Air Pollution

- Particulate Matter (PM) air pollution is composed of particles in the air, of 2 types:
 - Primary particles emitted directly from air pollution sources, such as diesel trucks.
 - Secondary particles formed in the atmosphere from gaseous air pollutants, such as sulfur dioxide from power plants that forms sulfates.

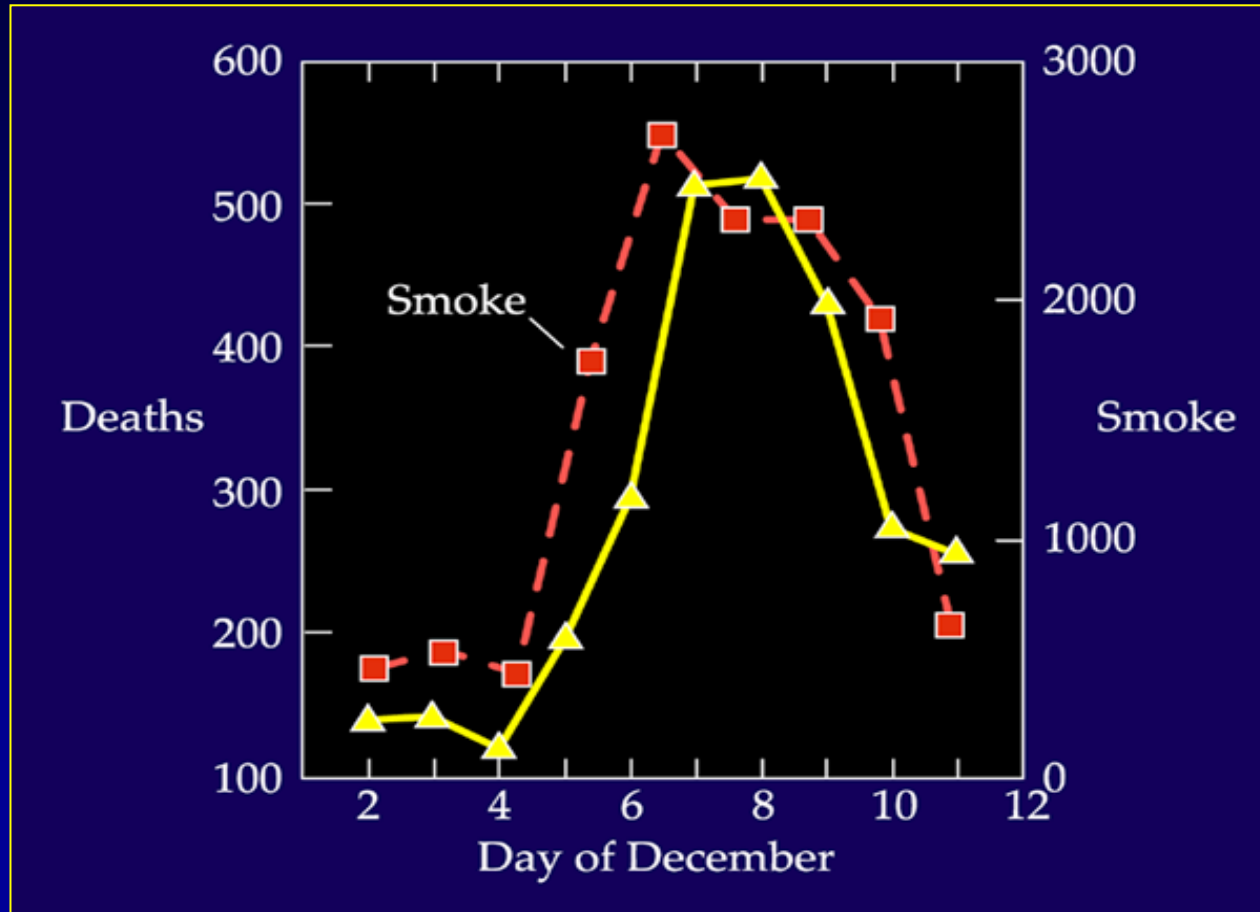
People Most Affected by Ambient Air Pollution

- Older Adults
- Persons with Pre-Existing Respiratory Disease
(e.g., Chronic Obstructive Pulmonary Disease, COPD, such as emphysema, those with Cardiac problems)
- Children, especially those with Asthma.
- Healthy adults who work or exercise outdoors.
- Persons with inadequate health care, such as the poor and working poor.

Historical London Fog Episodes



When PM Pollution Gets High, Deaths Increase: 1952 London Fog Episode Deaths vs. PM

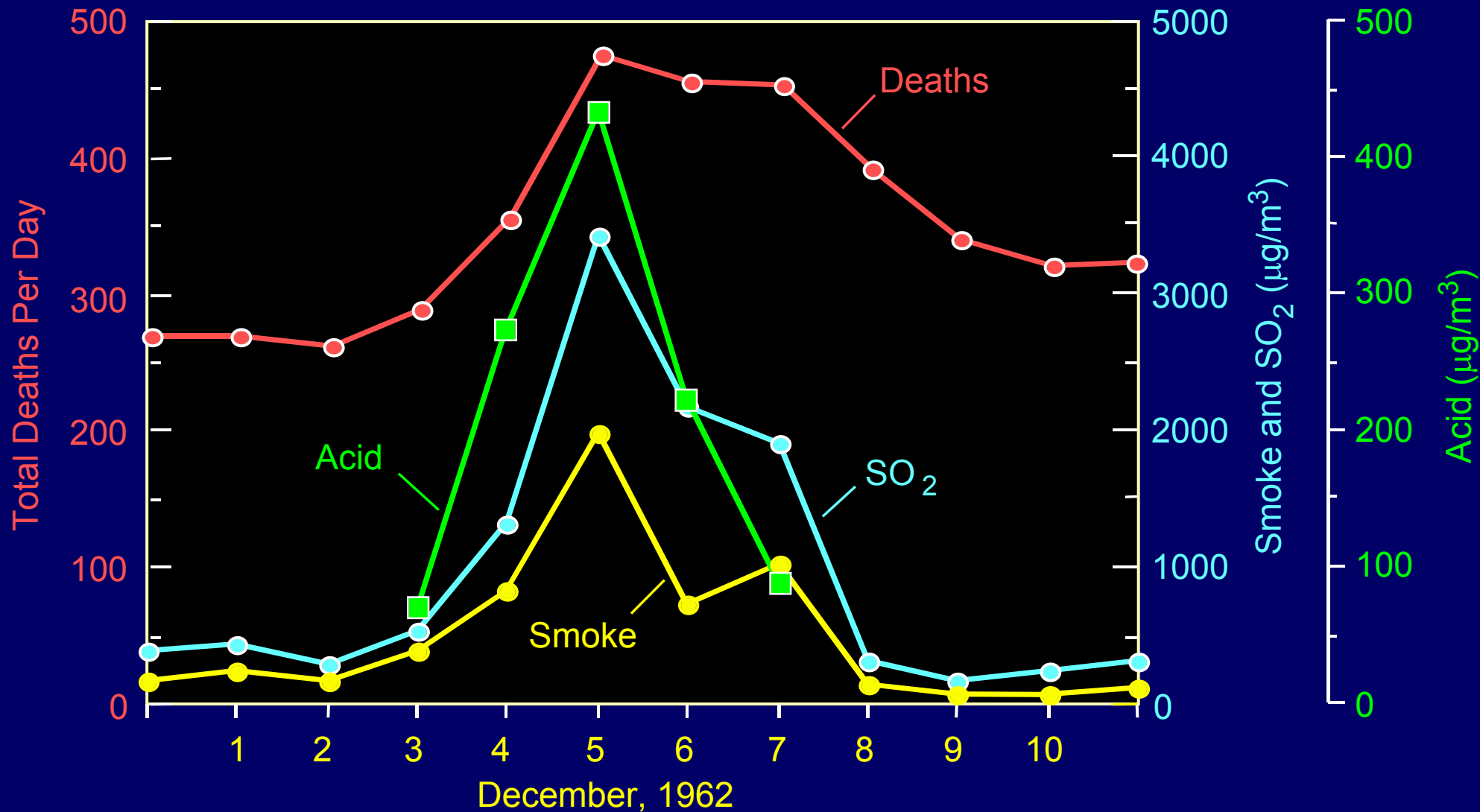


Neonatal Infants and Older Adults Affected Most in 1952 London Fog

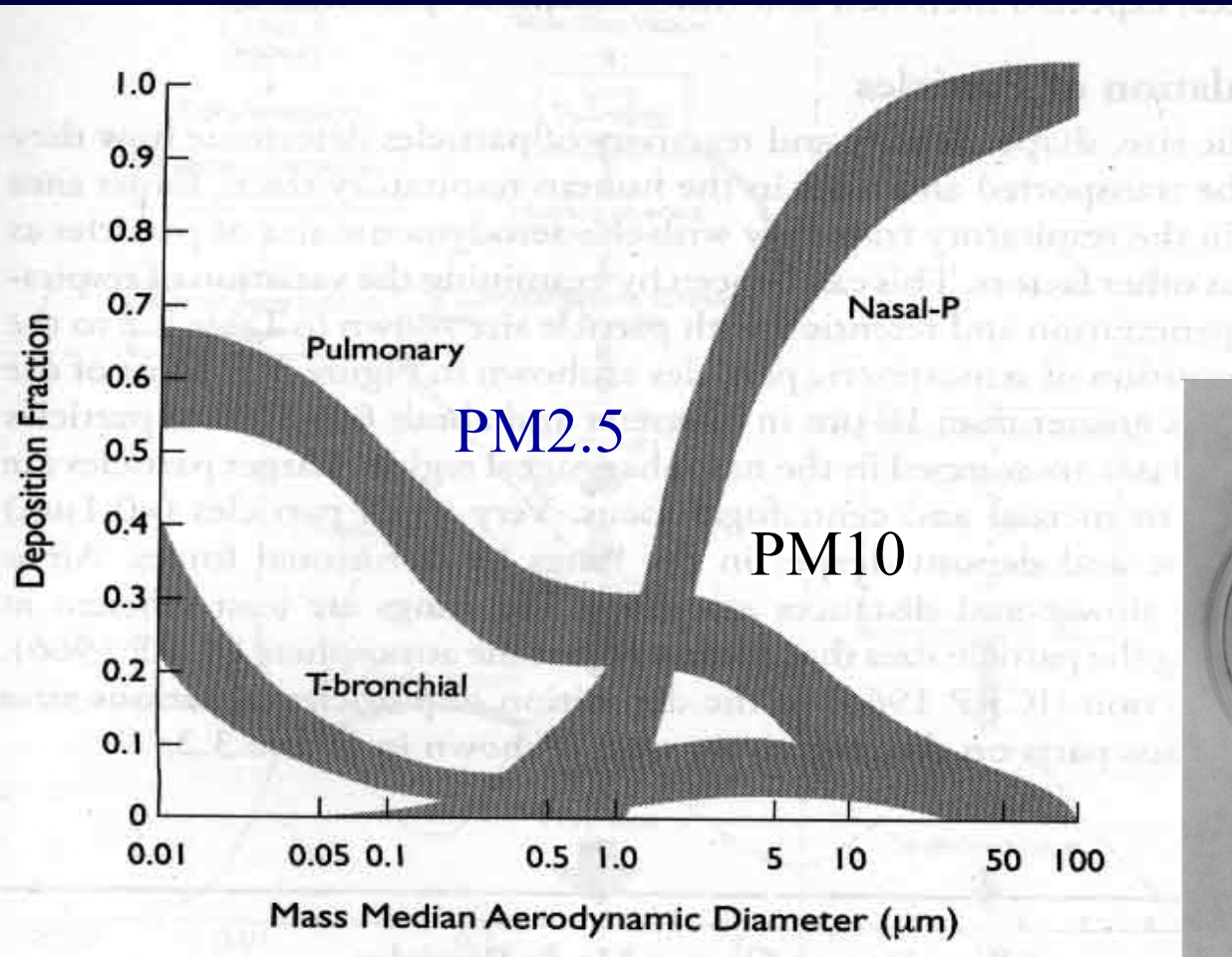
Deaths Registered in London Administrative County Classified by Age (Bates, 1995)							
	< 1 Month of Age	1-12 Mo. Old	1-14 Years of Age	15-44 Years of Age	45-64 Years of Age	65-74 Years of Age	75+ Years of Age
Week Before the Episode	16	12	10	61	237	254	335
Week After the Episode	28	26	13	99	652	717	949
Before/ After Episode Ratio	1.75	2.17	1.3	1.62	2.75	2.82	2.83

1962 Episode Confirmed the Presence of Acidic Aerosols

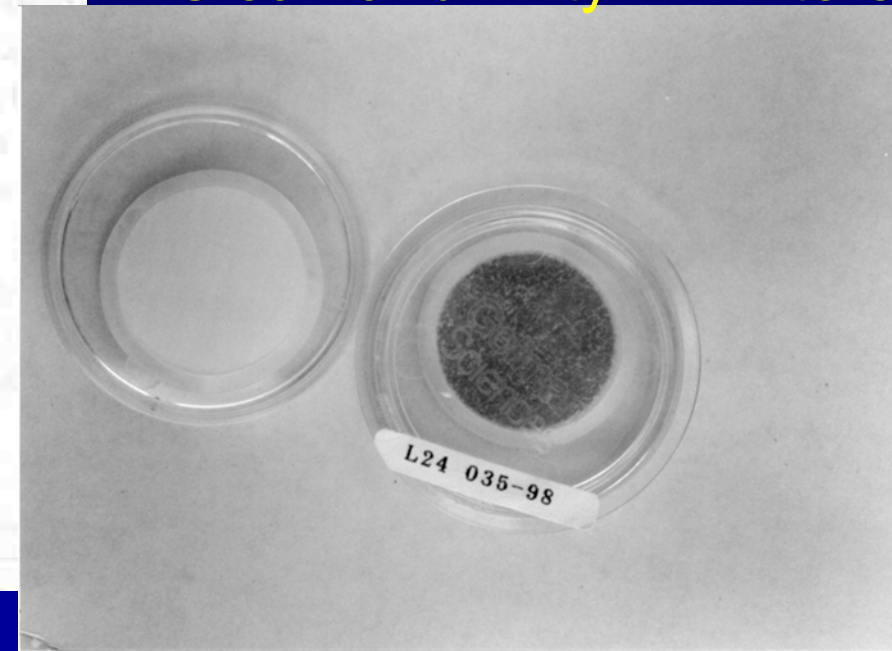
(likely as Sulfuric Acid and/or Ammonium Bisulfate)



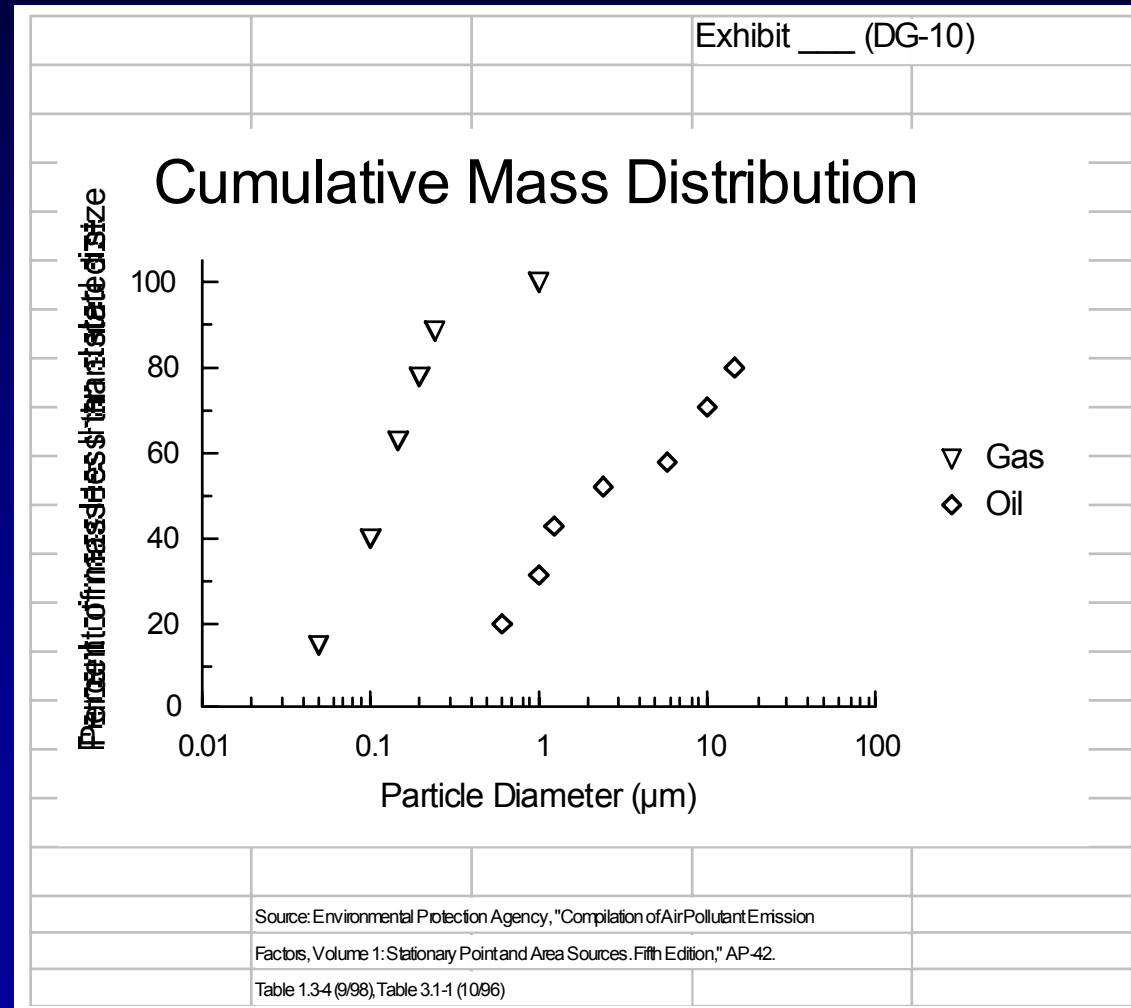
Microscopic Fine Particle Pollutants formed From Fossil Fuel Combustion Can Get Deep Into Your Lungs.



Clean and Dirty PM filters



Combustion Sources Cause Particles in the Smaller Size Range



Primary Soot Particles Are Emitted Directly From Many Sources

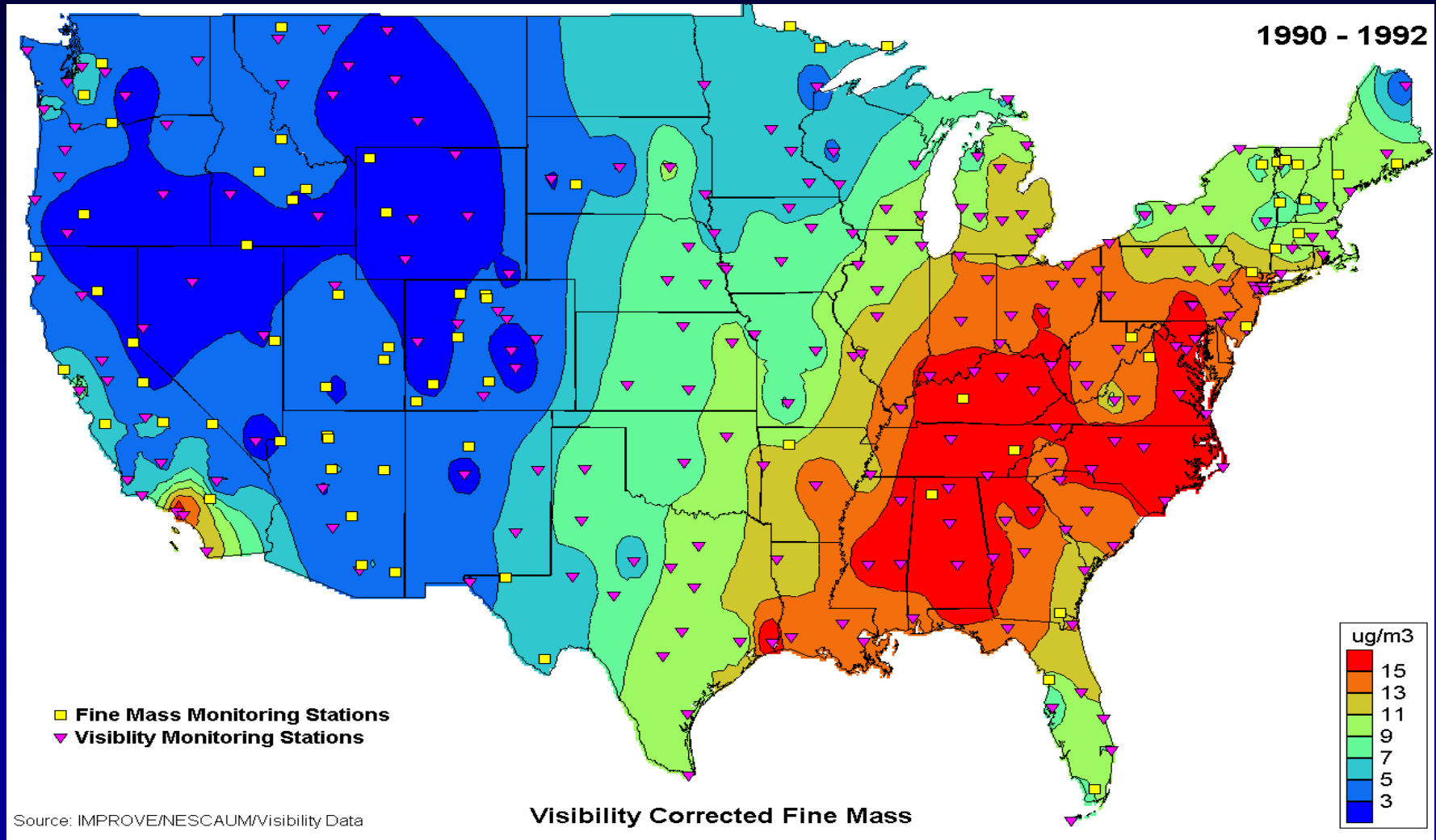


Gaseous Industrial, Power Plant, And Motor Vehicle Emissions Also Form Secondary Particulate Matter (PM) and Ozone Smog

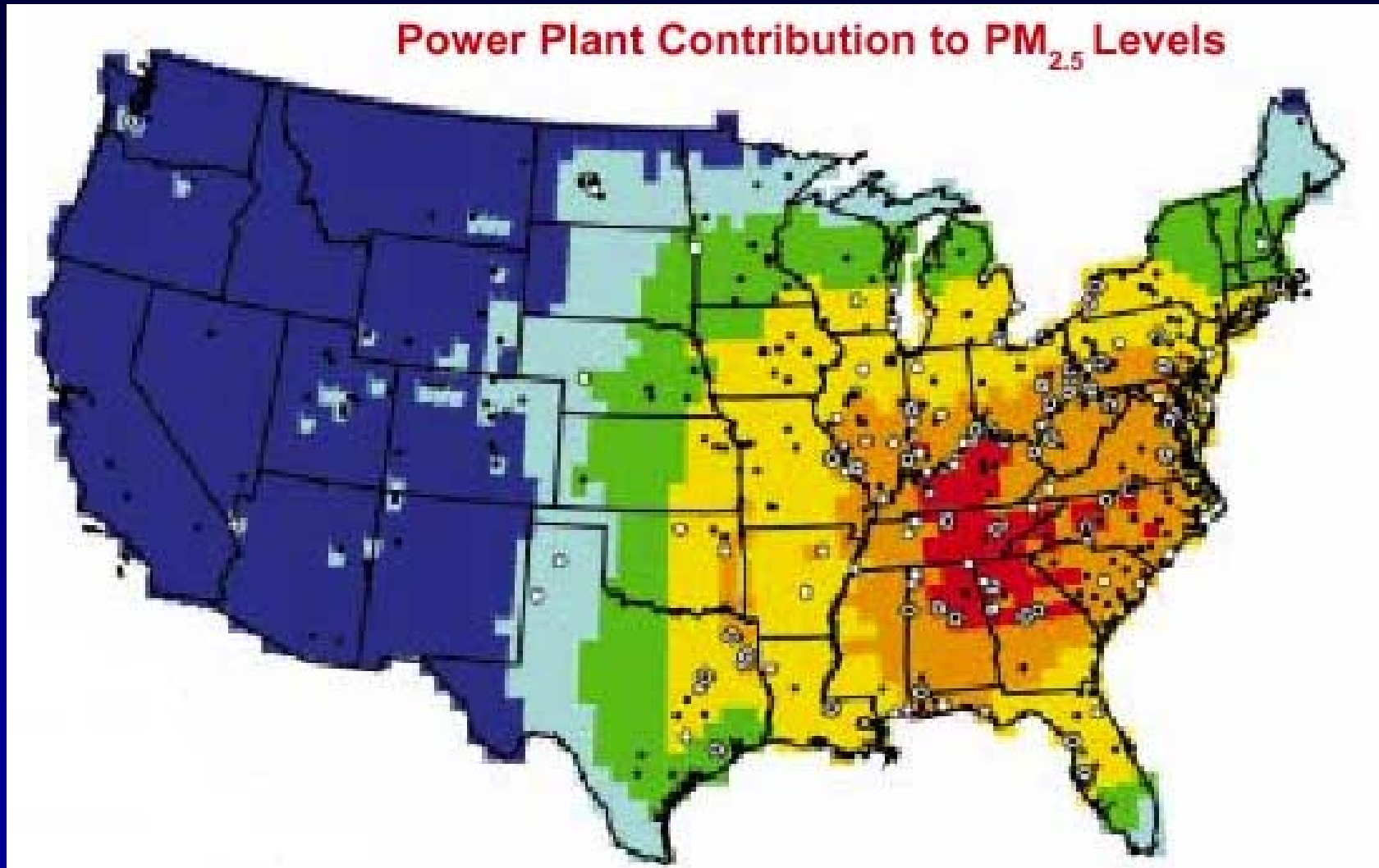
- NO_x forms ozone and fine nitrate particulate matter
- SO_2 : a dangerous gas that forms especially toxic acidic sulfate particulate matter



Where Particulate Matter is the Greatest Problem:

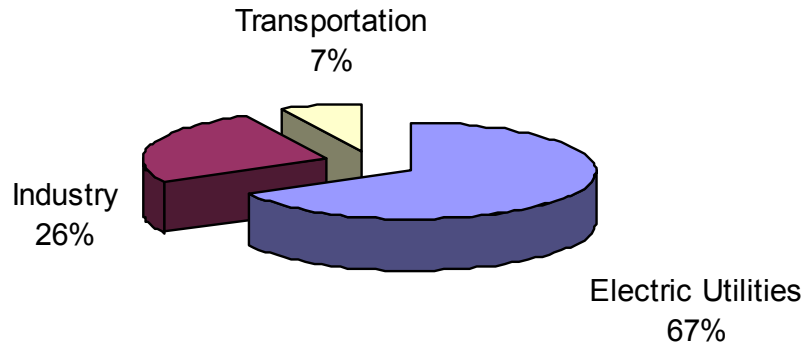


A Major Reason: Fossil Fuel Power Plant Contributions to Fine Particles

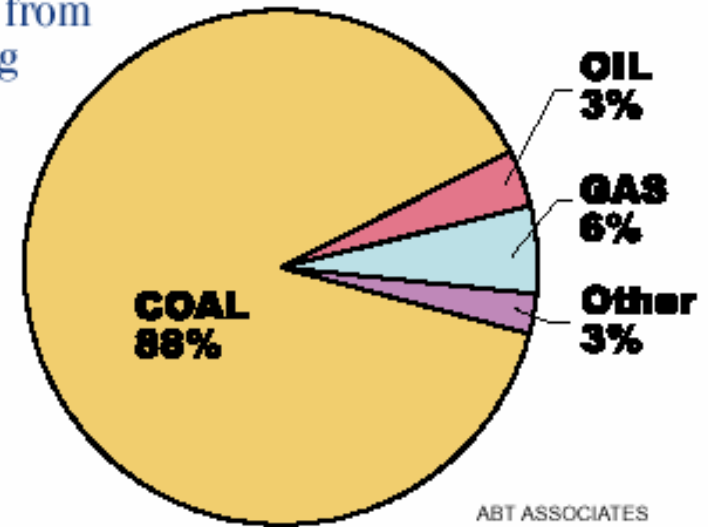


Power Plants Cause Most of the Sulfur-Containing Secondary Particles in the U.S. Atmosphere

1998 Sulfur Dioxide Emissions



Most of the sulfur dioxide pollution from power plants comes from burning coal.



Fine Particle Aerosols Reduce Visibility

$(\text{SO}_4^{2-} = 30 \text{ ug/m}^3)$ $(\text{H}^+ = 80 \text{ nmoles/m}^3)$



PM Pollution Obscures the Air in Texas, too!



Outdoor Air Pollution Effects are Increased in Children

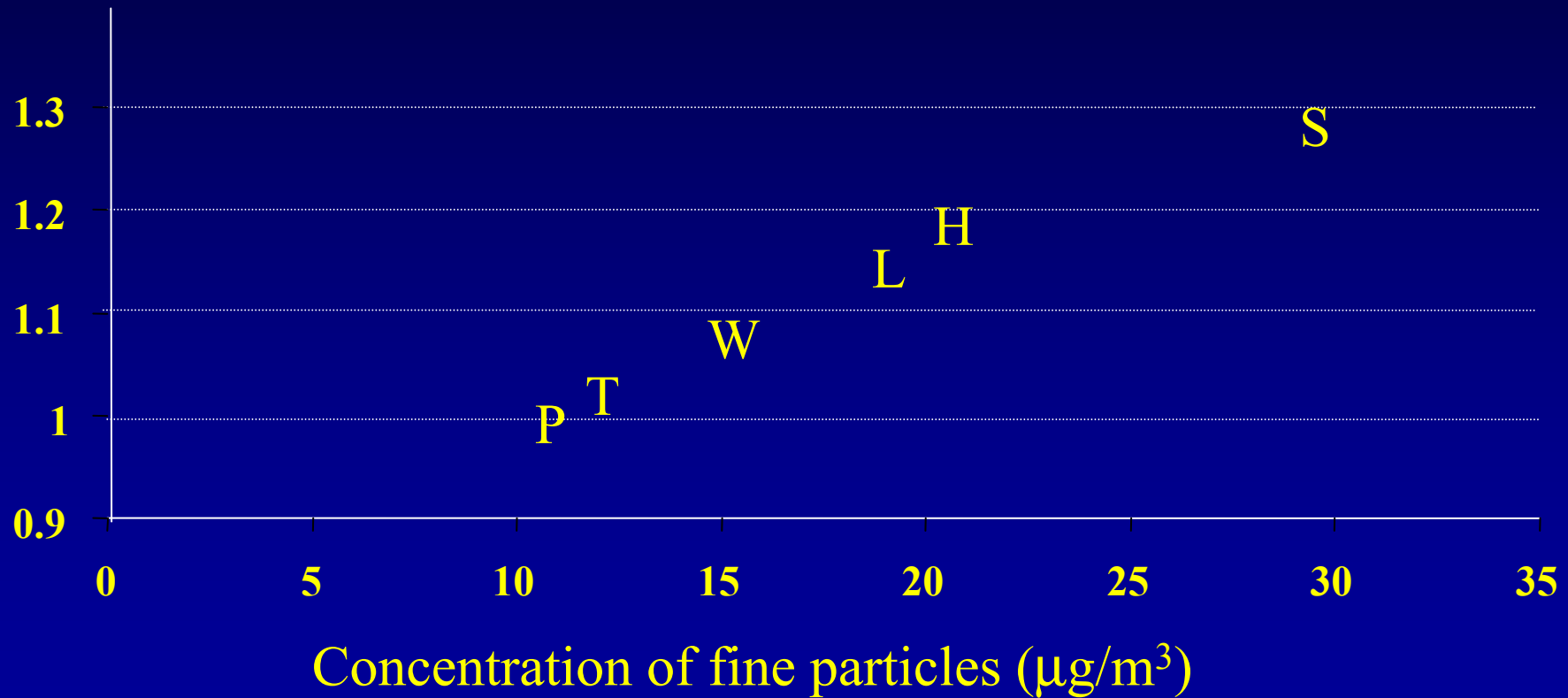
- more time spent outdoors and greater activity;
- greater PM personal cloud than adults;
- higher prevalence of asthma in children;
- Children are growing and developing, and pollution may inhibit this process.

Recent Published Evidence

- Cross-sectional epidemiological studies suggest that sulfate-associated fine particles (i.e., fossil fuel combustion products) are among the most toxic (e.g., Thurston and Ozkaynak, 1987; Dockery et al., 1993; and Pope et al., 1995).
- Recent JAMA extended follow-up analysis (16 years) of the ACS data (Pope, Burnett, Thun, Calle, Krewski, Ito and Thurston, 2002):
 - ◆ Confirmed the original associations of sulfates and PM_{2.5} with human cardiovascular mortality.
 - ◆ Also found cancer deaths to also be associated. The cancer risk of living in a polluted U.S. city was comparable to that from living with a smoker.

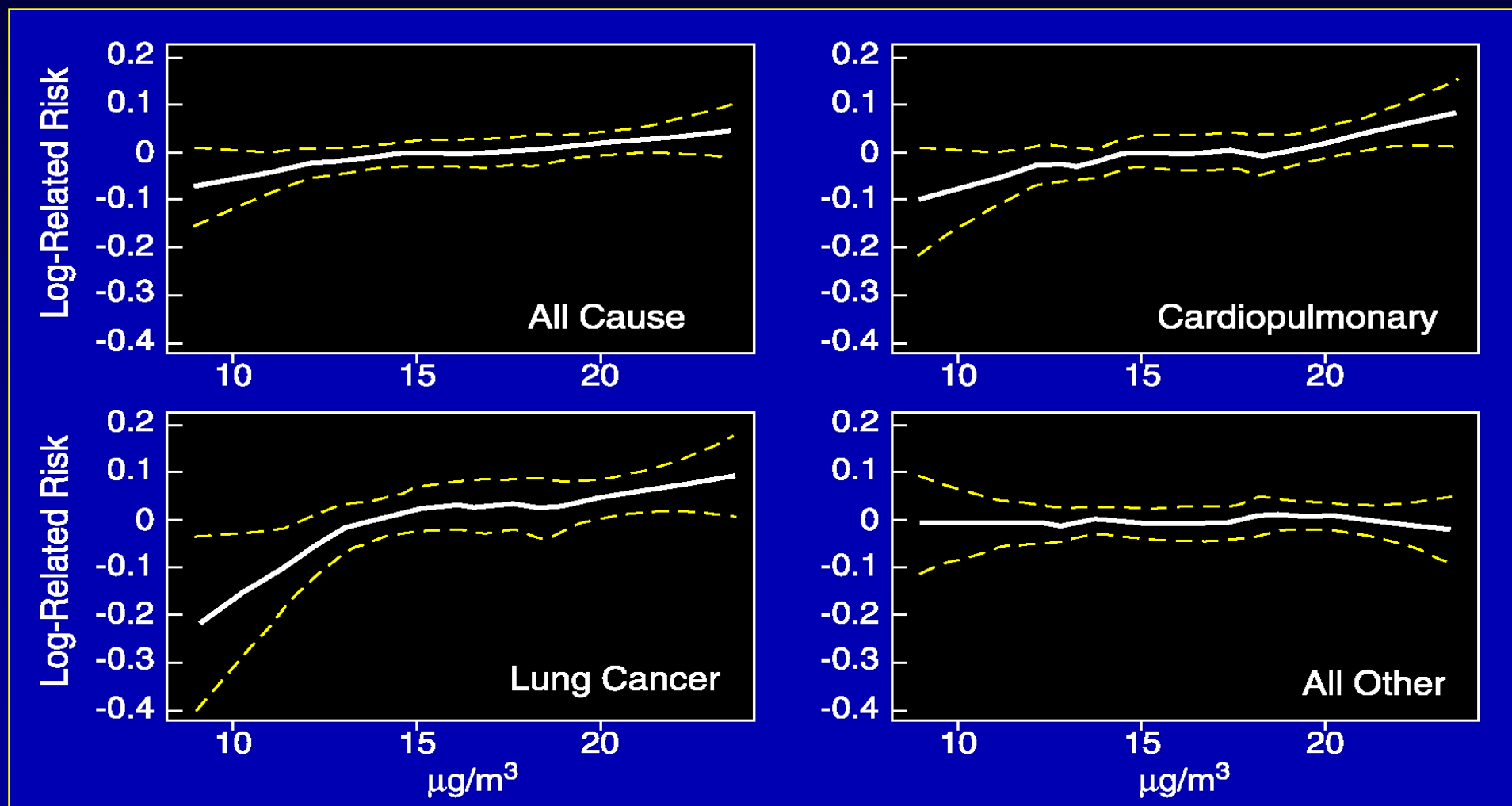
Higher risk of death in more polluted cities: Harvard Six Cities Study (1993)

Risk ratio

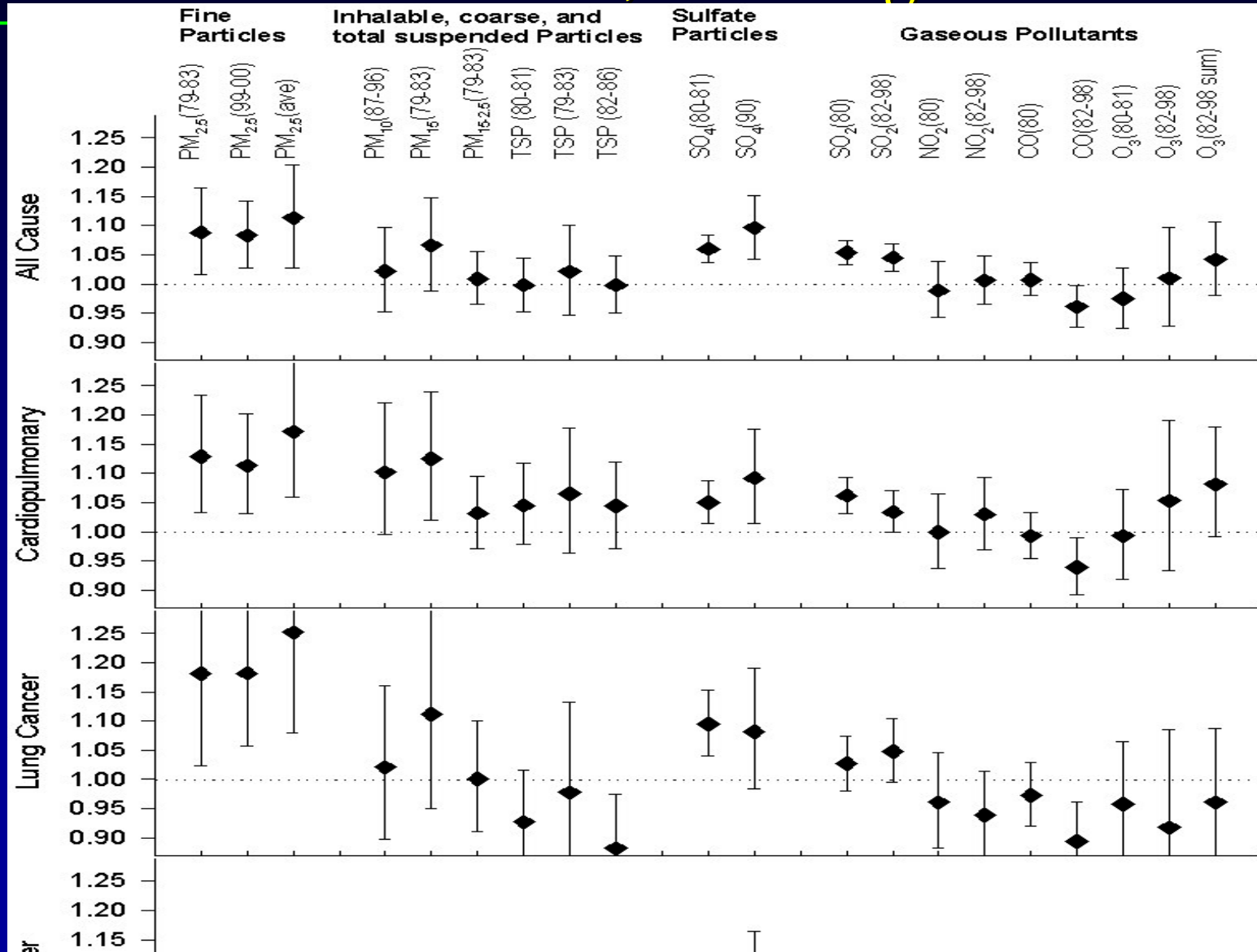


The Mortality Risks of Long-Term Fine PM Exposure Increases Monotonically with Exposure

(Pope, Burnett, Thun, Calle, Krewski, Ito, and Thurston) (JAMA, 2002)



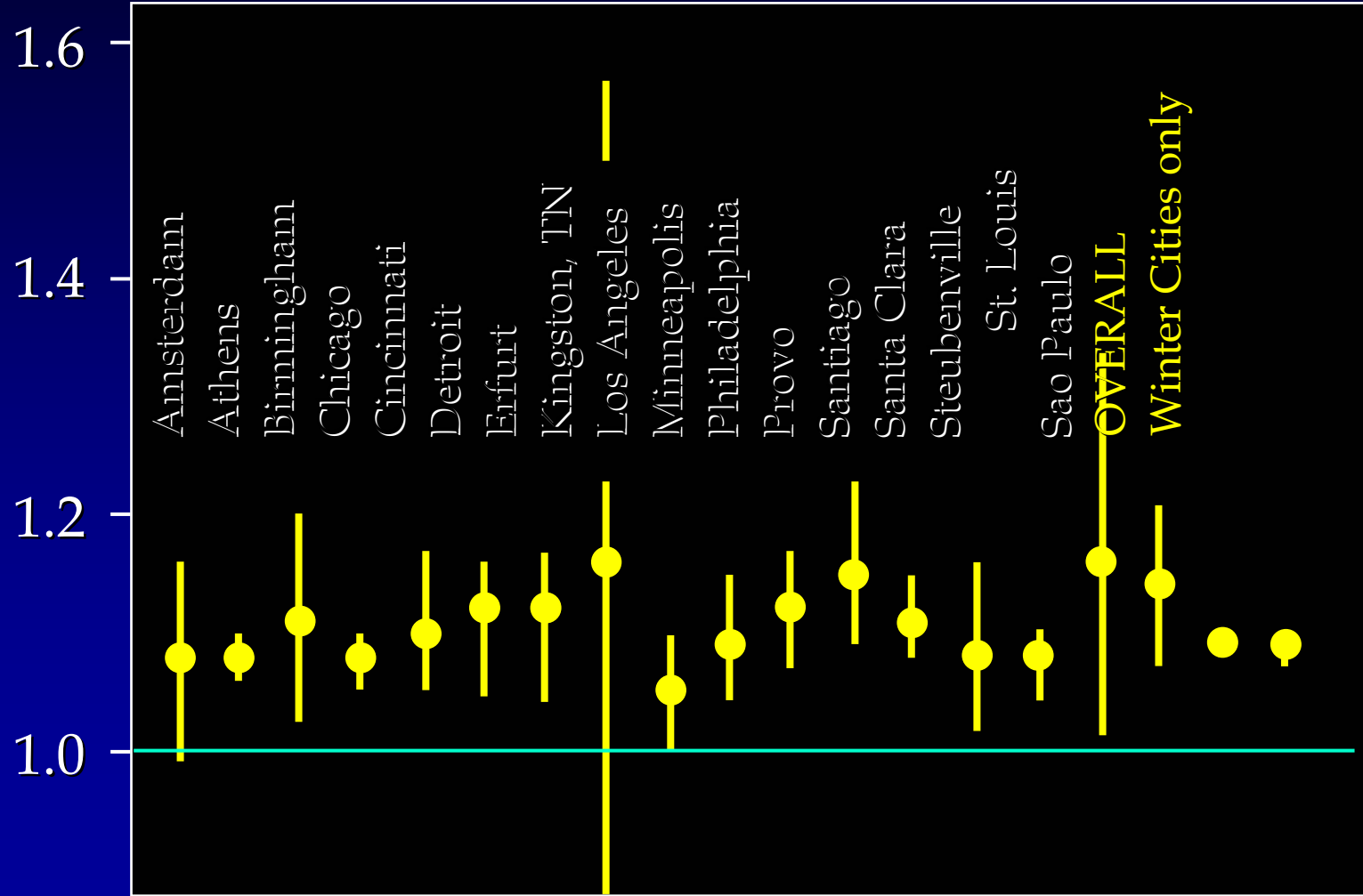
JAMA Study (2002) Found Cardiopulmonary and Lung Cancer Mortality to be Associated with Combustion-related Pollution, Including Sulfates



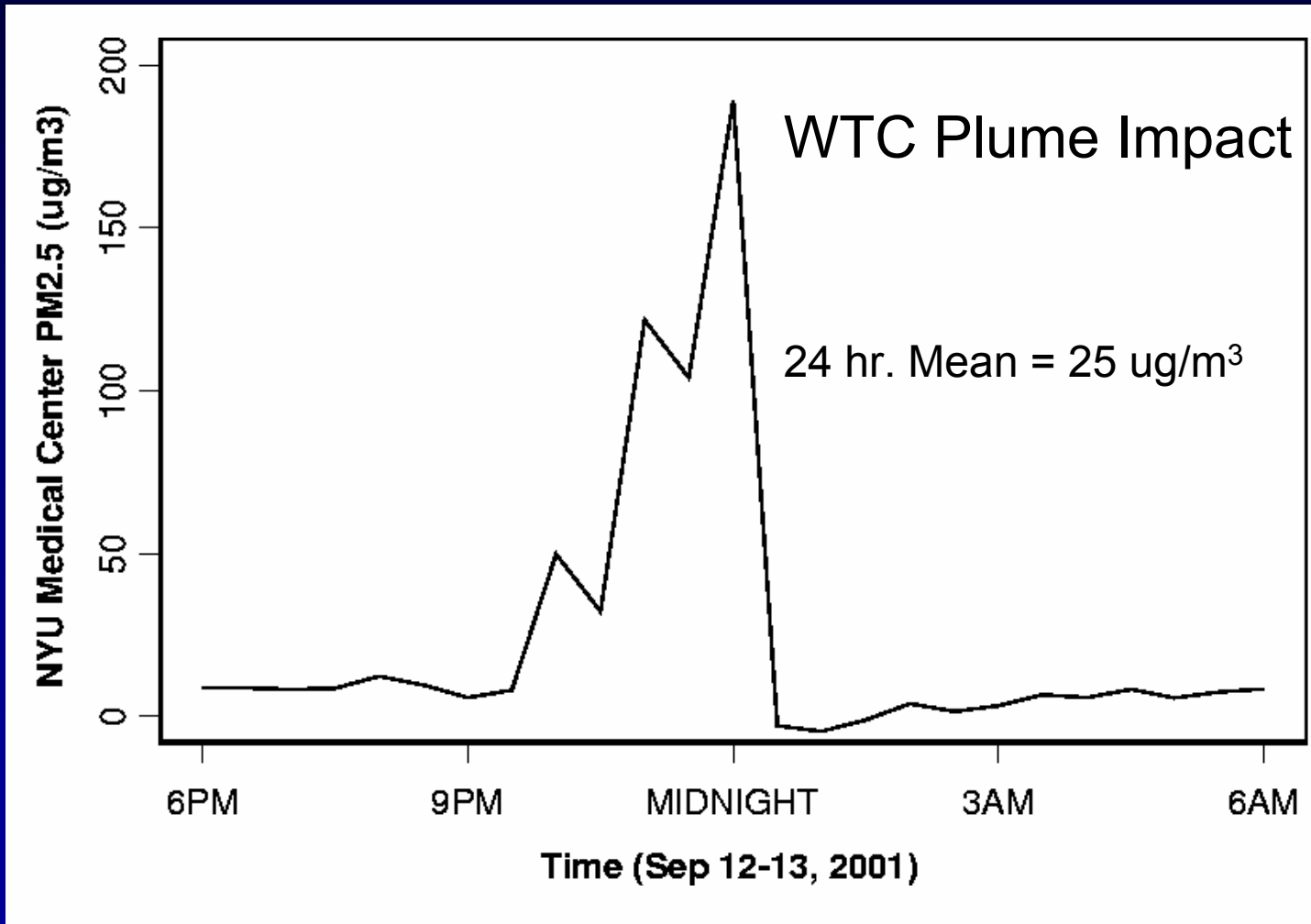
Today's Studies Also Show Increased Acute Mortality at Higher Daily Particulate Matter Pollution Concentrations

(Source: Schwartz, J. in *Health at the Crossroads*, 1997)

Relative Risk (RR) of Death for
a $100\mu\text{g}/\text{m}^3$ Increase in PM10

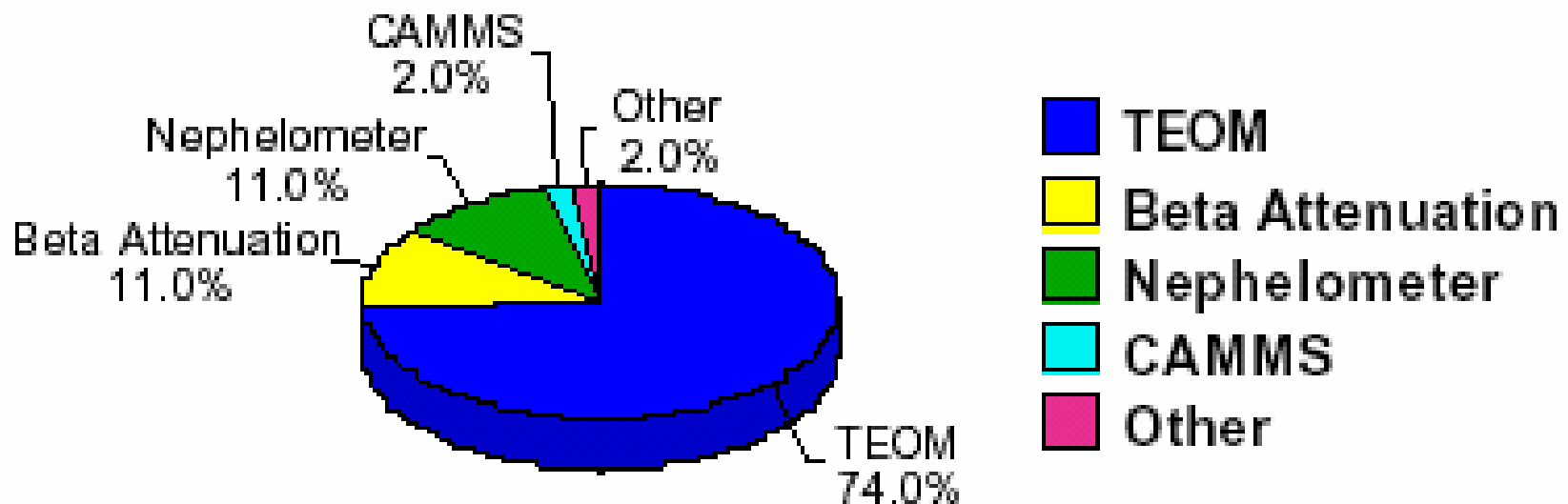


New PM Monitors Can Even Provide Hourly PM_{2.5} Concentration Levels



Most Continuous Monitors in Use Today are TEOMs

PM2.5 Continuous Monitors
Estimated percent of the National Network



Continuous PM Samplers Provide Mass Concentration Estimates Similar to Filter Samplers

Figure 2-7 New York, NY

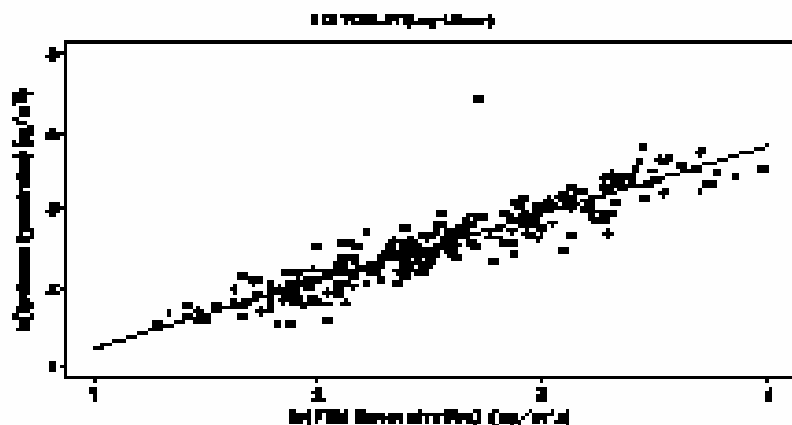
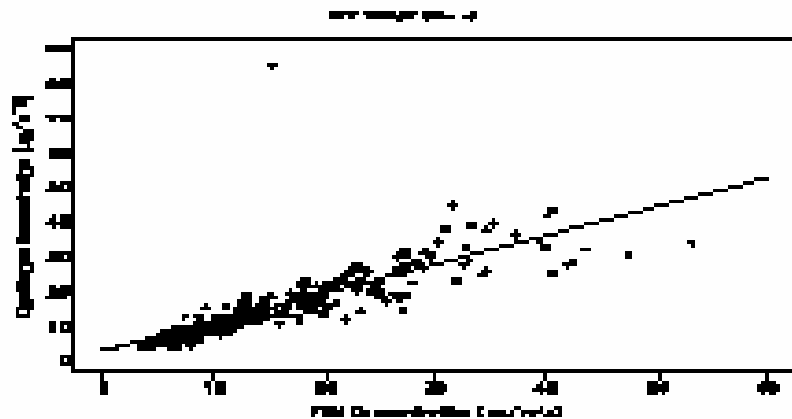
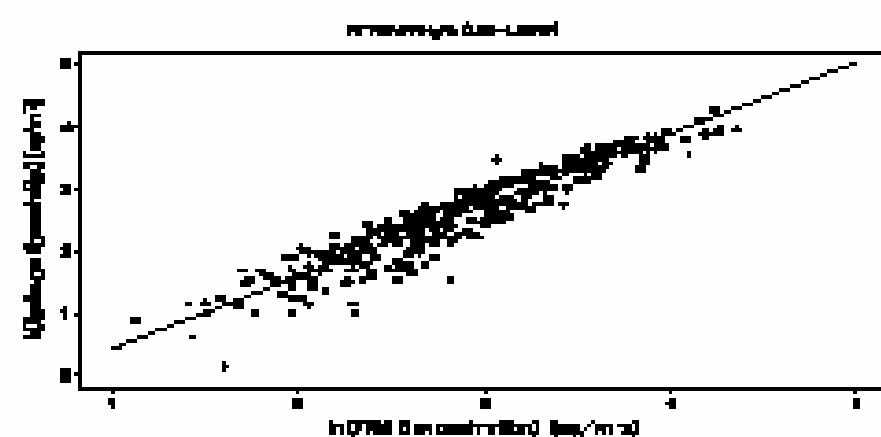
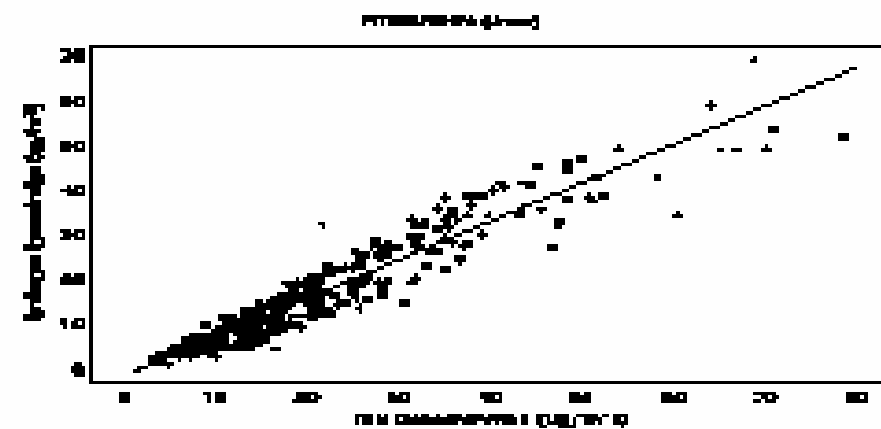
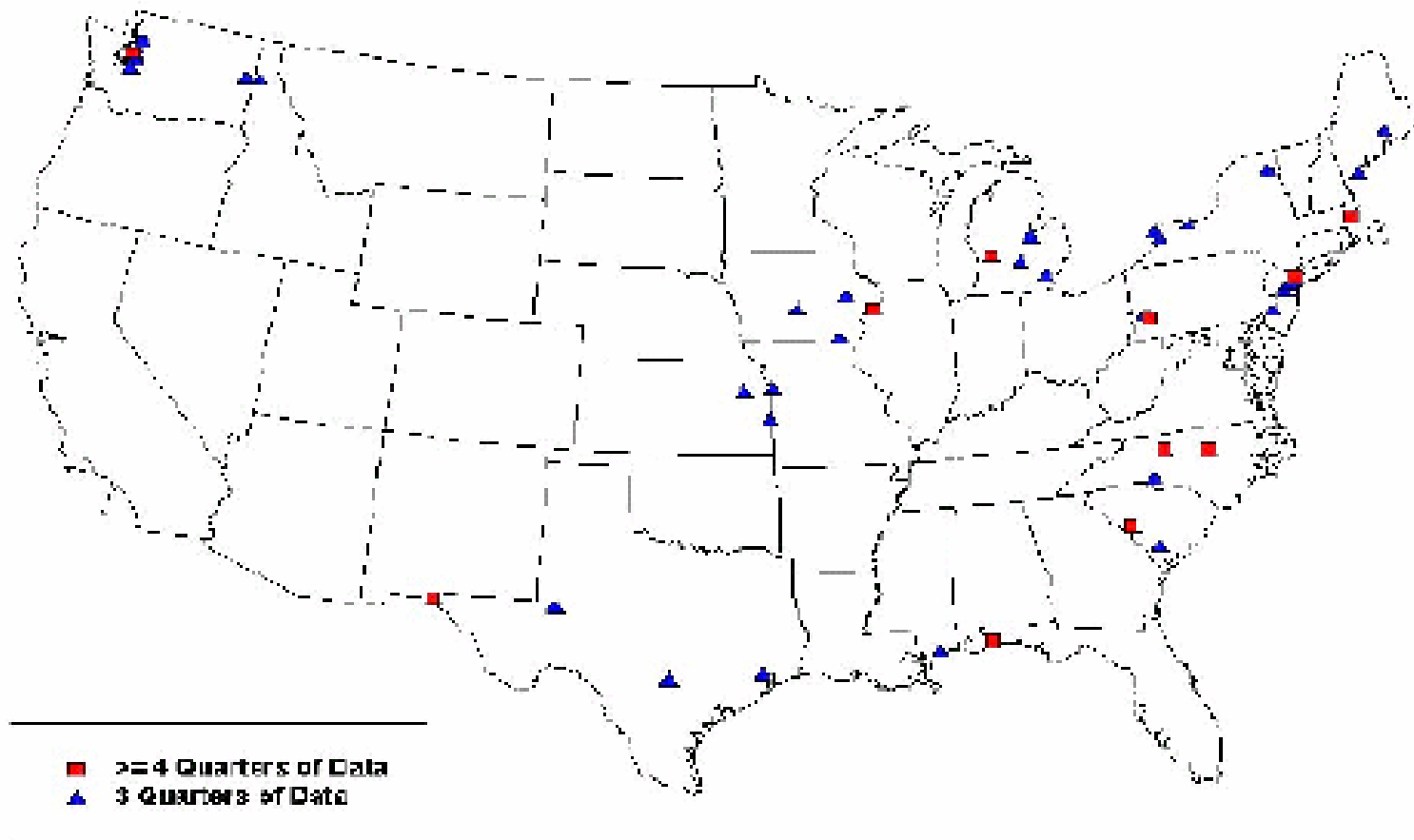


Figure 2-8 Pittsburgh, PA



Continuous PM Monitors are Present in Only Limited Numbers Nationwide

Figure 2-2 Map of 47 Sites used in PM_{2.5} Continuous Monitors Analyses

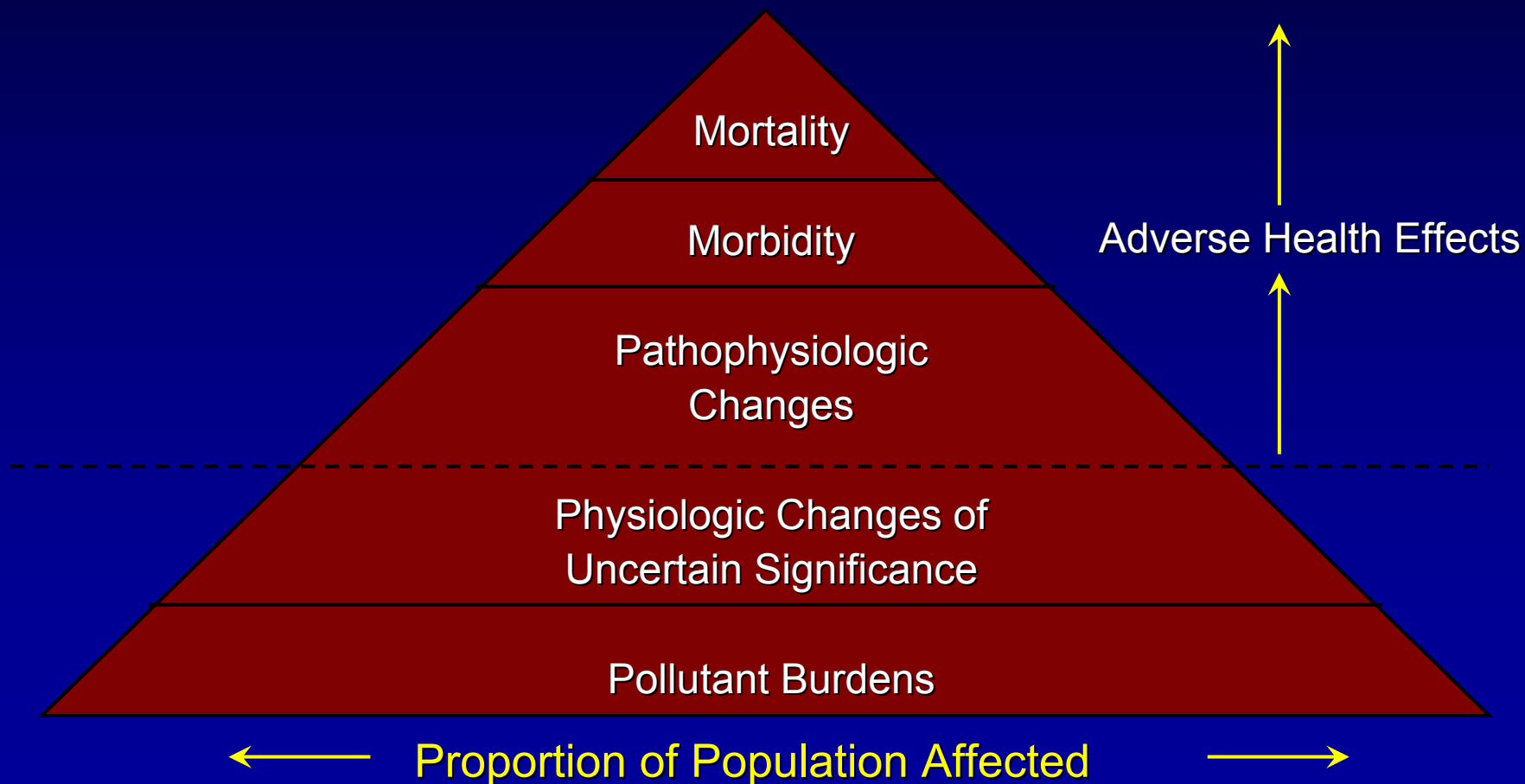


Using Such Data, High PM Exposures of Just a Few Hours Found to Increase Risk of Illness

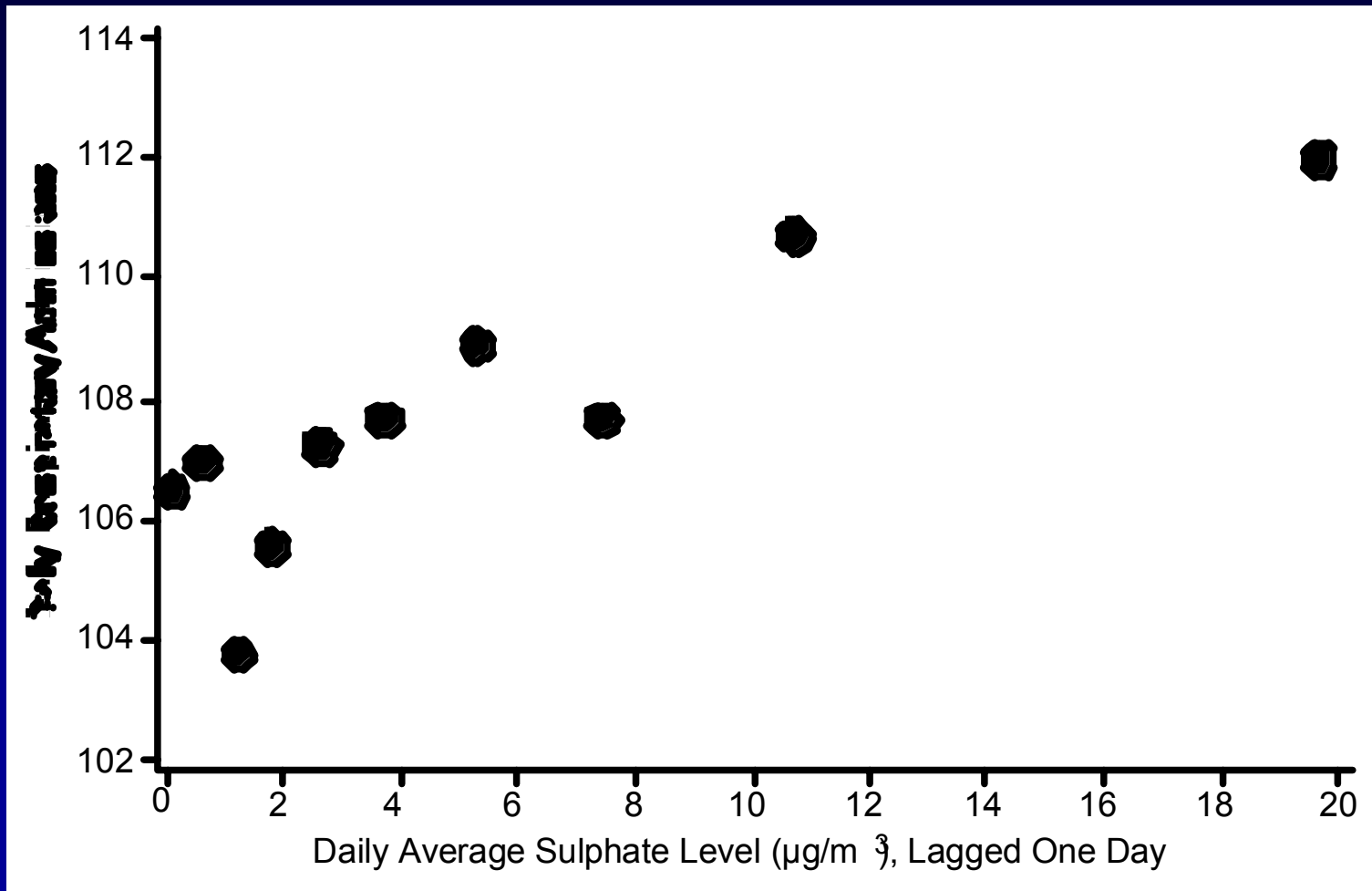
- Peters et al (2001) found that elevated concentrations of fine particles in the air can increase the risk of Myocardial Infarctions (MI's) within a few hours after PM exposure.
- The Harvard University team found:
 - ◆ a 48 percent increase in the risk of MI was associated with an increase of **25 ug/m³ PM_{2.5}** during a 2-hour period before the onset of MI.

Mortality is Just the “Tip of the Iceberg” of PM Pollution’s Adverse Effects

Spectrum of Biological Response to Pollutant Exposure



Hospital Admissions Rise with Fine Particle Air Pollution Levels



New Analyses of Older vs. Younger Adults

- Chronic Exposure to Particulate Matter: A re-evaluation of the Long-term (1982-1998) ACS data set for $PM_{2.5}$ associations as a function of age.
- Acute Exposure to Particulate Matter: A new analysis of 1985-1994 New York City, NY daily deaths as a function of age (DeLeon, Ito and Thurston, 2002).

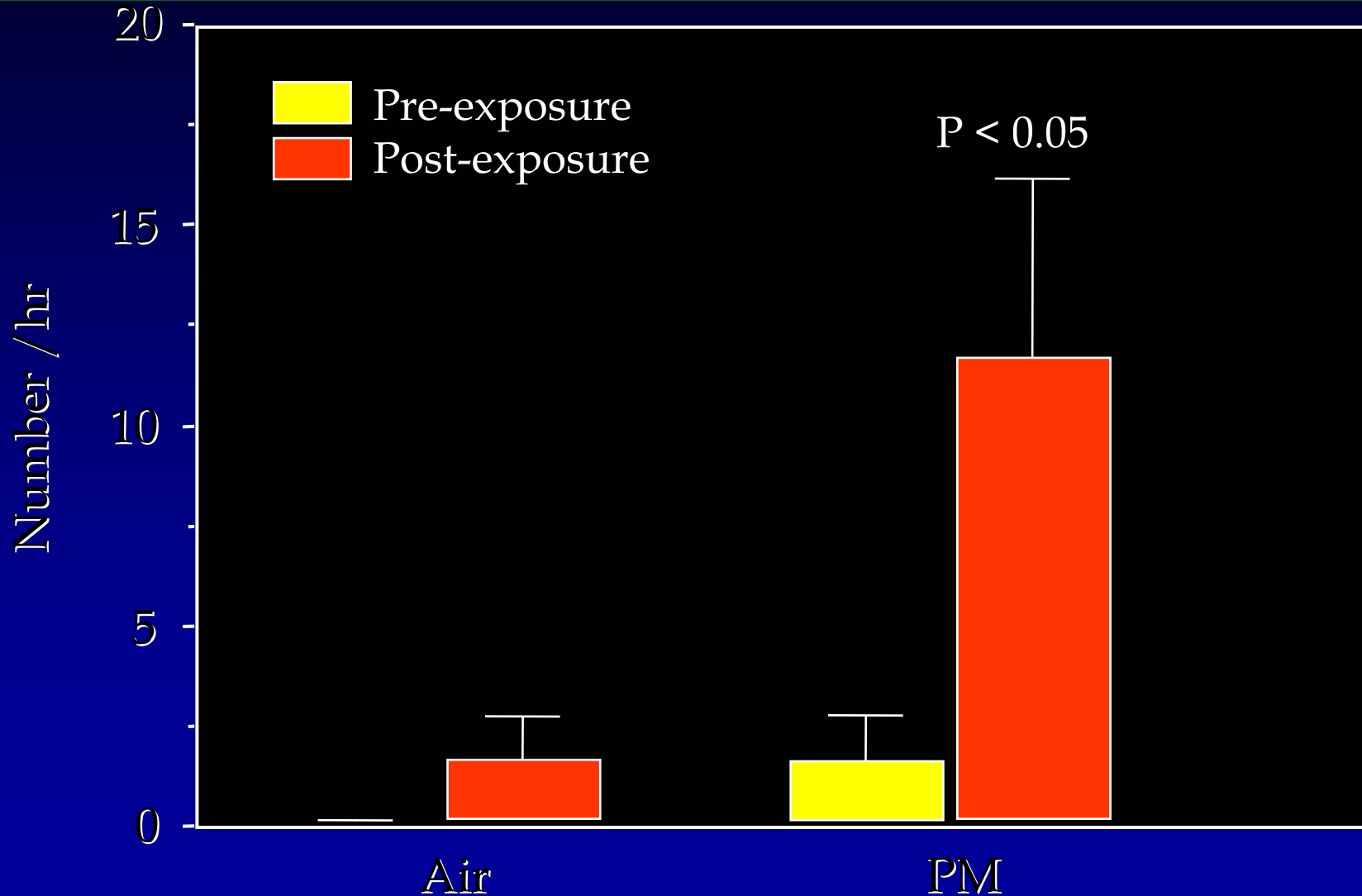
In the ACS Data, the Long-Term RR of Death Of 10 ug/m³ PM_{2.5} Air Pollution Is Increased by a Factor of Two in Older Adults

	<75 Years of Age	75+ Years of Age
RR of Cardio-Pulmonary Disease	1.049 CI=1.023 -1.076	1.098 CI=1.050 -1.148

In New York City, the Presence of Respiratory Disease Increases the Acute Relative Risk of Death in Older Adults

	<75 Y rs. of Age	75+ Y rs. of Age
Circulatory Deaths Without Resp. Disease	1.027 CI=1.012-1.043	1.022 CI=1.008-1.035
Circulatory Deaths With Resp. Disease	1.033 CI=0.98-1.089	1.066 CI=1.027-1.106

Animal Tests Also Indicate PM Effects in Older Animals: Frequency of Sinus Arrhythmias in Old Rats Increases After Exposure to Concentrated Ambient PM (Nadziejko et al., 2002)



Why Combustion/Industrial Particles May be More Toxic

- Humans are now exposed to industrial and fossil fuel combustion particles that the lung did not evolve to deal with.
- These particles have different sizes, different physiochemical characteristics, and deposit in different parts of the lung than more “natural” particles (e.g., wind blown soil).
- Since the lung evolved defenses to keep particles out of the alveolar region, this suggests a cause for concern.

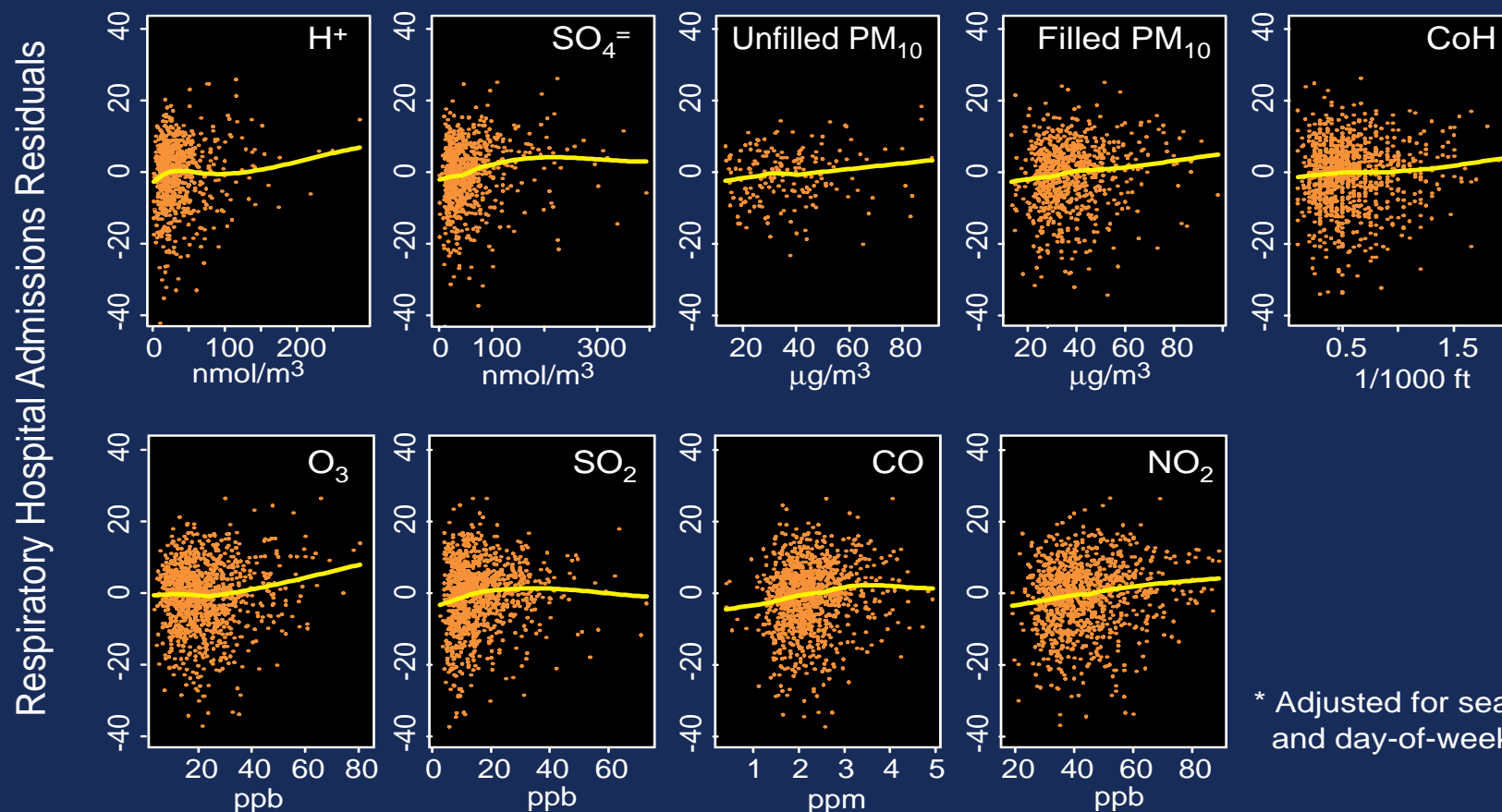
Power Plant Particles, Transition Metals, and Oxidative Stress

- Transition metals (e.g., Fe and V) can mediate electron transfer via Fenton Reactions causing oxidative stress.
- Oxidative Stress can lead to cellular damage:
 - ◆ OS is known to be involved in inflammation, tissue aging, cardiac ischemia, arthritis, cancer, and fibrosis (Mossman and Marsh, 1989, Janssen et al, 1993, Costa et al, 1989a, 1989b; Ewing, 1983; Slaga, 1983; Harman, 1981).
- The presence of acids with metals in a particle greatly enhance the solubility, and therefore the bio-availability, of these transition metals, increasing OS.
- ARIES Study found no association of sulfates with health effects in the absence of aerosol acidity: indirect confirmation of importance of acidity.

NY Hospital Admissions Rise with Increasing Acidic Sulfate Pollution Levels

(Gwynn et al, EHP, February 2000)

Respiratory Hospital Admission Residuals* versus Daily Mean Values of each Pollutant Variable for New York City



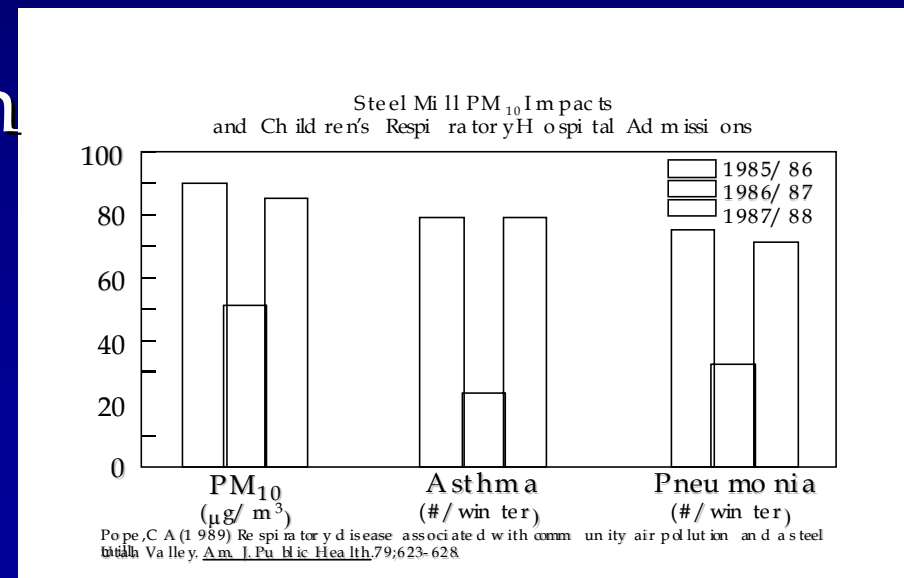
* Adjusted for season and day-of-week

BUT

Health Also Improves When Pollution Goes Down

- During the Atlanta Olympics Games, reduced vehicle traffic lowered pollution by 30 percent, and Pediatric emergency visits dropped by 17%.

- During a Steel Mill Strike in Utah, when the pollution went down, asthma and pneumonia hospital visits declined also.



CONCLUSIONS

- Acute and Long-Term Exposure to Fine Particulate Matter Can Have Severe Health Impacts
- Avoiding acute exposures to PM can help protect public health, especially among susceptible populations.
- Enhancing the network of continuous PM_{2.5} monitors would:
 - ◆ Help better inform the public to avoid this pollution, and
 - ◆ Help researchers better evaluate the effects of short-term exposures to PM.



THANK YOU!!!

For The Important Public Health
Work You Do!!!