Air Pollution Health Effects: What We Know and What We Think We Know

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Air pollution particles are blamed for deaths

By H. JOSEF HEBERT
Associated Press

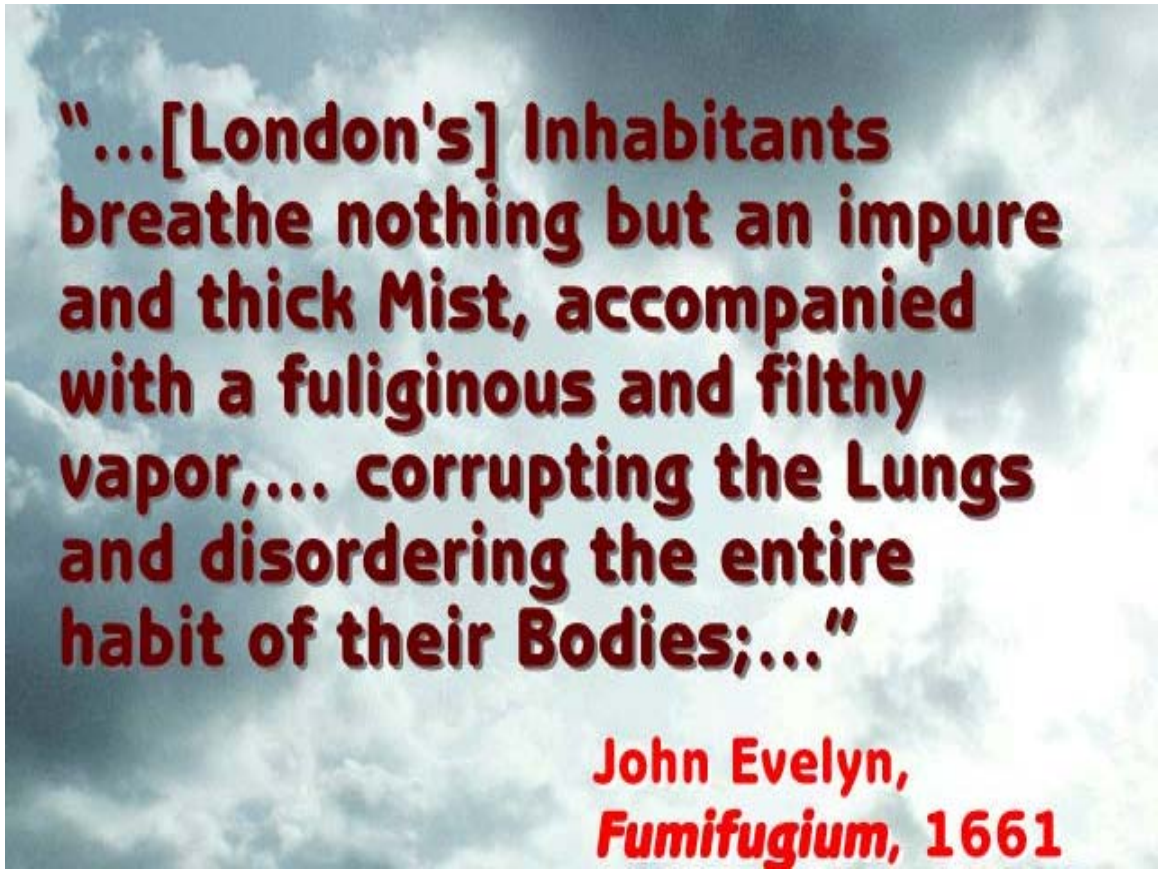
WASHINGTON — Dust, soot and tiny particles in polluted air over the nation's major cities cause tens of thousands of premature heart and lung-related deaths each year, an environmental group said Wednesday.

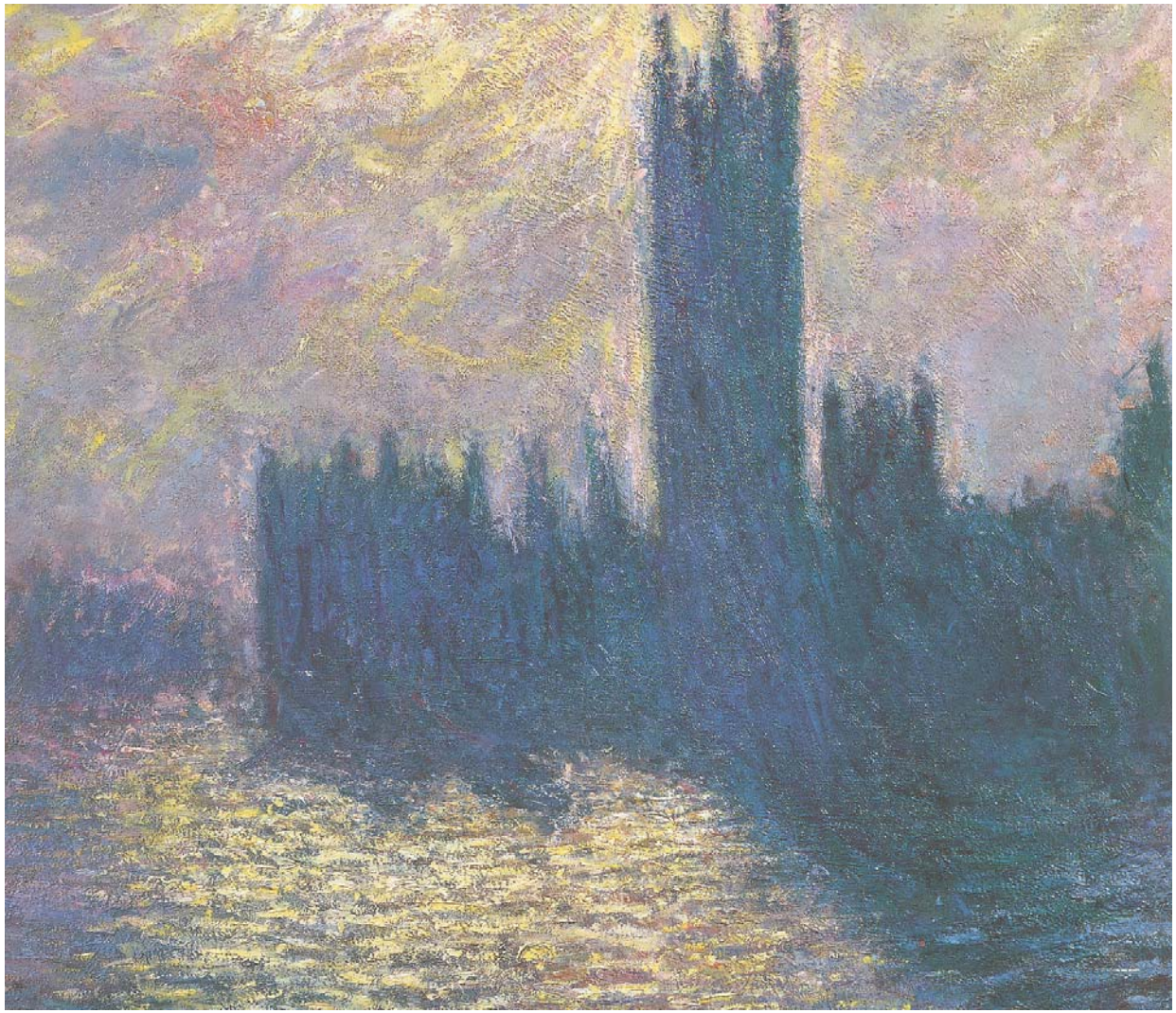
The Natural Resources Defense Council released the findings in a study on air pollution in 239 cit-

The NRDC study projected that as many as 64,000 premature deaths from cardiopulmonary causes "may be attributed to particulate air pollution each year," or about 6.5 percent of the nearly 1 million such deaths annually. Such pollution also has been linked to increased childhood asthma cases and health problems for the elderly.

"People face a risk of prema-

A Brief History of PM





The Houses of Parliament, Stormy Sky

Claude Monet, 1904

Air Pollution Disasters

1930 Meuse River Valley, Belgium

A three-day episode of severe air pollution makes 6,000 ill and kills 63.

1948 Denora, PA

Oct. 26 to 31: air pollution episode leaves 20 dead out of 14,000 persons.

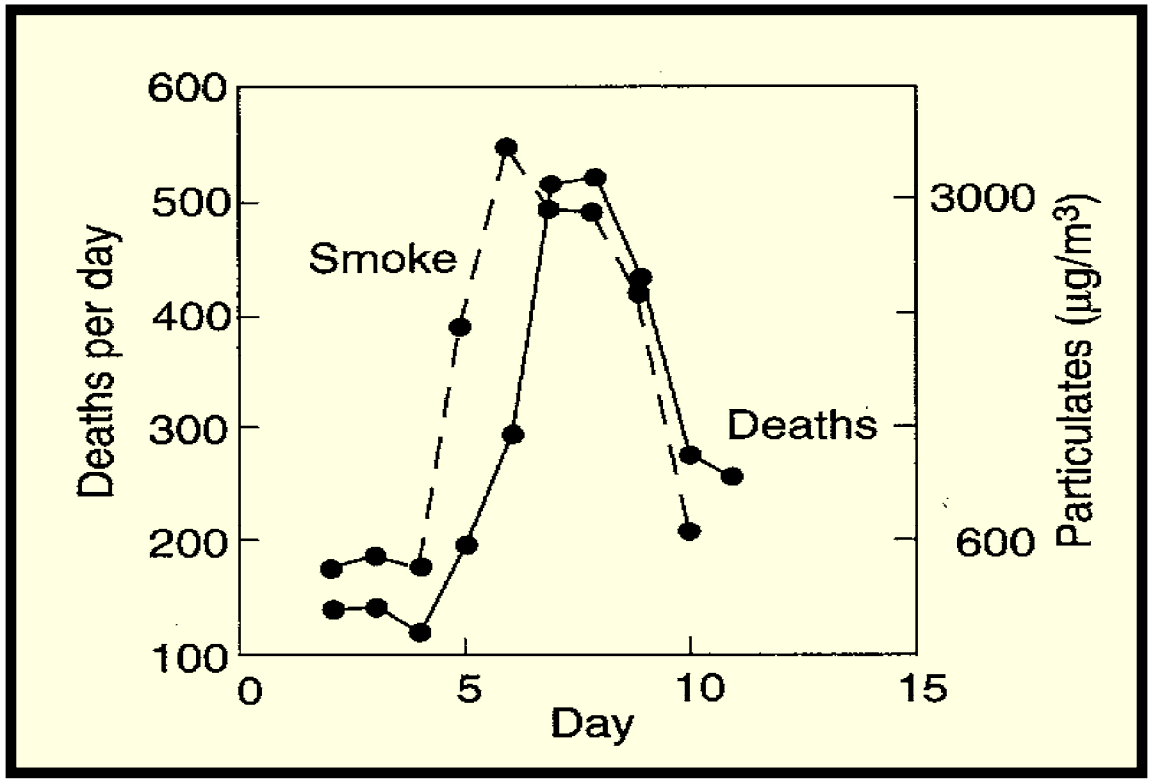
Donora, PA at noon on Oct. 29, 1948

1952 London, England

Dec. 4 to 9: “Killer Fog” leaves three to four thousand people dead.

London buses are escorted by lantern at 10:30 in the morning.

Mortality Attributed to the London Fog



Schwartz, 1994

Acute Mortality Associated with Ambient PM Concentration

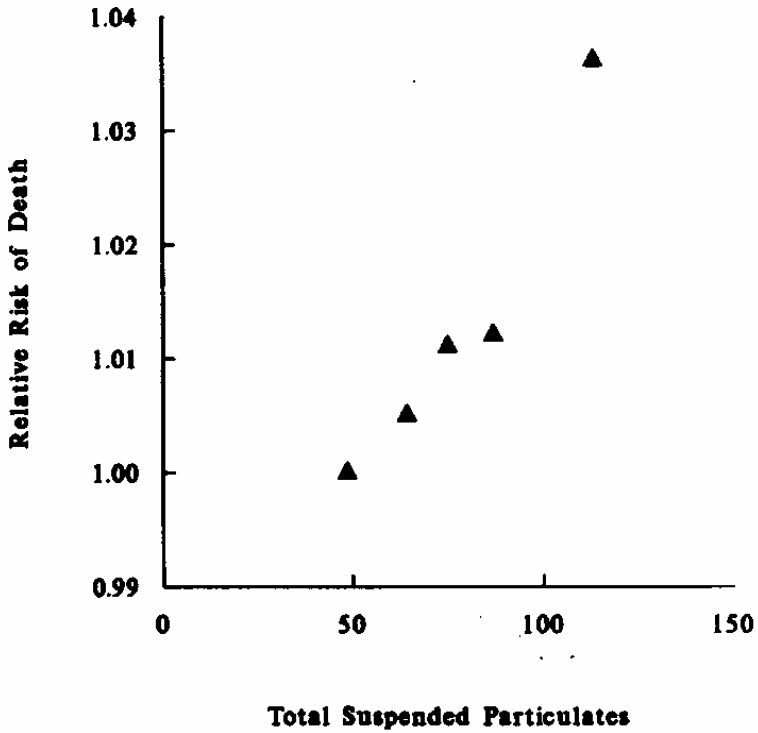


Fig. 1. Relative risk of death in Philadelphia by quintile of total suspended particulates controlling by regression for year of study, time trend, and weather.

Schwartz et al., 1992

The National Morbidity, Mortality, and Air Pollution Study

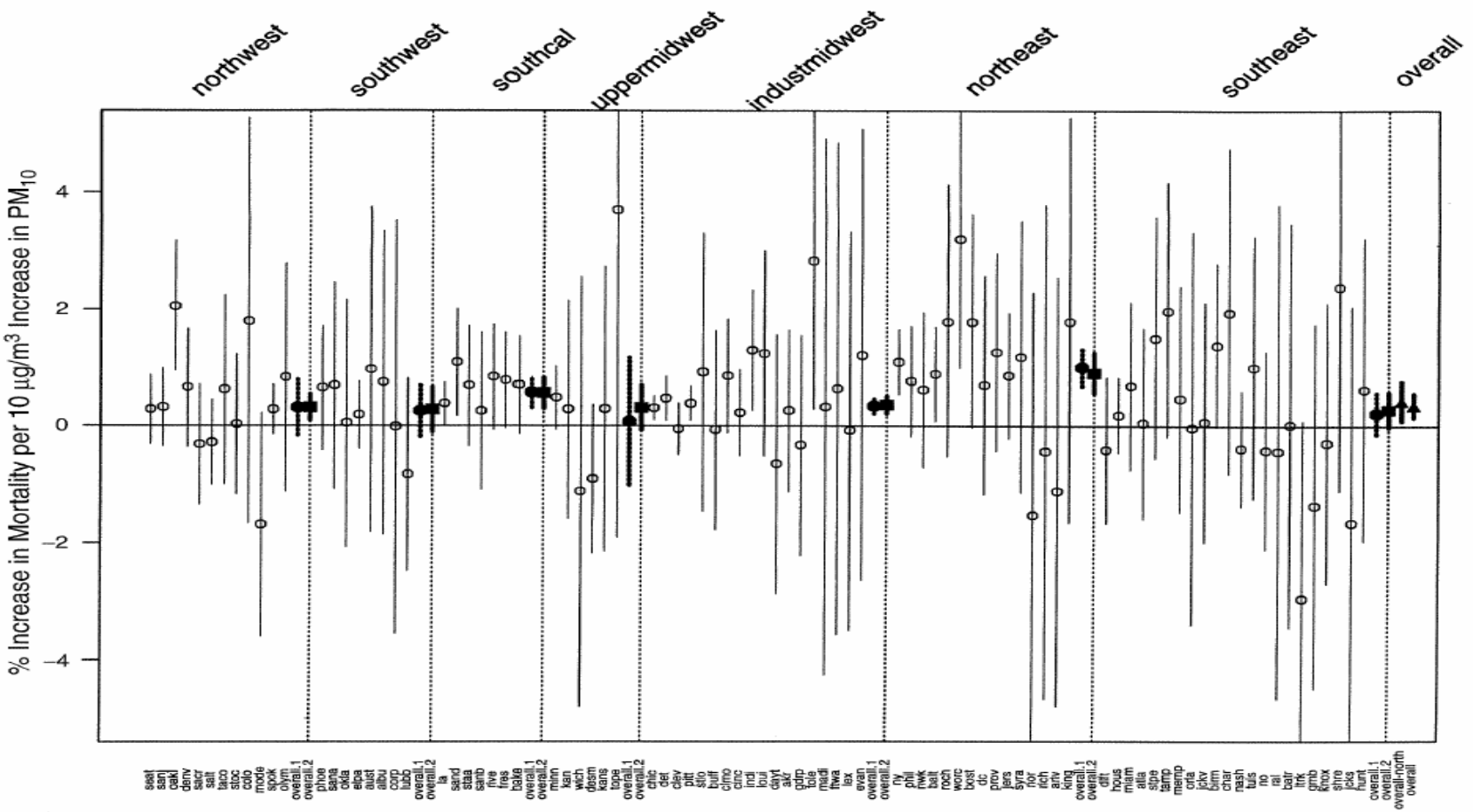


Figure 21. Effects of PM_{10} on total mortality and 95% CIs for each of the 90 cities, grouped by region.

Samet et al., 2000

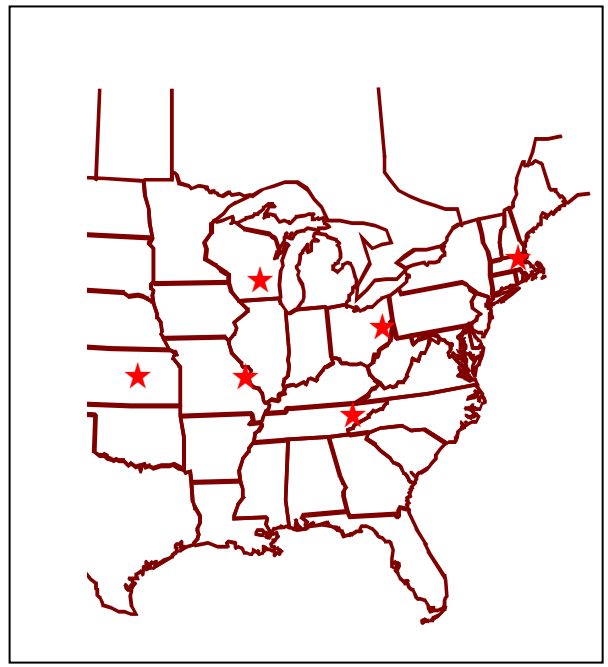
Association Between Long Term Exposure to PM and Mortality

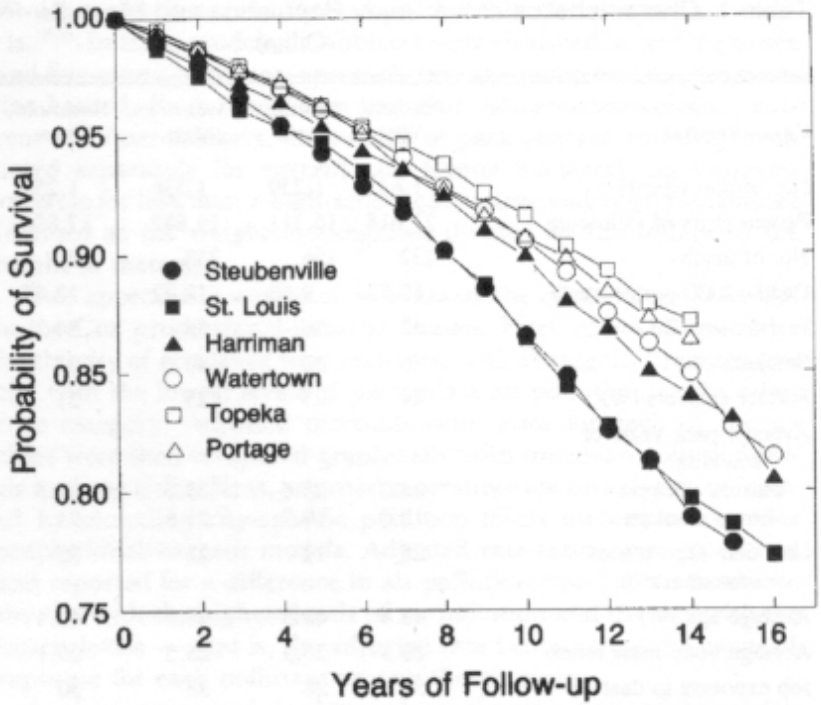
Harvard Six-Cities Adult Cohort

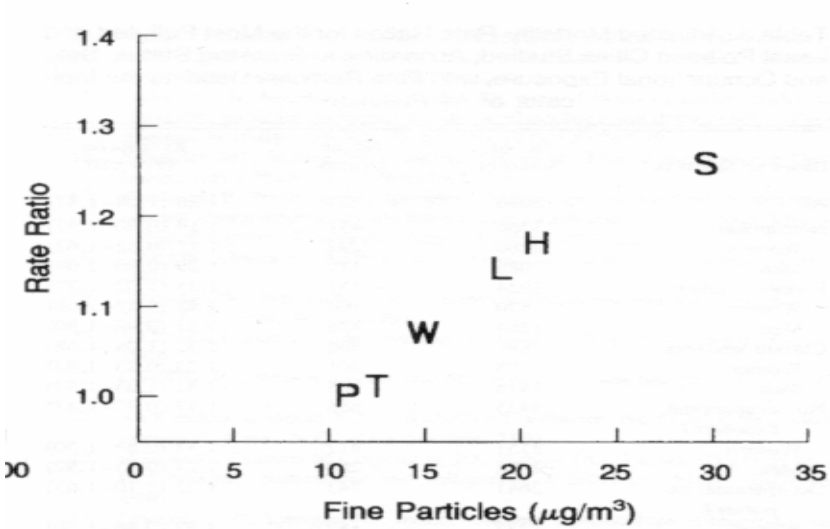
- Purpose was to study the association between pulmonary changes and long term exposure to sulfates and sulfur dioxide

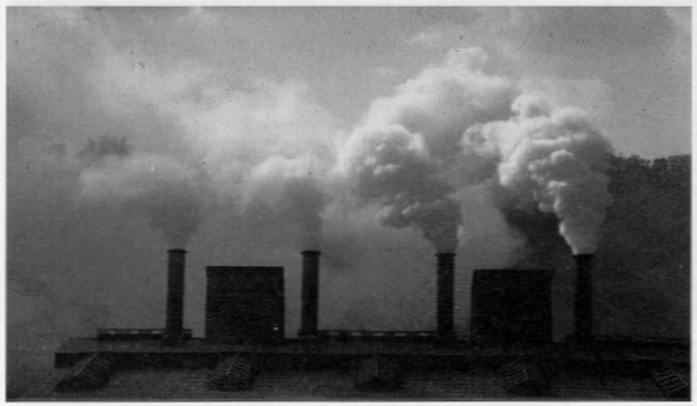
- Enrollment 1974 – 1977
  - 8,111 white men and women
  - About 1,300 in each of six cities
  - Age range 25 to 74 years

- Followed until 1991 (now 1999)
  - 14 to 17 years of follow-up
  - 111,076 person-years
  - 1,430 death









Foundry along Ohio River near Stubenville, OH.
Photo: J. Spengler or D. Dockery

Dockery et al., 1993

Why Were the Epidemiology Studies So Hard to Believe?

- **Similar results were obtained from cities all around the world**
  - But chemical composition differs geographically and temporally
- **PM levels are very low compared with other particle exposures**
  - One cigarette = 10x more than a 24 hr exposure to PM
- **No widely accepted pathophysiological process or mechanism that could explain the epidemiology findings**

PM: Who Done It?

How many people were attacked by what...

...and where did this occur (indoors, outdoors)?

Did they act alone or did gases aid and abet?

Where did the guilty pollutants come from?

How can the guilty be stopped before they can kill again?

Current PM Health Effects Program

- **In 1997 President Clinton stated: "The EPA, in partnership with other Federal Agencies, will develop a greatly expanded coordinated interagency PM research program, which will contribute to understanding the science associated with PM health effects, as well as developing improved monitoring methods and cost-effective mitigation strategies."**

- **In 1998 Congress allocated substantial new funds for PM Research.**

  more than 250 million dollars in the past 6 years

- **At the same time it directed the EPA to arrange for an independent study by the National Research Council to develop priorities for a comprehensive PM Research Plan.**

The NRC Reports

The NRC has issued 3 reports which identify important research needs and recommend a multi-year portfolio of the highest priority research topics.

WHO Is Susceptible to PM?

HOW does PM cause adverse health effects?

WHAT are the PM component(s) responsible for these effects?

WHO Is Susecptible to PM?

A Needle in A Haystack?

Given:

- 200 natural deaths per day for a city of 8 million (e.g. Philadelphia)

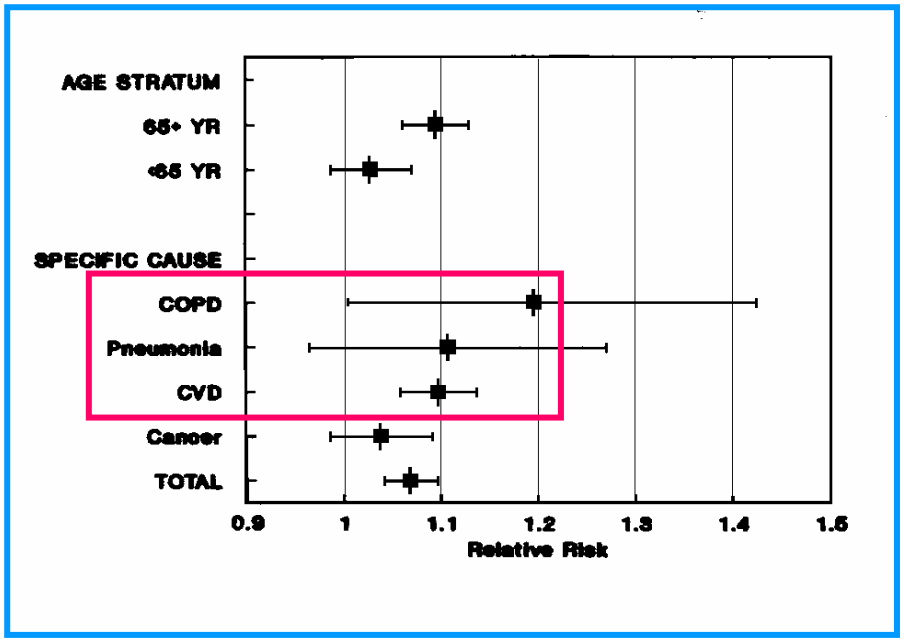
Assume:

- A 3-day PM episode raises the concentration from 30 to 80 ug/m^3
- A relative risk of 1.05 per 50ug/m^3 change in PM Concentration

Result:

- 10 extra deaths per day in Philadelphia
- East Coast impact might be ~100 excess deaths

Cardiopulmonary disease appears to predispose to PM effects.



Schwartz et al., 1992

PM Can Trigger Myocardial Infarction

772 MI patients who survived 24 hours and completed interview

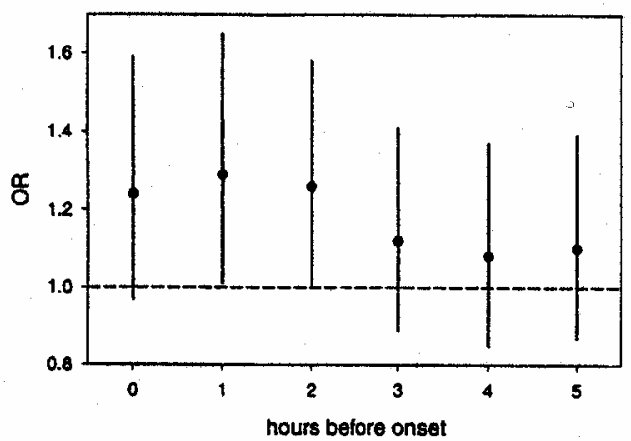
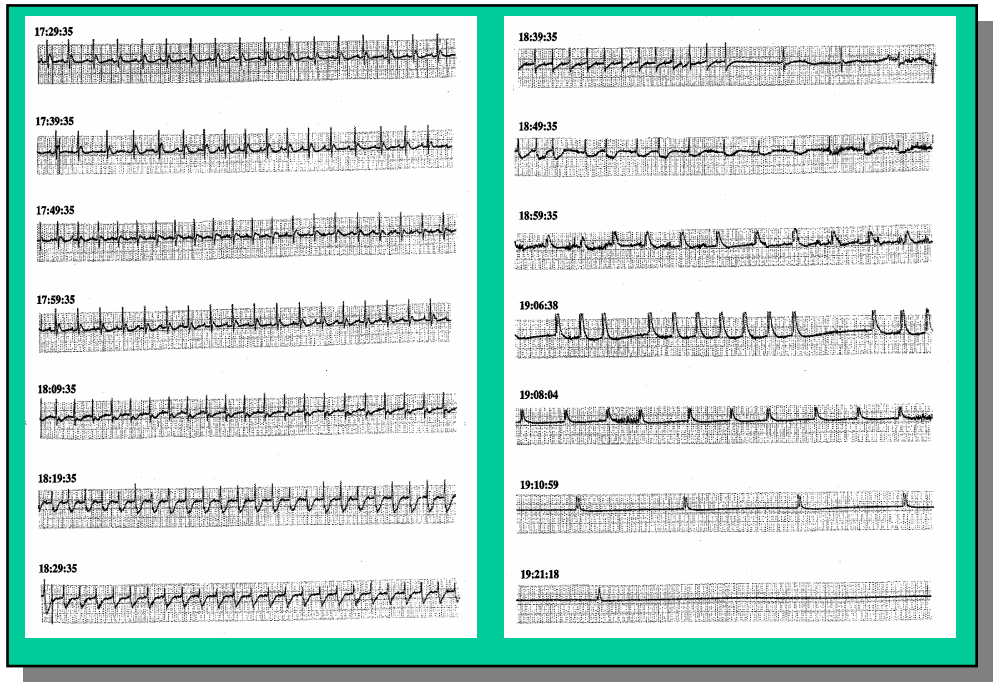


Figure 1. Univariate analyses for association between onset of MI and hourly concentrations of $PM_{2.5}$. Odds ratios and 95% CIs for an increase of 25 $\mu g/m^3$ $PM_{2.5}$.

Peters et al, 2001

ECG Abnormalities and death rats exposed to PM



Watkinson et al., 1998

Other Populations May Also Be Susceptible to PM

Diabetics

	Cases	Effect Estimate (%)	95% CI (%)	*P*-value Homogeneity
All Cases	33557	1.47	0.81, 2.13	
Atrial Fibrillation				
Yes	7976	1.24	-0.22, 2.72	
No	25581	1.54	0.82, 2.27	0.642
COPD				
Yes	7257	1.52	0.03, 3.04	
No	26300	1.46	0.74, 2.18	0.921
Type II Diabetes				
Yes	4354	2.91	1.15, 4.70	
No	29203	1.26	0.57, 1.95	0.045
Recent Myocardial Infarction				
Yes	1316	4.53	1.75, 7.38	
No	32241	1.34	0.67, 2.01	0.020
Ischemic Heart Disease				
Yes	12357	1.16	-0.20, 2.53	
No	21200	1.65	0.87, 2.43	0.392
Acute Respiratory Infections				
Yes	2113	0.10	-2.21, 2.46	
No	31444	1.56	0.89, 2.24	0.203

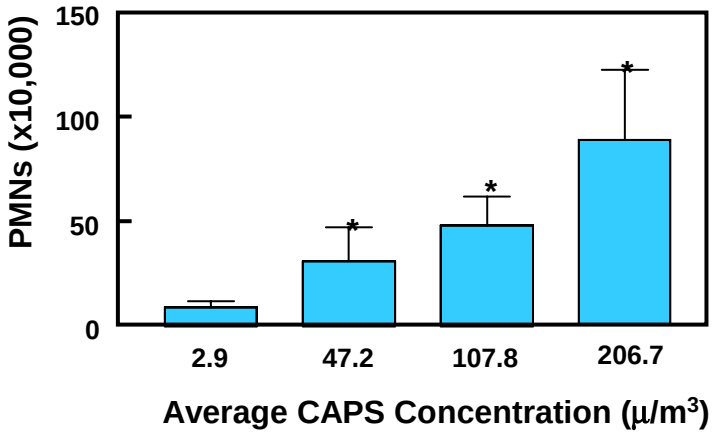
Zanobetti et al., 2002

Infants

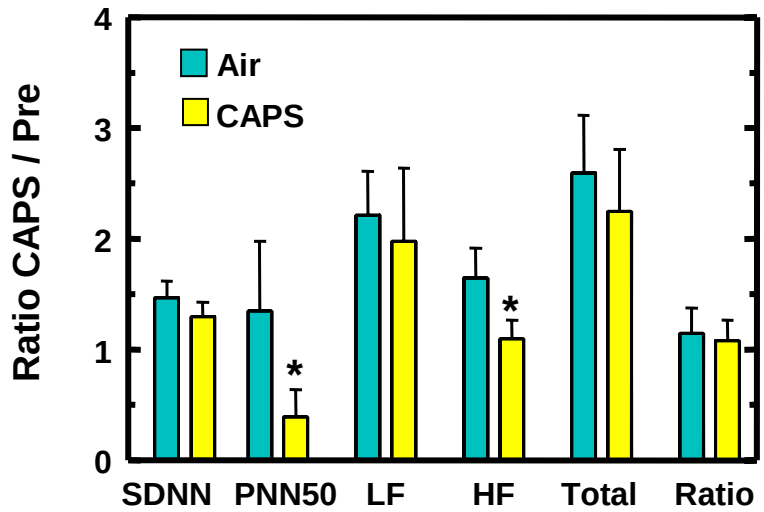
- 20% increase in pre-term births per 50 µg increase in PM10
- Association between cardiac and aortic artery defects in new-borns and CO, levels

Ritz et al., 2002

PM May Cause Effects in Healthy People



Ghio et al., 2003

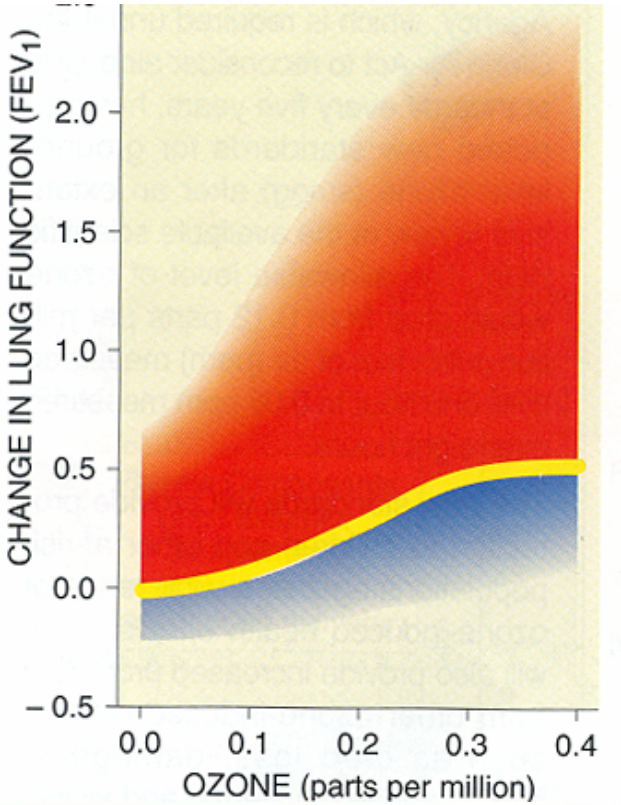


Devlin et al., 2003

The Role of Genes in Susceptibility to Pollutants

Genes load the gun.

The environment pulls the trigger.



The extent of O_3 induced decrements in lung function varies by almost an order of magnitude in normal healthy subjects.

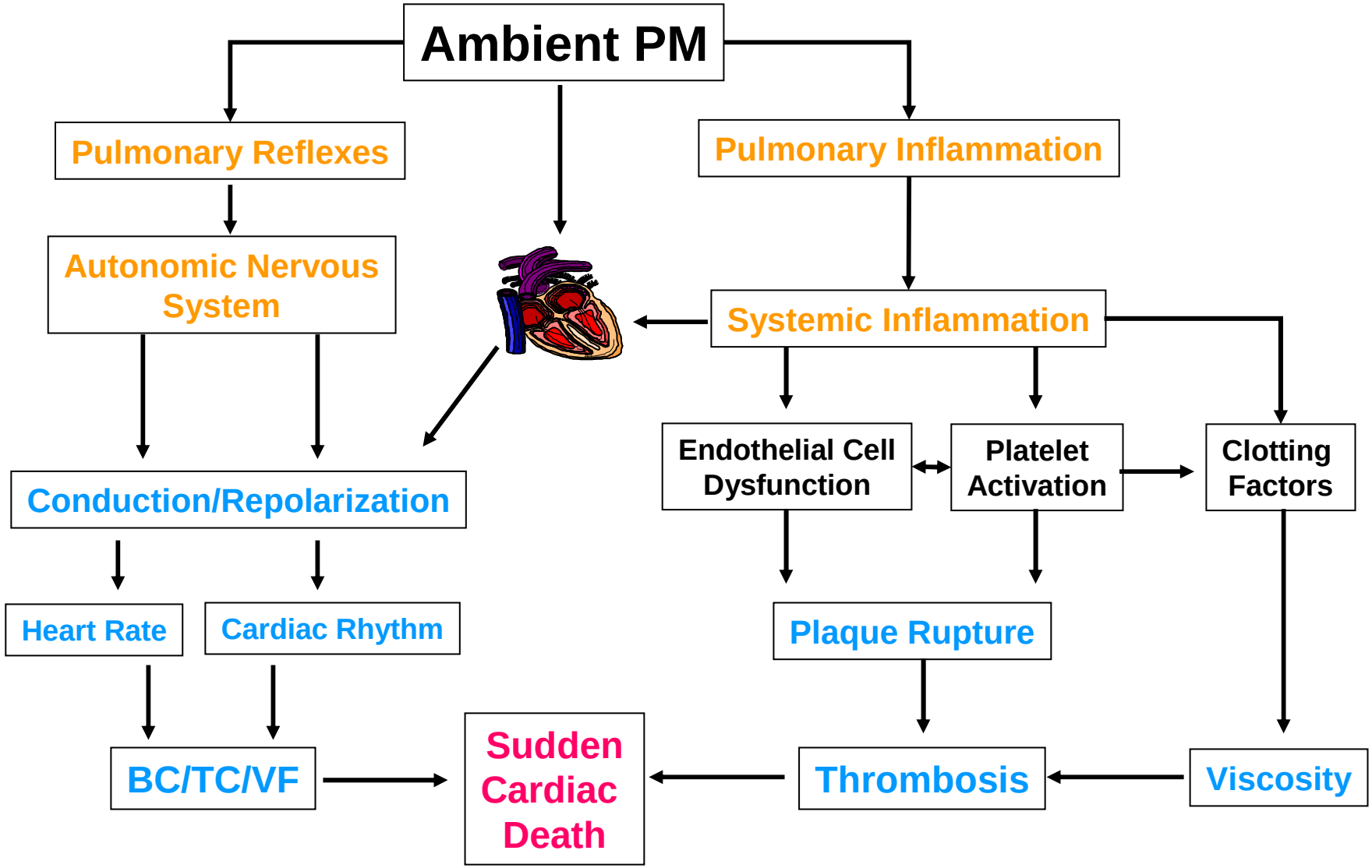
Subjects brought back for a second exposure show the same degree of response, suggesting a genetic contribution to O_3 responsiveness.

McDonnell et al., 1993

HOW Does PM Cause Adverse Health Effects?

A New Kind of Challenge to Air Pollution Toxicologists

- **Traditionally, toxicologists have focused on respiratory tract responses to air pollutants**
  - Ozone, NO_2, SO_2
- **The association between PM and cardiovascular effects required a new approach to the study of air pollution**
  - CV effects, vascular effects (clotting, endothelial cell dysfunction)


Ambient PM
Pulmonary Reflexes
Pulmonary Inflammation
Autonomic Nervous System
Systemic Inflammation
Endothelial Cell Dysfunction
Platelet Activation
Clotting Factors
Conduction/Repolarization
Heart Rate
Cardiac Rhythm
Plaque Rupture
BC/TC/VF
Sudden Cardiac Death
Thrombosis
Viscosity

Suwa et al. (2002)

Exposure to PM collected from Ottowa caused a progression of atherosclerotic lesions towards a more advanced phenotype in hyperlipidemic rabbits.

Seaton et al. (1999)

Elevation in CRP associated with increase in PM; decrease in red blood cells (Aberdeen study)

Peters et al. (2000)

Elevation in CRP associated with increase in PM (MONICA study)

Seaton et al. (1999)

Aberdeen PM exposure associated with increased plasma fibrinogen, Factor VII

Prescott et al. (2001)

Edinburgh PM exposure associated with increased plasma fibrinogen

Costa et al. (1997)

Severe arrhythmias in monocrotaline treated rats exposed to ROFA

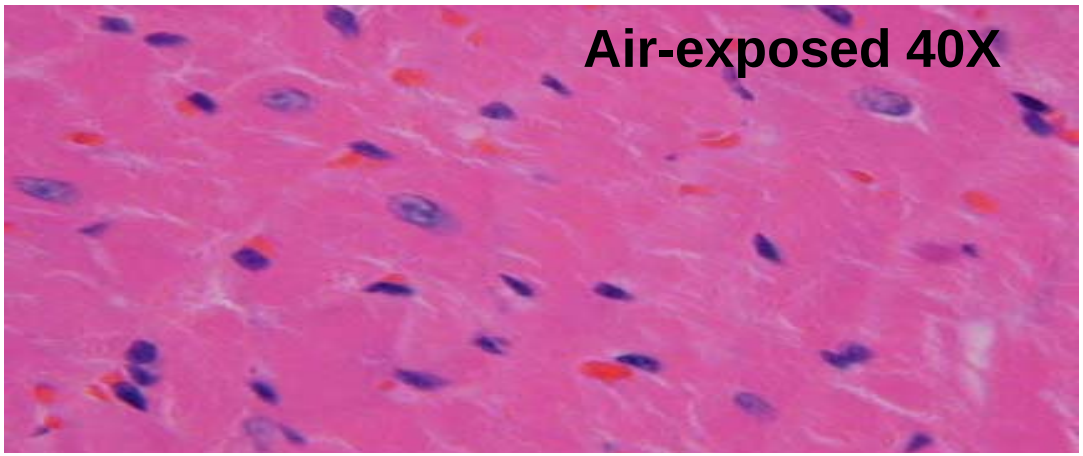
Muggenburg et al. (2000)

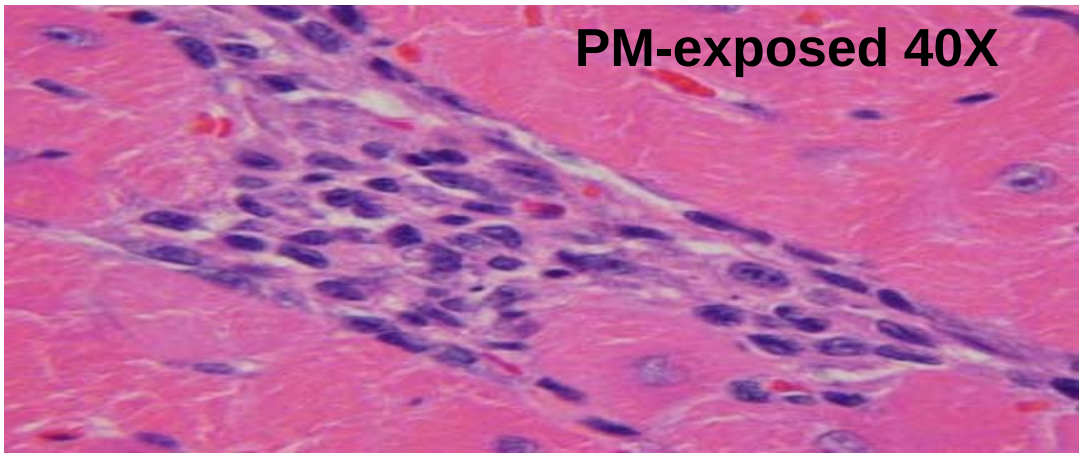
Slight bradycardia in dogs exposed to ROFA

Watkinson et al. (2000)

Increased arrthythmias in older rats exposed to PM collected in Ottowa

Direct Cardiac Injury in Rats Exposed to PM

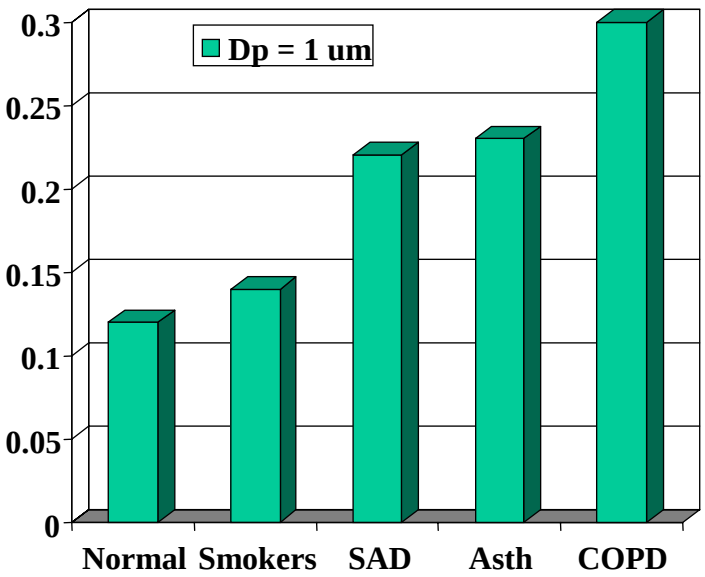


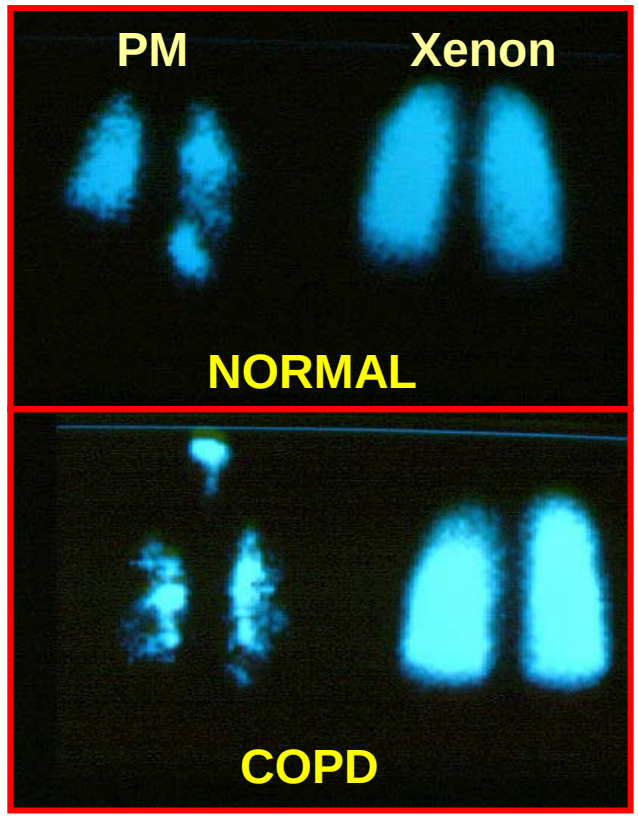


Rats exposed to ambient PM – 1 d/wk/16 wks

Kodavanti et al., 2003

Deposition and Clearance of Inhaled Particles





Kim et al., 1997

WHAT Are the PM Component(s) Responsible for These Effects?

PM Is a Very Complex Pollutant

PM-Associated Attributes

Size

Surface Area

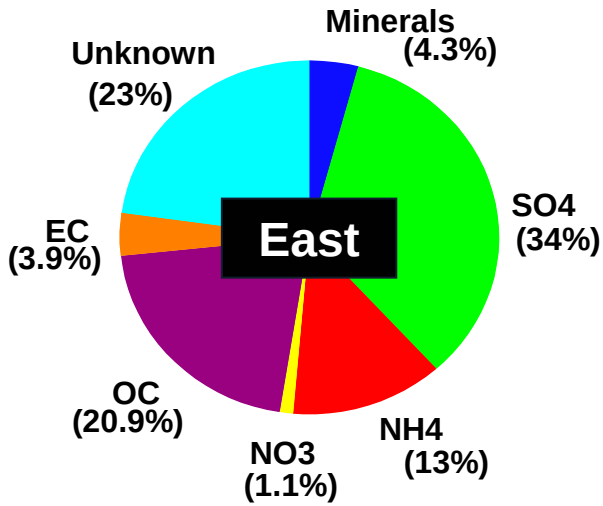
Acids

Metals

Organics

Peroxides

Bioaerosols

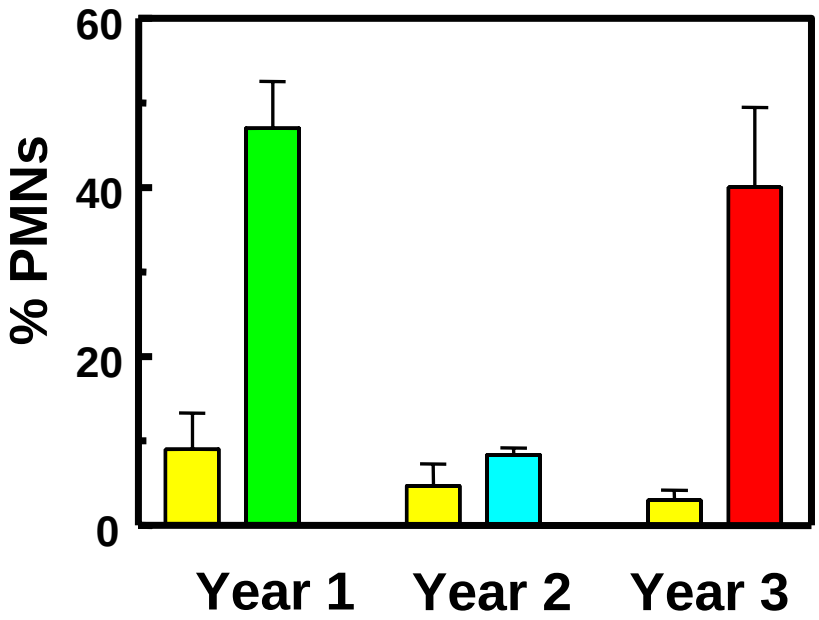


Geneva Steel Mill: The Utah Valley

Concentration (μg/g)	Jan-Mar 1986 (open)	Jan-Mar 1987 (closed)	Jan-Mar 1988 (open)
Iron	107.2	50.2	117.8
Copper	163.3	50.5	327.0
Zinc	264.8	95.5	113.2
Lead	91.7	30.5	122.2
Nickel	18.6	26.9	18.6

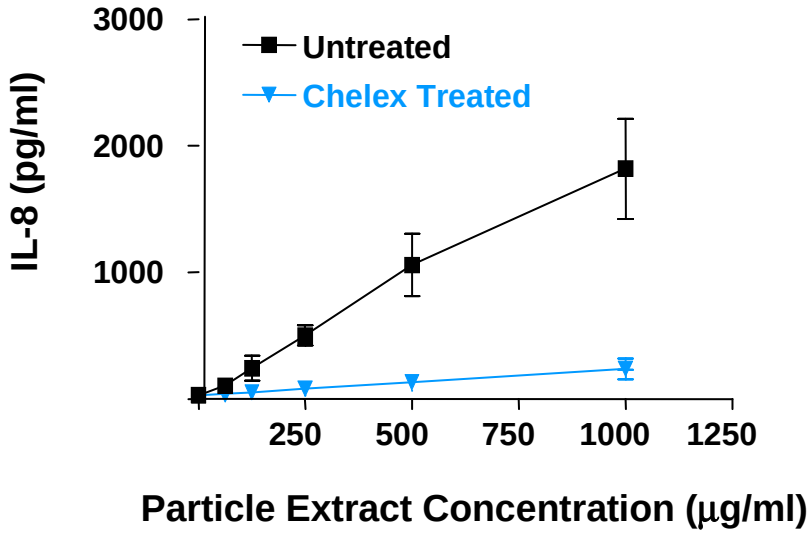
Metals Present in UV PM Can Cause Lung Inflammation and Injury

Instillation of UV PM into Human Lungs

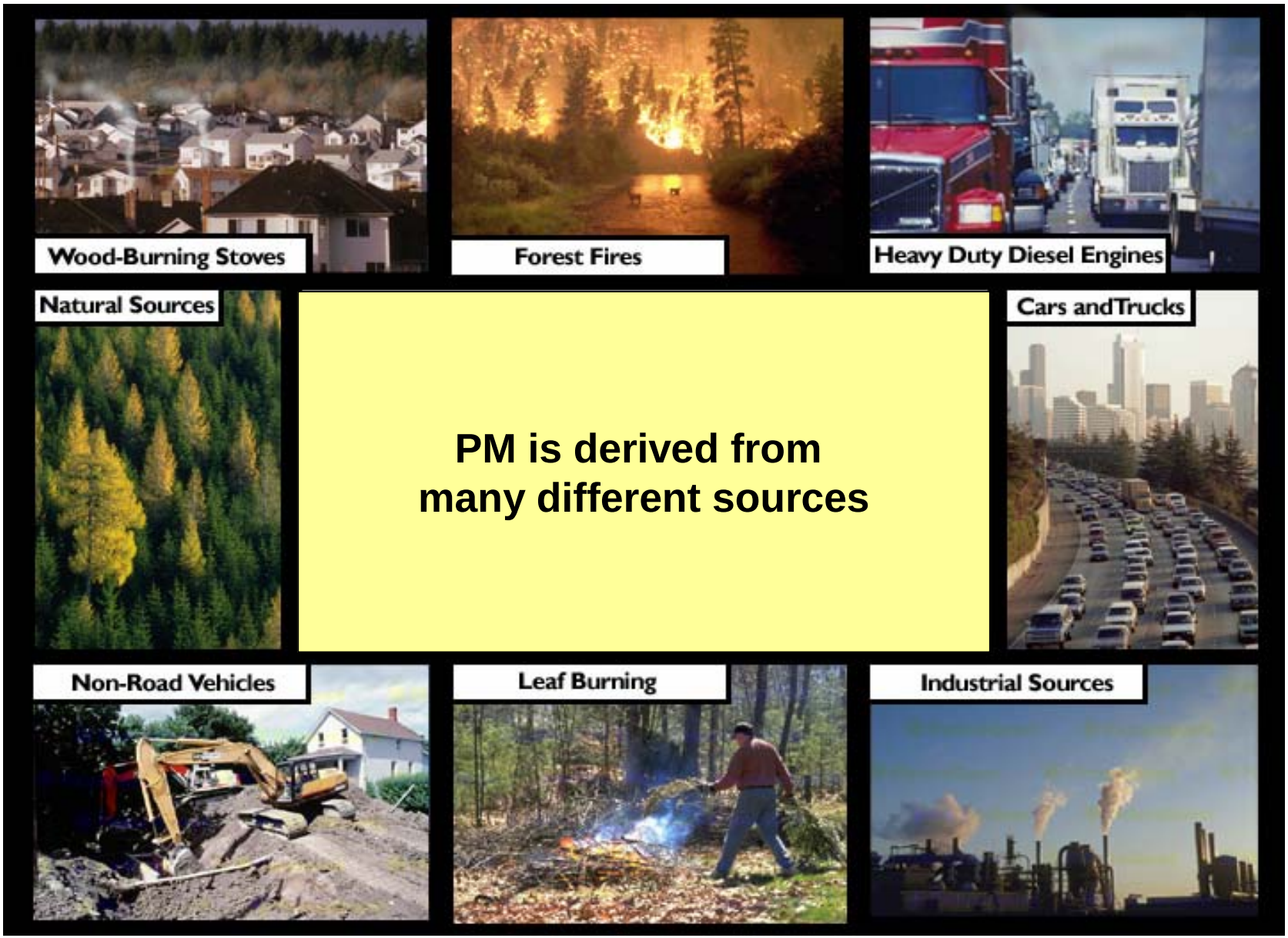


Ghio et al., 2001

Removal of metals eliminates inflammation

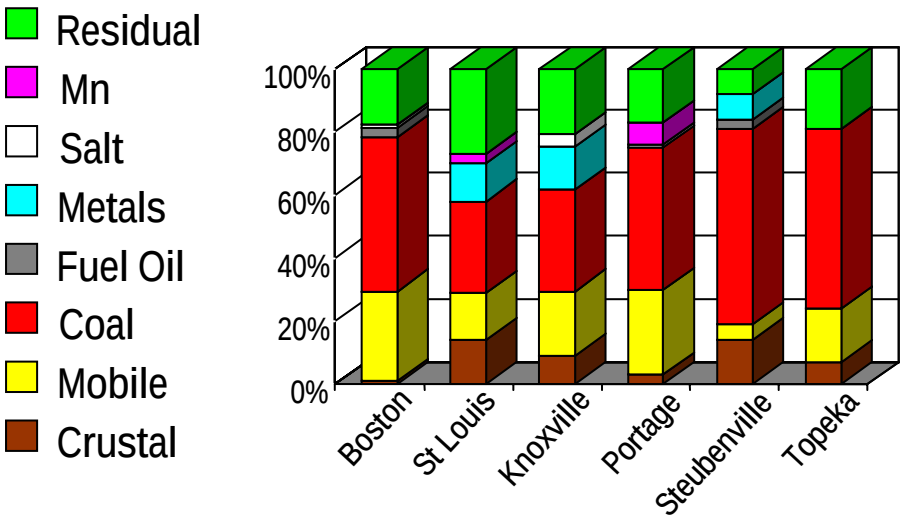


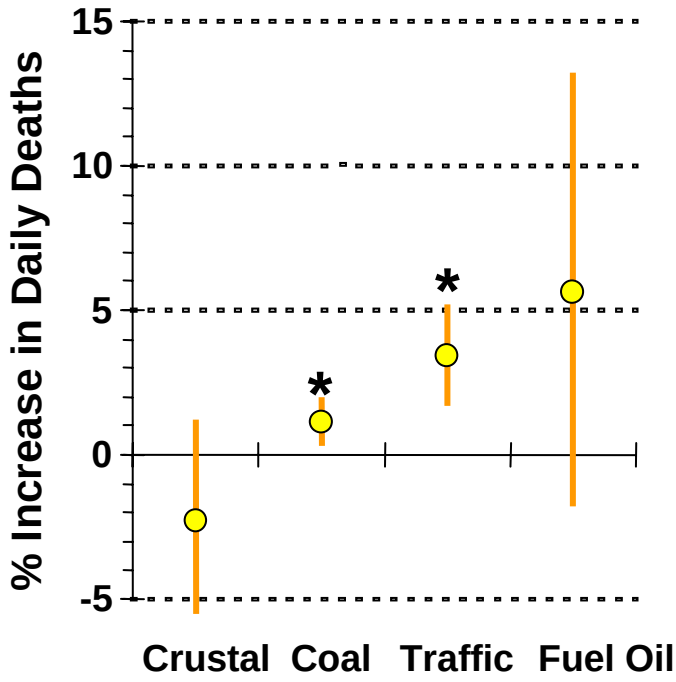
Molineri et al., 2002


Wood-Burning Stoves
Forest Fires
Heavy Duty Diesel Engines
Natural Sources
PM is derived from
many different sources
Cars andTrucks
Non-Road Vehicles
Leaf Burning
Industrial Sources

Can We Link PM Effects with Specific Sources of Pollution?

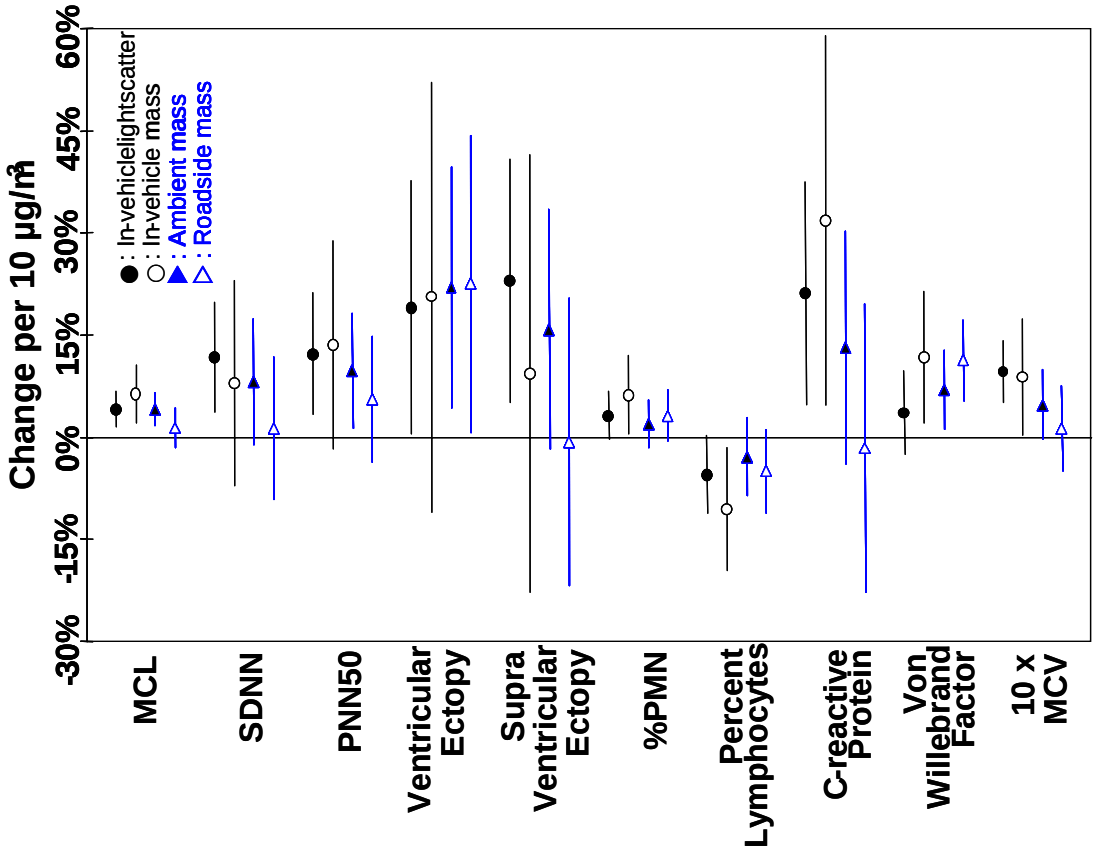
Speciation monitoring of airsheds of differing composition may enable identification of components, and sources of those components, that contribute to adverse health outcomes





Laden et al., 2000

Cardiovascular Effects Associated with PM Derived from Mobile Sources



Riediker et al., 2004

Will It Matter if Air Pollution Decreases?

The Dublin Experience

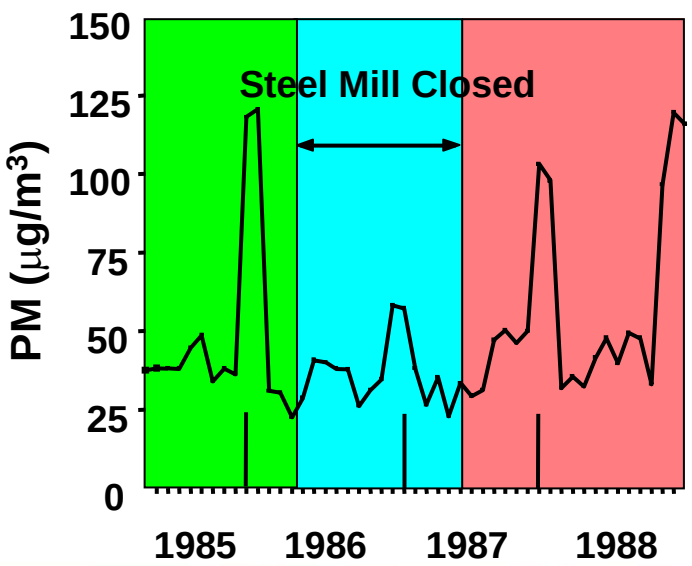
- **Dublin's air quality deteriorated in the 1980s after a switch from oil to cheaper bituminous coal for heating.**
- **In 1990 the Irish Government banned the use of bituminous coal within the city of Dublin, resulting in a reduction in PM concentrations.**

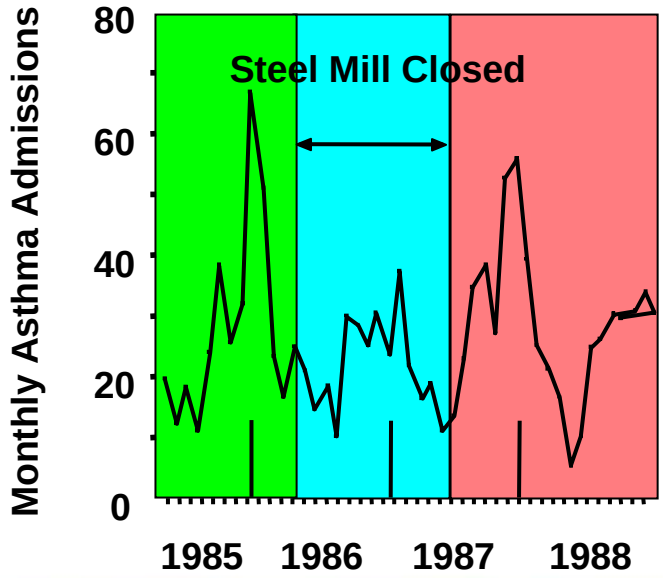
Table 3. Change in age-standardized total, cause-specific, and age-specific mortality rates for Dublin County Borough for 72 months before and after ban of sale of coal in Dublin

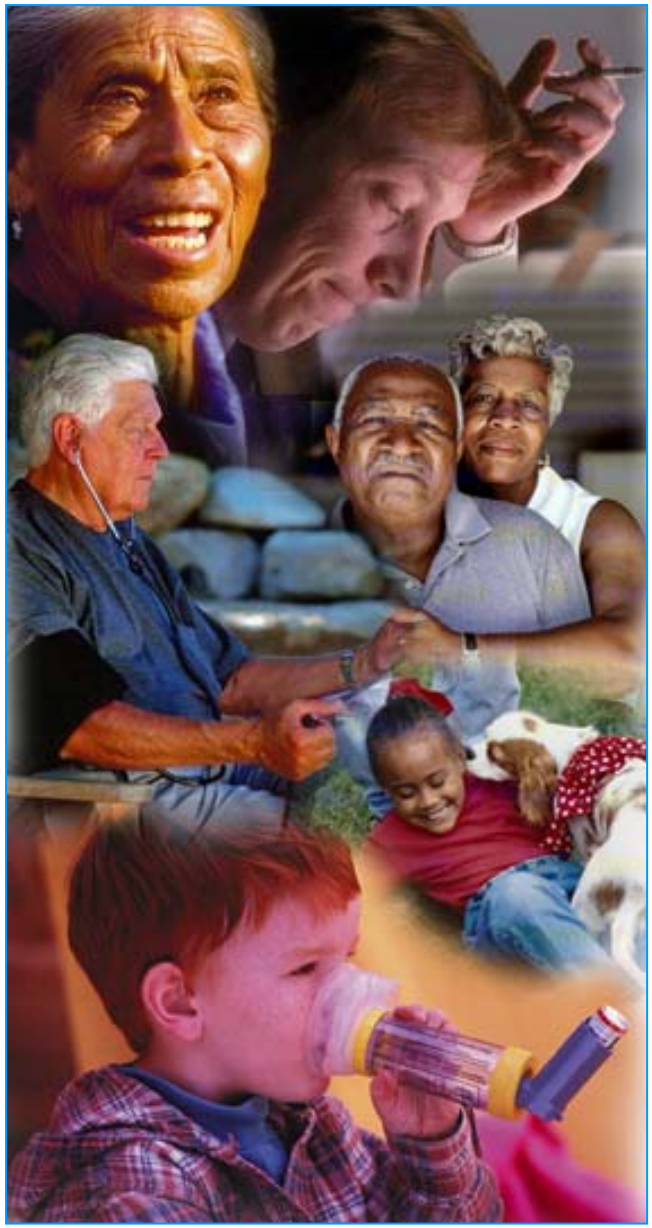
	Unadjusted % change (95% CI)	P	Adjusted % change* (95% CI)	p
Total				
Non–trauma	−8 · 0 (−9 · 8 *to* −6 · 2)	< 0 · 0001	−5 · 7 (−7 · 2 *to* −4 · 1)	< 0 · 0001
Cause-specific				
Cardiovascular	−13 · 4 (−15 · 9 *to* −10 · 8)	< 0 · 0001	−10 · 3 (−12 · 6 *to* −8 · 0)	< 0 · 0001
Respiratory	−16 · 1 (−20 · 4 *to* −11 · 6)	< 0 · 0001	−15 · 5 (−19 · 1 *to* −11 · 6)	< 0 · 0001
Other	1 · 4 (−1 · 6 *to* 4 · 6)	0 · 36	1 · 7 (−0 · 7 *to* 4 · 2)	0 · 17
Age-specific				
Younger than age 60 years	−8 · 1 (−12 · 3 *to* −3 · 7)	< 0 · 0001	−7 · 9 (−12 · 0 *to* −3 · 6)	< 0 · 0001
Age 60–74 years	−8 · 6 (−12 · 3 *to* −9 · 6)	< 0 · 0001	−6 · 2 (−8 · 8 *to* −3 · 5)	< 0 · 0001
Age 75 years or older	−7 · 6 (−8 · 1 *to* −7 · 0)	< 0 · 0001	−4 · 5 (−6 · 7 *to* −2 · 3)	< 0 · 0001

Clancy et al, 2002

The Utah Valley







EPA's Goal for Clean Air

"The air in every American community will be safe and healthy to breathe. In particular, children, the elderly, and people with respiratory ailments will be protected from health risks of breathing polluted air."