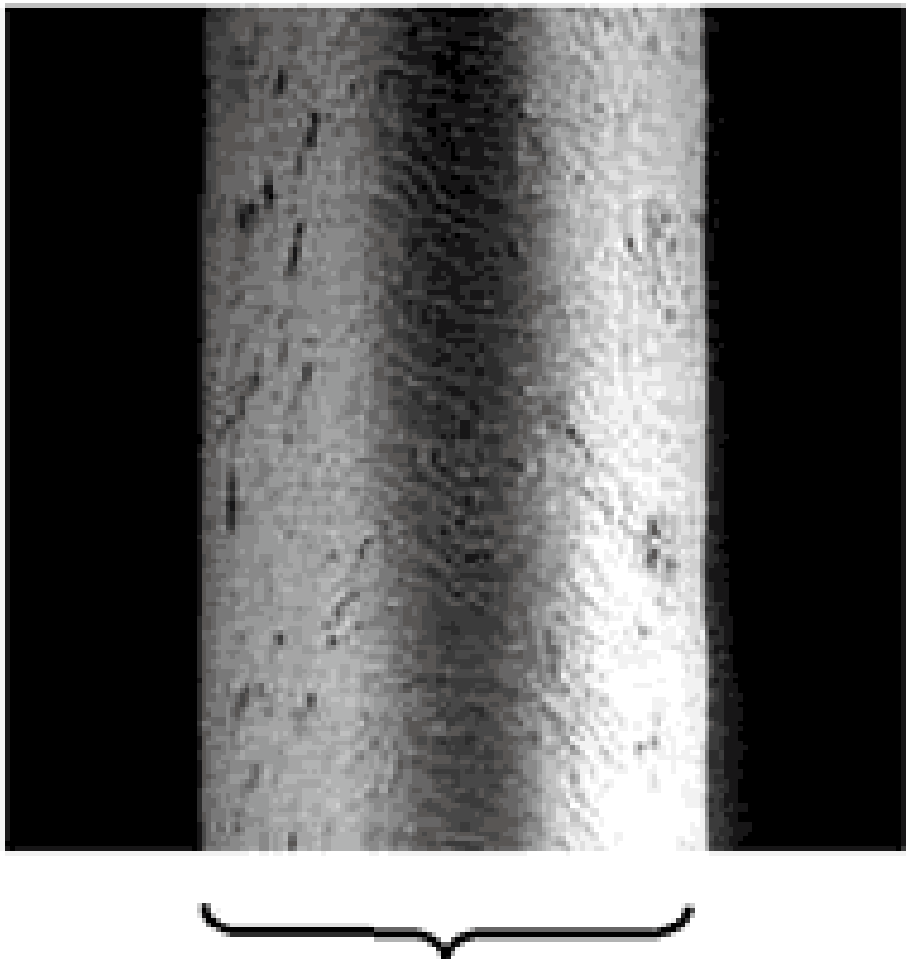
Controlling Air Pollution in Utah:
Trends, Health and Economic Benefits

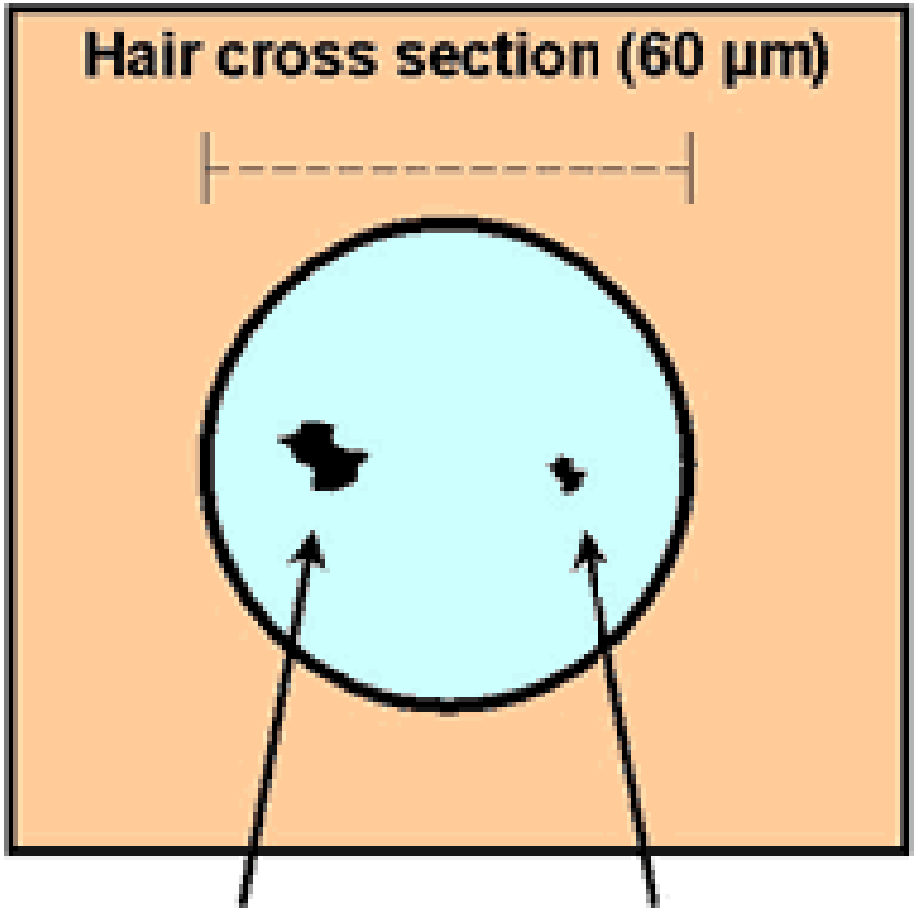
C. Arden Pope III, Ph.D.
Mary Lou Fulton Professor of Economics

Presented at
Economic Development Task Force
Utah Legislature
October 4, 2012

How small are fine particles?

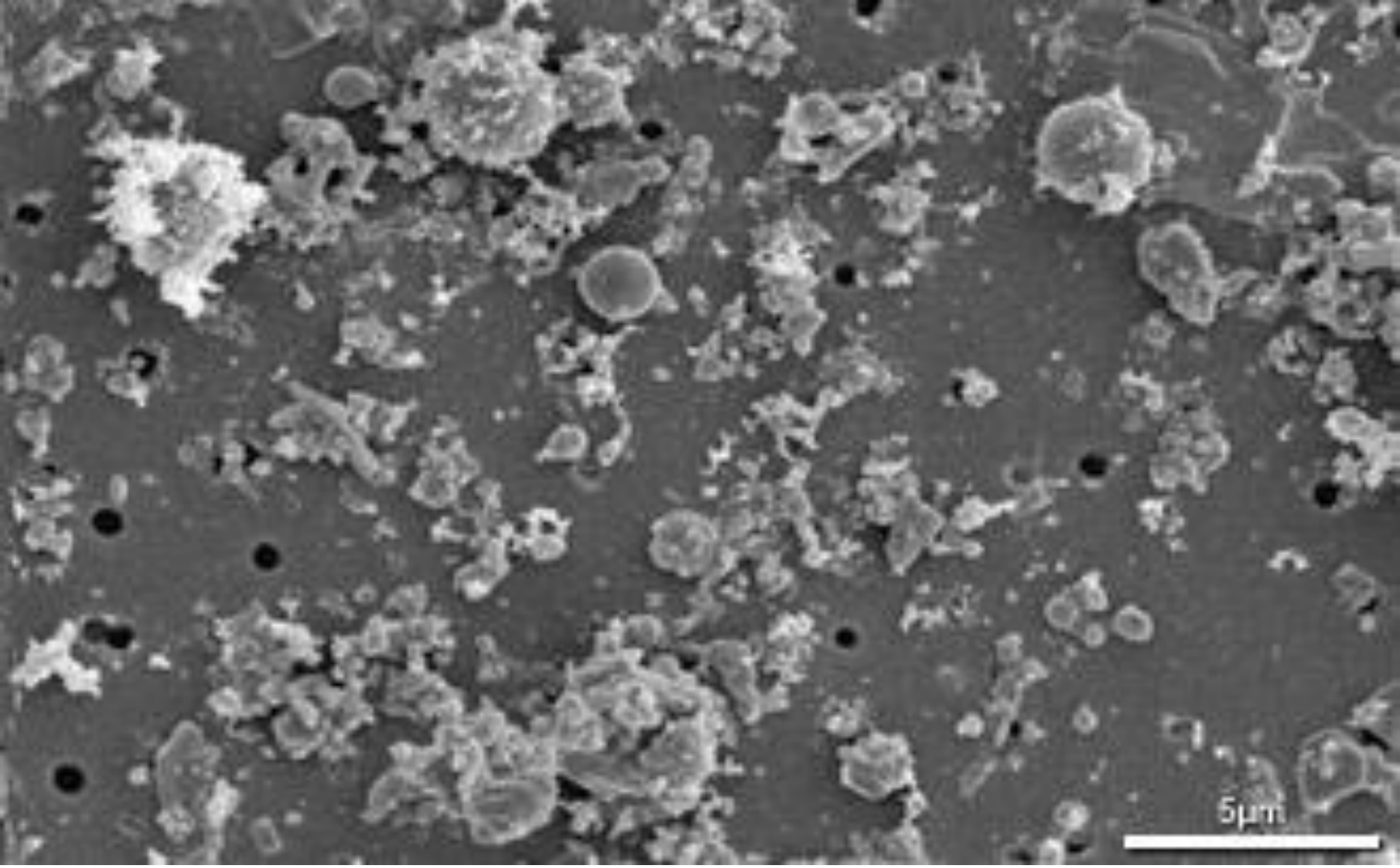


Human Hair
(60 μm diameter)



PM_{10}
(10 μm)

$PM_{2.5}$
(2.5 μm)

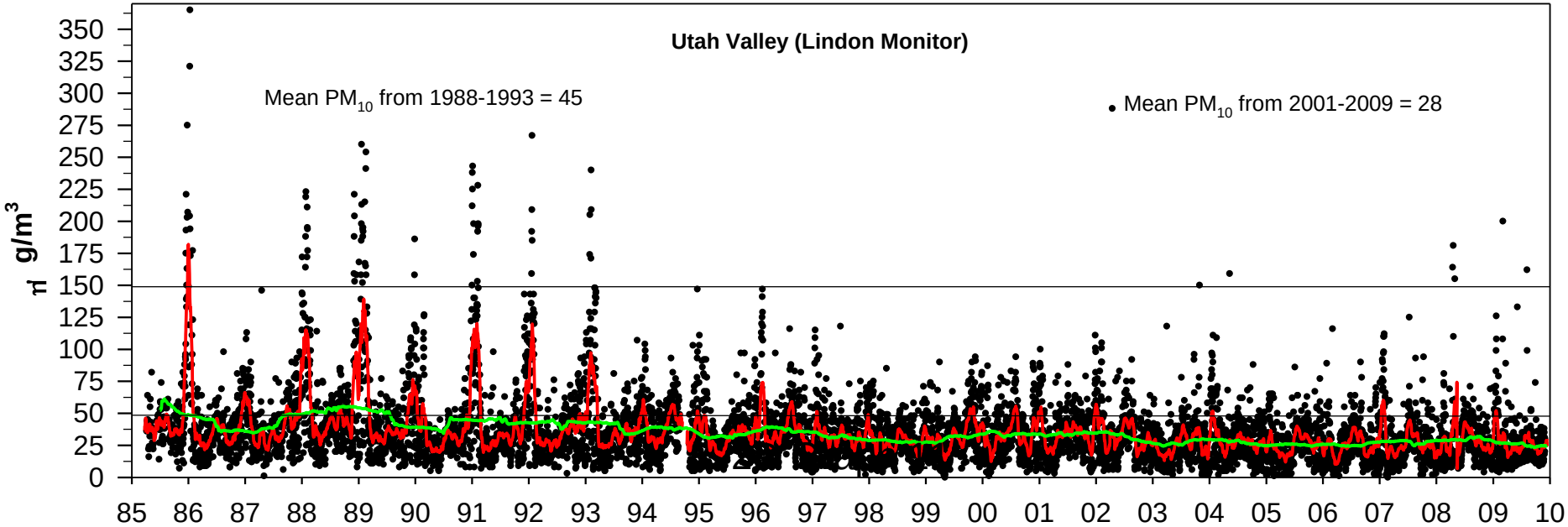


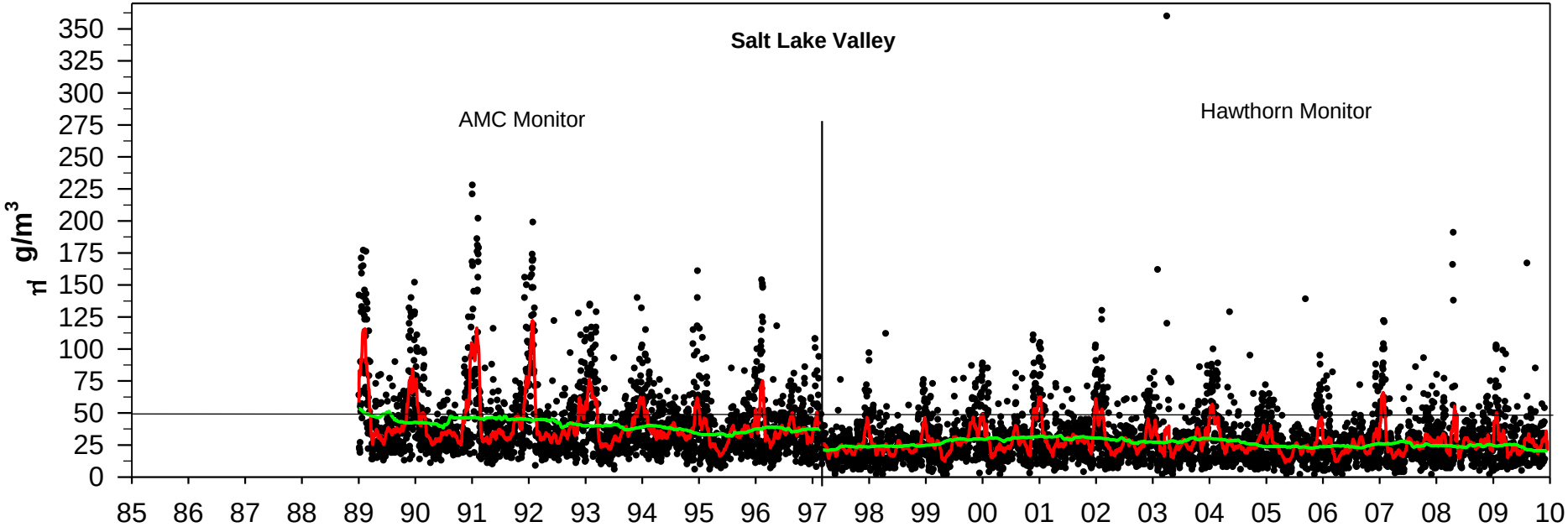
Magnified ambient particles (www.nasa.gov/vision/earth/environment)

Air pollution over SLC, UT

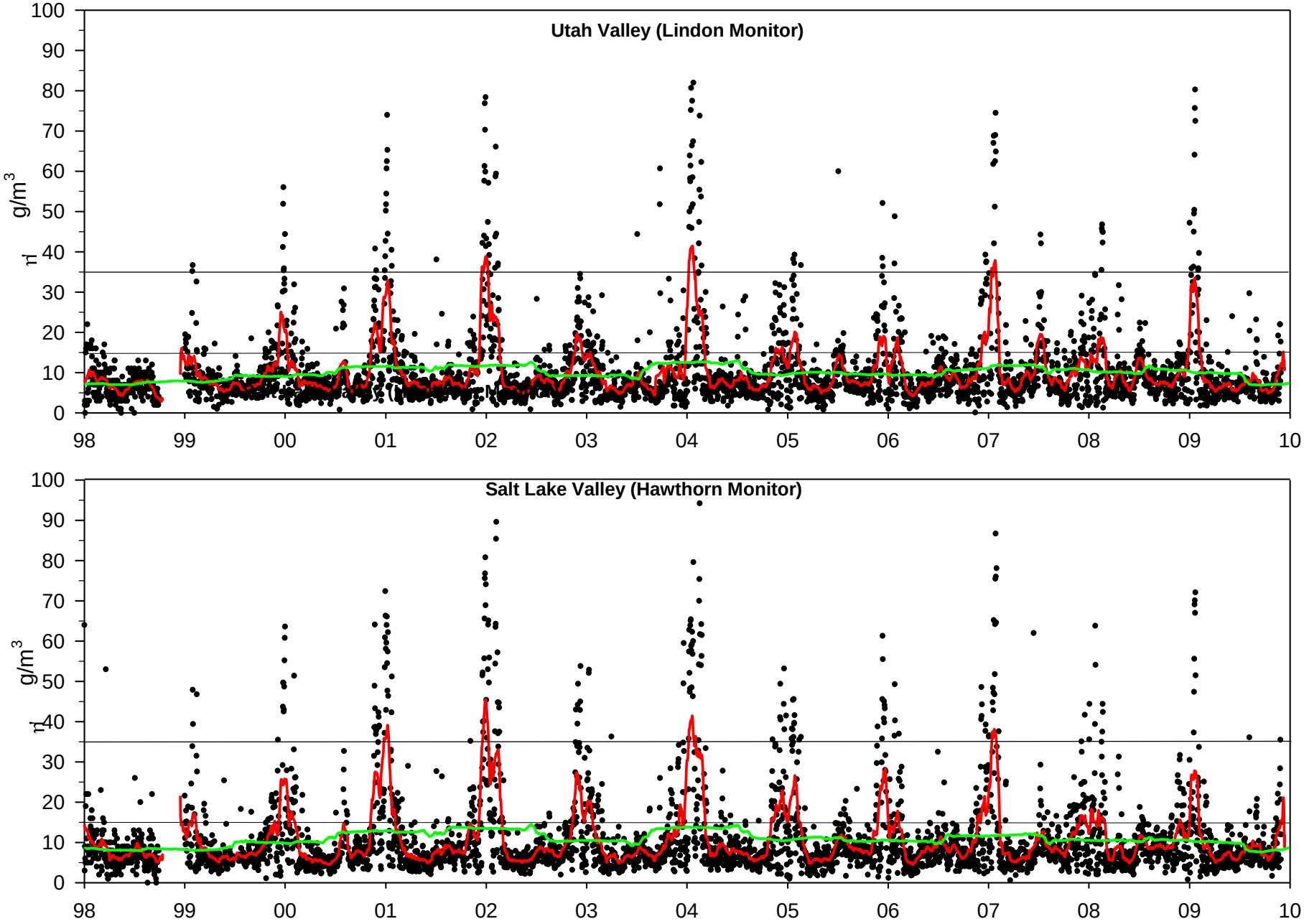
High concentrations of fine particles clearly cause ugly haze. . .

But what is the evidence that they contributes to adverse human health effects?





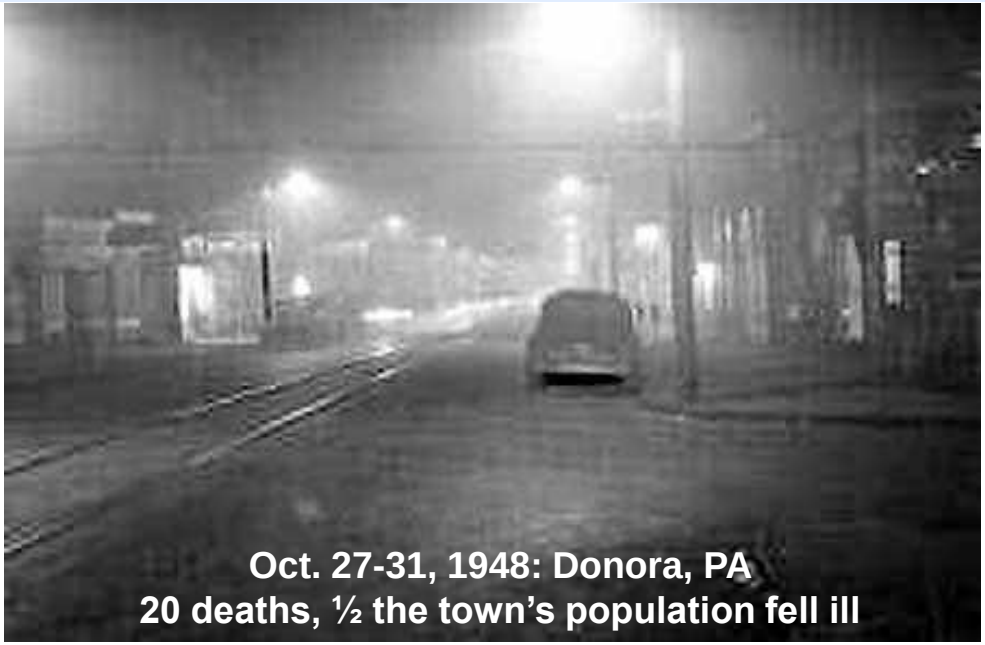
PM_{10} concentrations in Utah and Salt Lake Valleys, April 1985 - December 2009. Black dots, 24-hr PM_{10}, Red line, 30-day moving average PM_{10}, Green line, 1-yr moving average PM_{10}



$PM_{2.5}$ concentrations January 1 1998-December 12 2009. Black dots, 24-hr $PM_{2.5}$; Red line, 30-day moving average $PM_{2.5}$; Green line, 1-yr moving average $PM_{2.5}$.

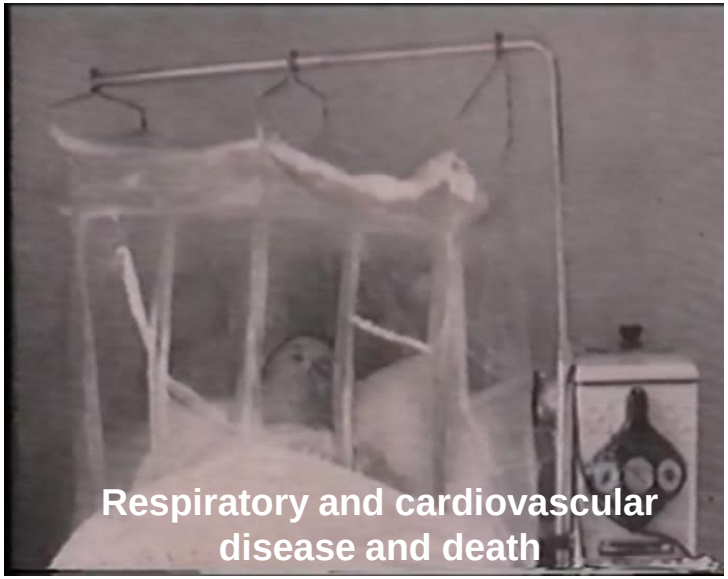
Early **“Killer smog”** episodes demonstrated that air pollution at extreme levels can contribute to respiratory and cardiovascular disease and death

Dec. 1-5, 1930: Meuse Valley, *Belgium*
60 deaths (10x expected)



Oct. 27-31, 1948: Donora, PA
20 deaths, ½ the town’s population fell ill

Dec. 5-9, 1952: London--1000’s of excess deaths

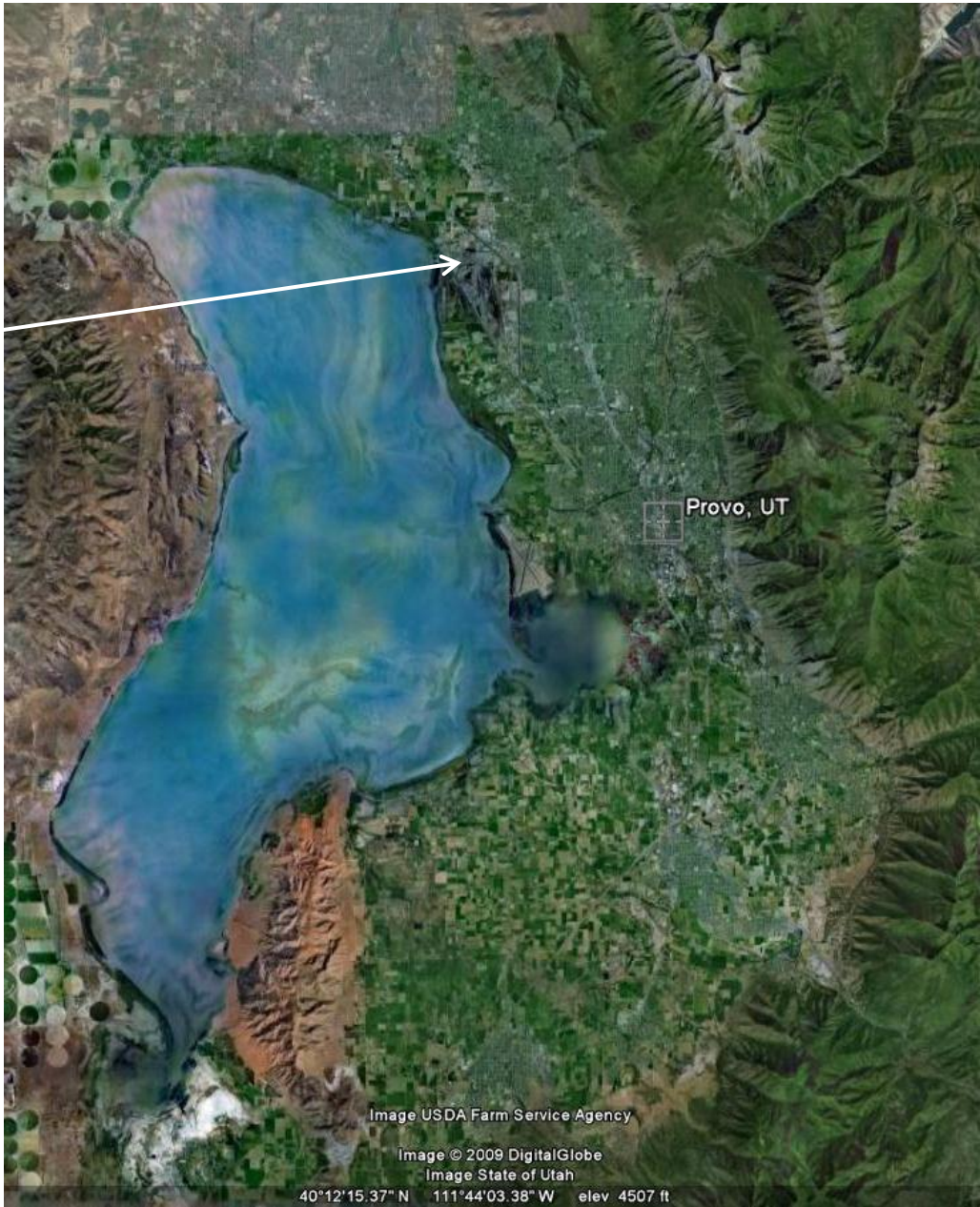


Respiratory and cardiovascular disease and death

Utah Valley, 1980s

- **Winter inversions trap local pollution**
- **Natural test chamber**

- **Local Steel mill contributed ~50% $PM_{2.5}$**
- **Shut down July 1986-August 1987**
- **Natural Experiment**

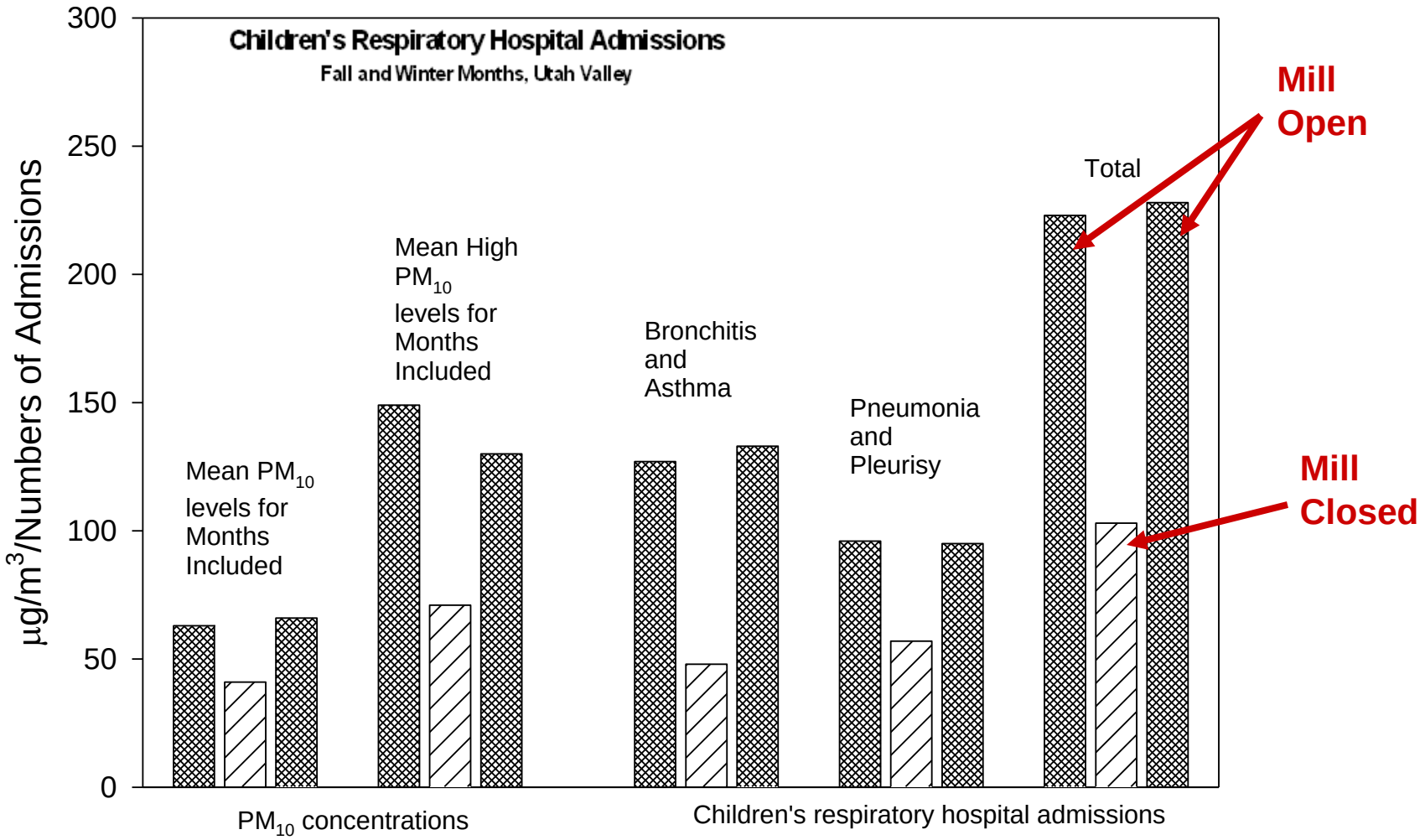


Large difference in air quality when inversions trap air pollution in valley

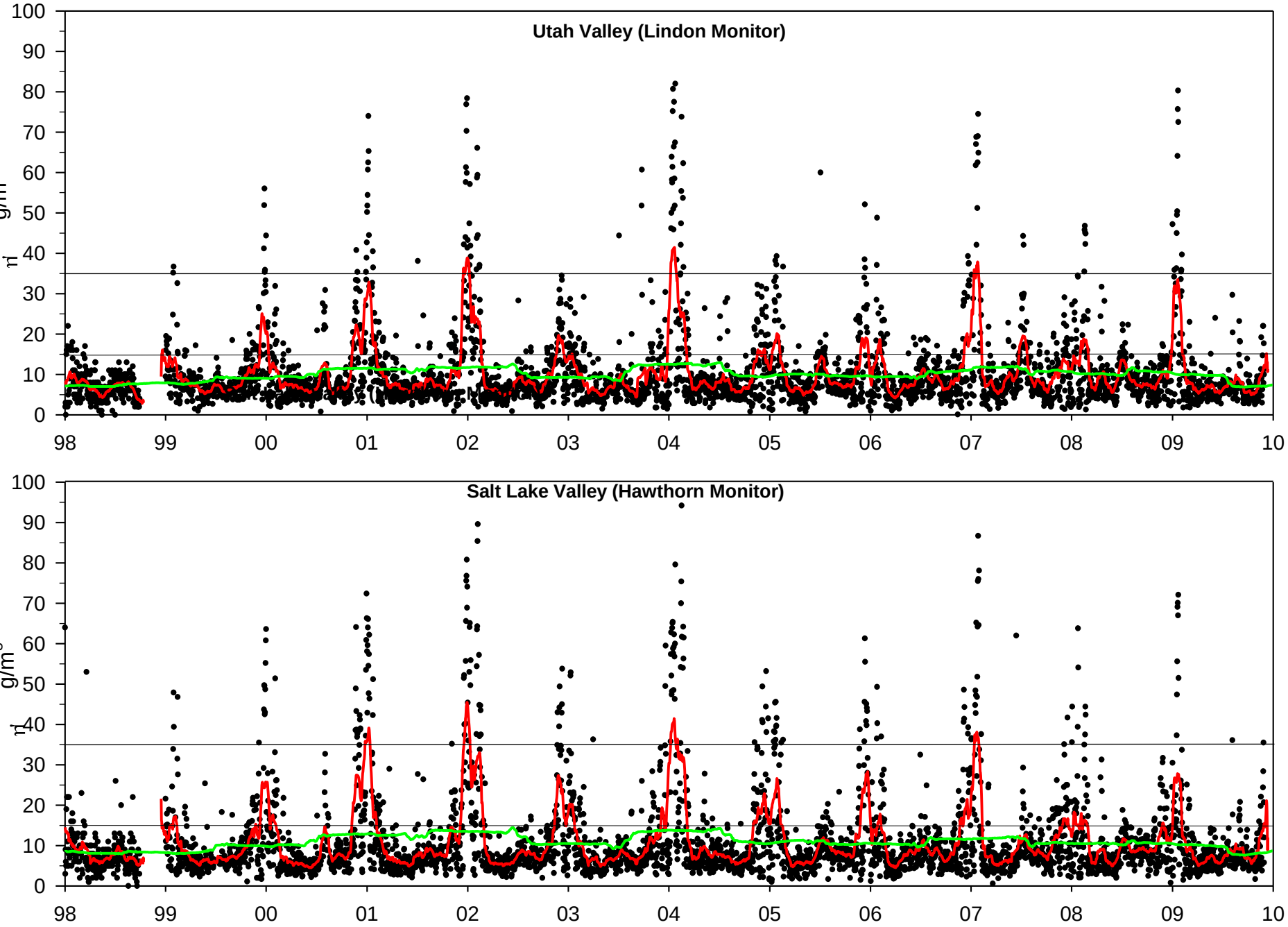
Utah Valley: Clean day

Utah Valley: Dirty day
(PM_{10} = 220 $\mu g/m^3$)

When the steel mill was open, total children's hospital admissions for respiratory conditions **approx. doubled.**

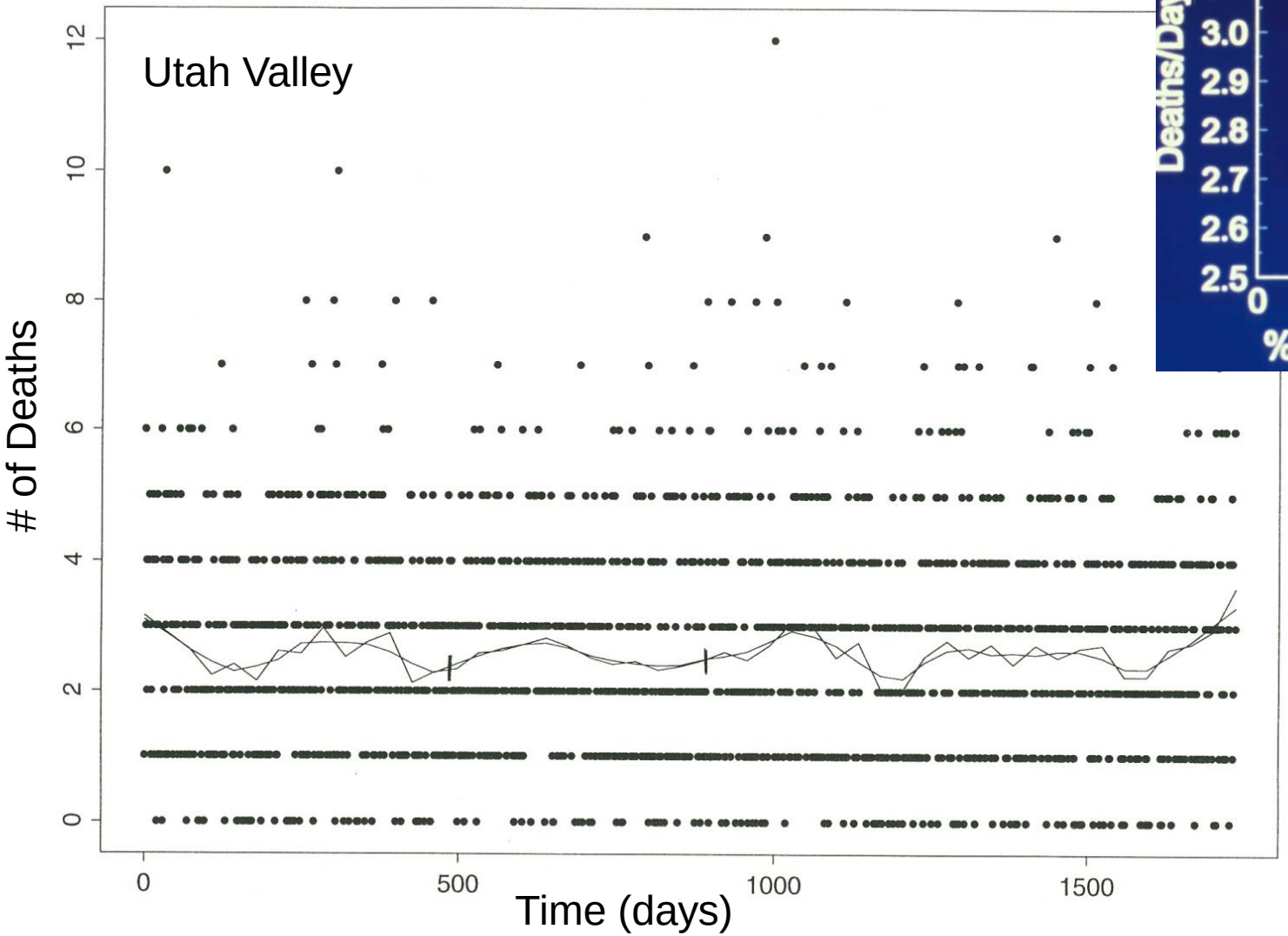


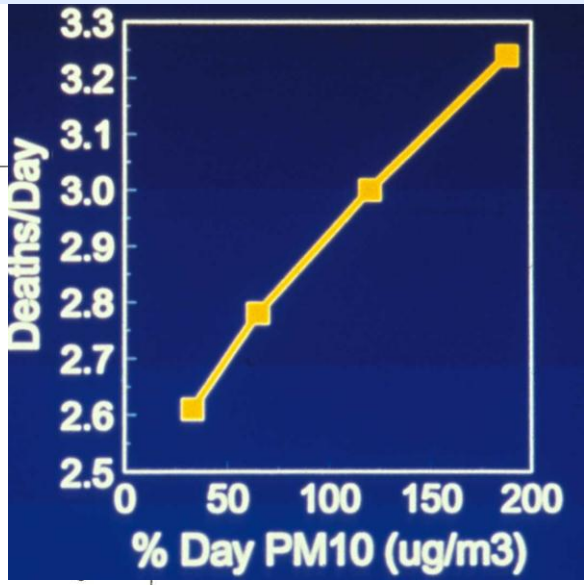
Sources: Pope. Am J Pub Health.1989; Pope. Arch Environ Health. 1991



$PM_{2.5}$ concentrations January 1 1998-December 12 2009. Black dots, 24-hr $PM_{2.5}$; Red line, 30-day moving average $PM_{2.5}$; Green line, 1-yr moving average $PM_{2.5}$.

Daily changes in air pollution ➡ **daily death counts**



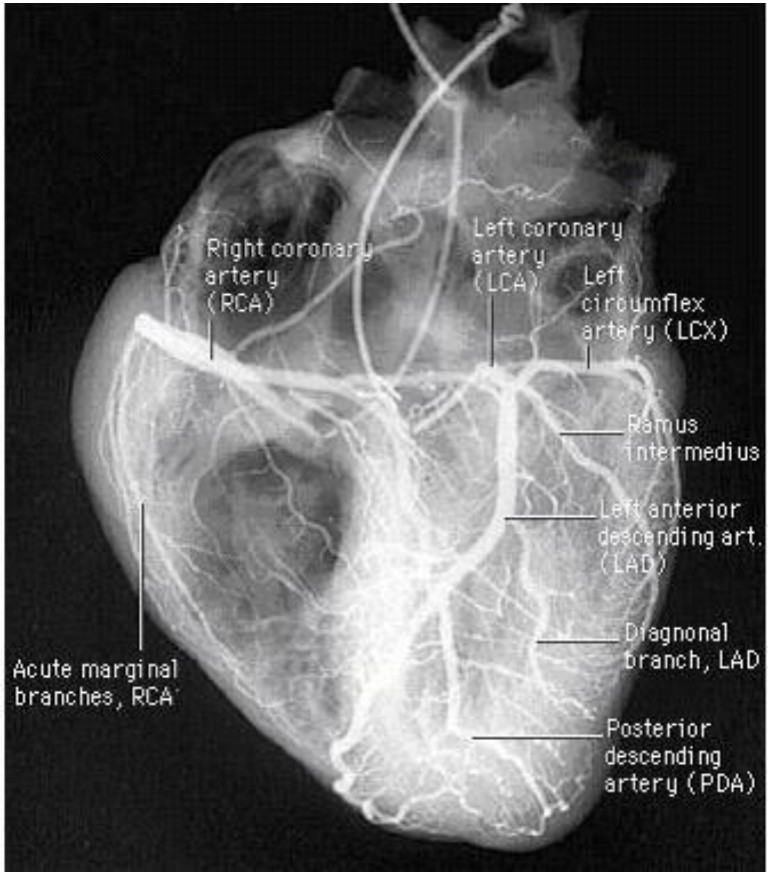


Evidence mounted suggesting that air pollution has significant impacts on cardiovascular health.

Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION
2006;114:2443-48

Ischemic Heart Disease Events Triggered by Short-Term Exposure to Fine Particulate Air Pollution

C. Arden Pope III, PhD; Joseph B. Muhlestein, MD; Heidi T. May, MSPH; Dale G. Renlund, MD; Jeffrey L. Anderson, MD; Benjamin D. Horne, PhD, MPH



- **Case-crossover study of acute ischemic coronary events (heart attacks and unstable angina) in 12,865 cardiac patients on Utah's Wasatch Front**
- **Patients underwent coronary angiography**
- **Results showed associations between air pollution and cardiovascular disease**

Just a few days of PM exposure significantly increased risk for heart attacks and ischemic heart disease.

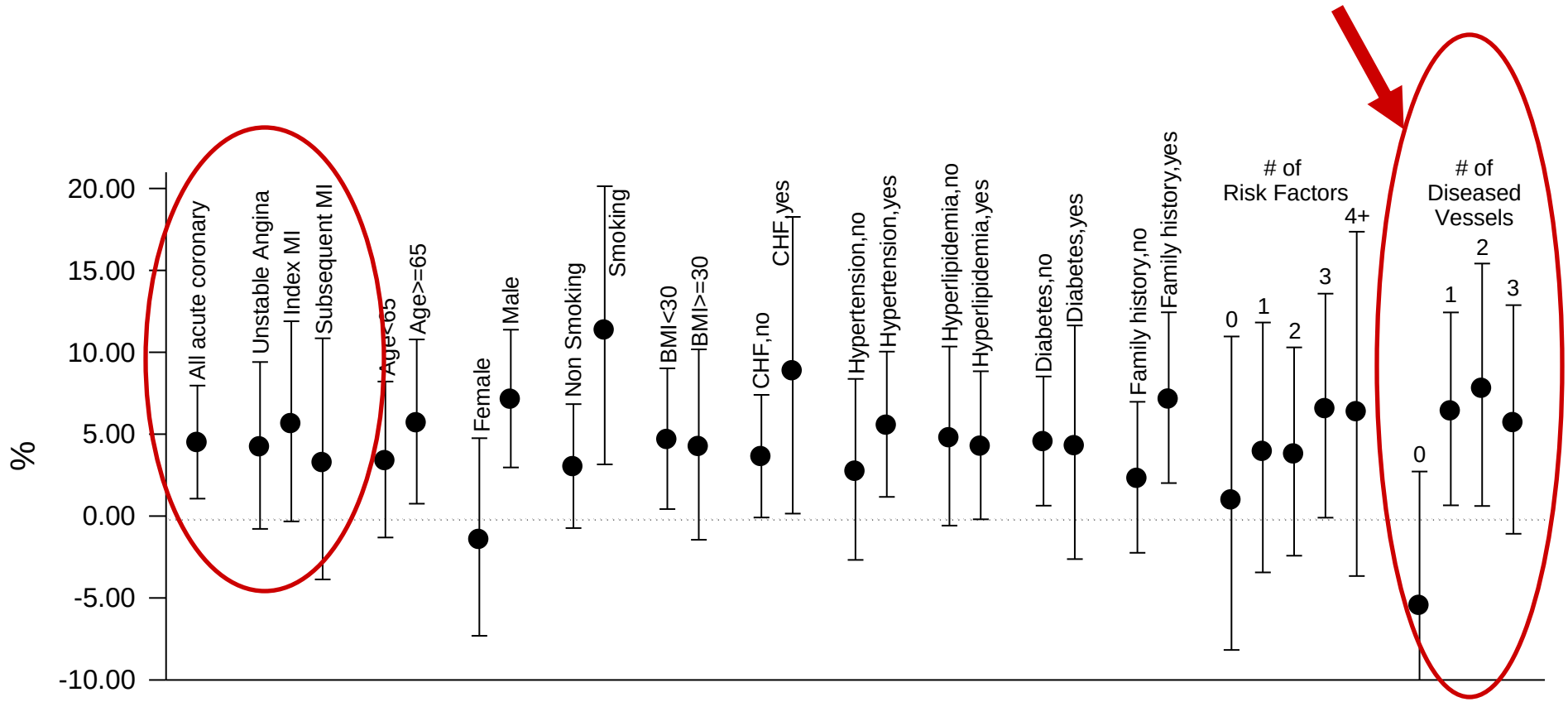
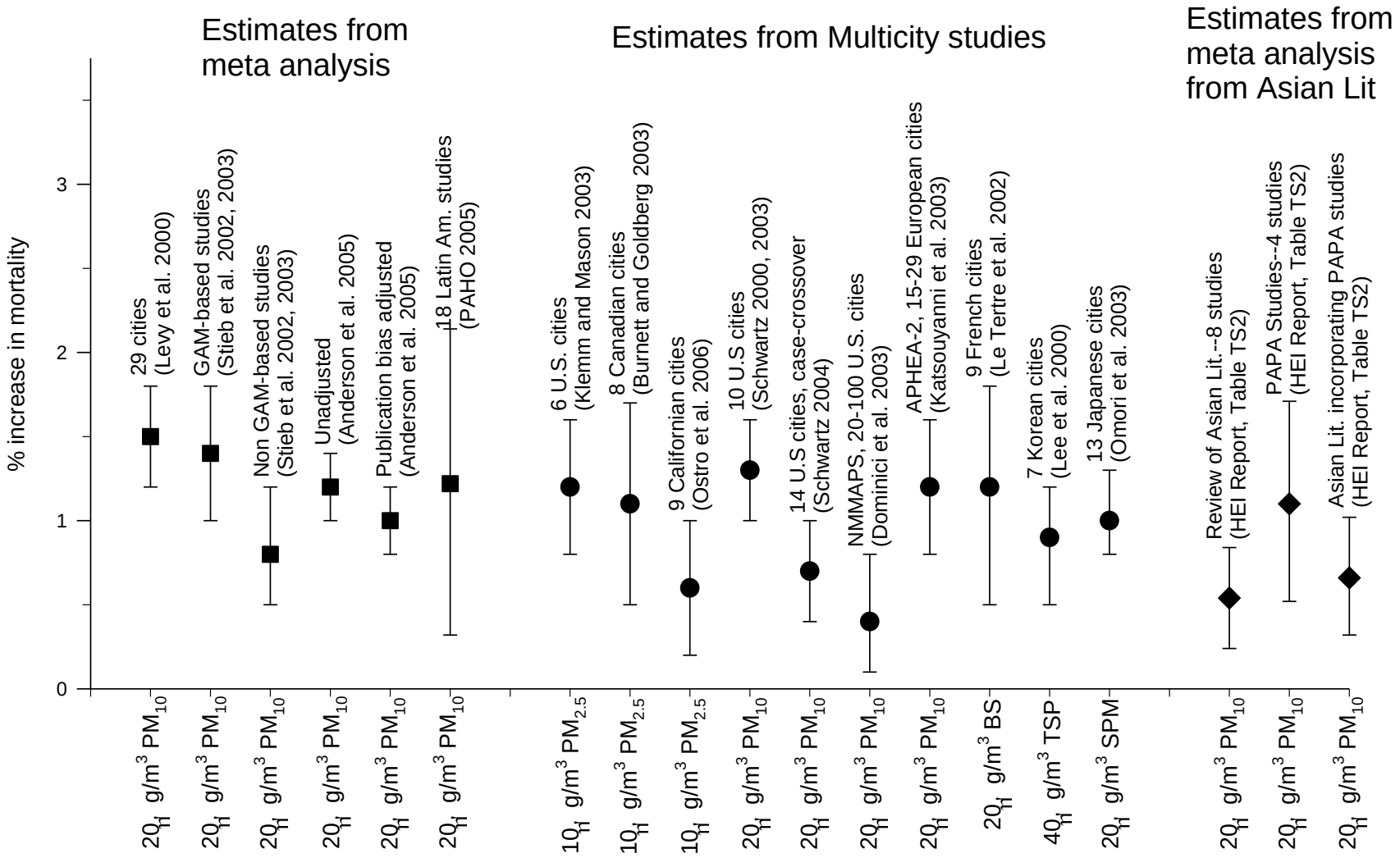


Figure 2. Percent increase in risk (and 95% CI) of acute coronary events associated with 10 $\mu g/m^3$ of $PM_{2.5}$, stratified by various characteristics.

Data from over 100 cities around the world have shown remarkably consistent associations between air pollution and cardiopulmonary death.



Short-term changes in air pollution exposure are associated with:

- Daily death counts (respiratory and cardiovascular)
- Hospitalizations
- Lung function
- Symptoms of respiratory illness
- School absences
- Ischemic heart disease
- Etc.

Longer-term air pollution exposure has been linked to substantially larger cardiopulmonary health effects.

In 1993, the Harvard "Six-Cities" study was published. It followed > 8,000 adults for 14-16 years to observe associations between air pollution and risk of death.

The NEW ENGLAND JOURNAL of MEDICINE

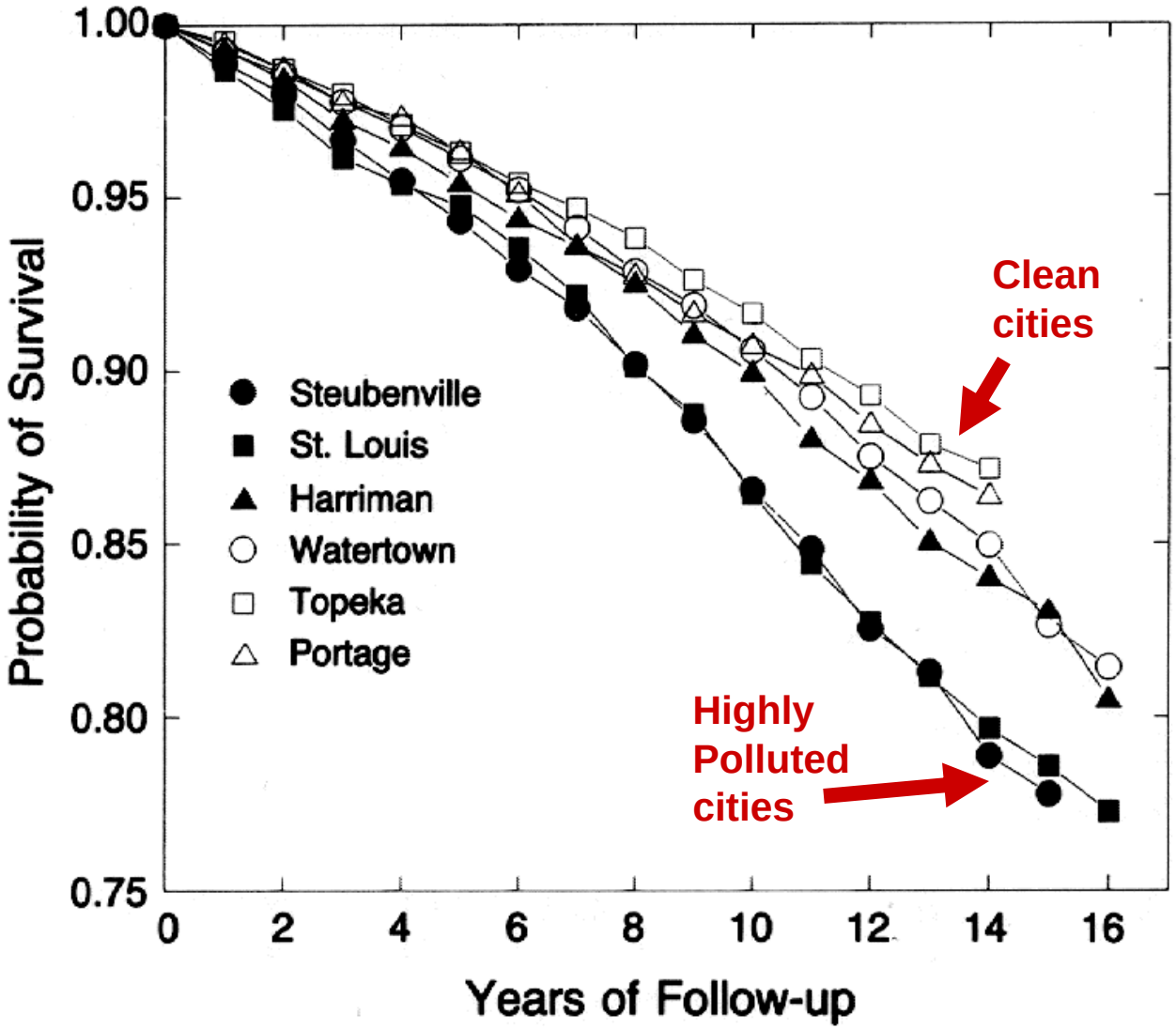
An Association Between Air Pollution and Mortality in Six U.S. Cities

Dockery DW, Pope CA III, Xu X, Spengler JD, Ware JH, Fay ME, Ferris BG Jr, Speizer FE. 1993

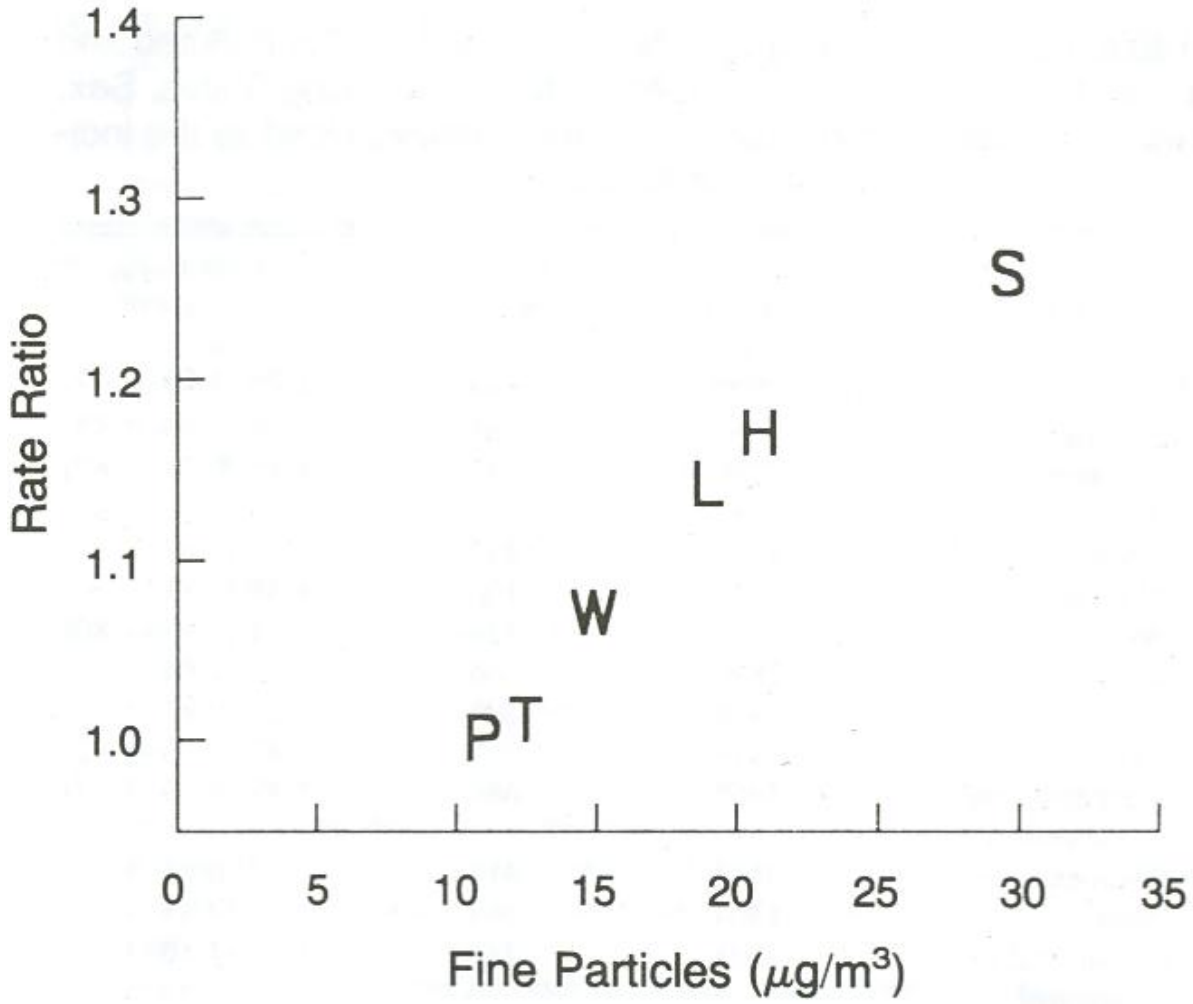
Methods:

- 14-16 year prospective follow-up of 8,111 adults living in six U.S. cities.
- Monitoring of TSP PM_{10}, $PM_{2.5}$, SO_4, H^+, SO_2, NO_2, O_3 .
- Data analyzed using survival analysis, including Cox Proportional Hazards Models.
- Controlled for individual differences in: age, sex, smoking, BMI, education, occupational exposure.

Splaying out of survival curves indicated lower probability of survival in the more-polluted cities.



Adjusted relative risk of dying were almost linearly associated with air pollution.

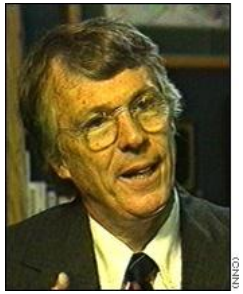


A collaborative study with the American Cancer Society using a cohort of **over 1 million people**.

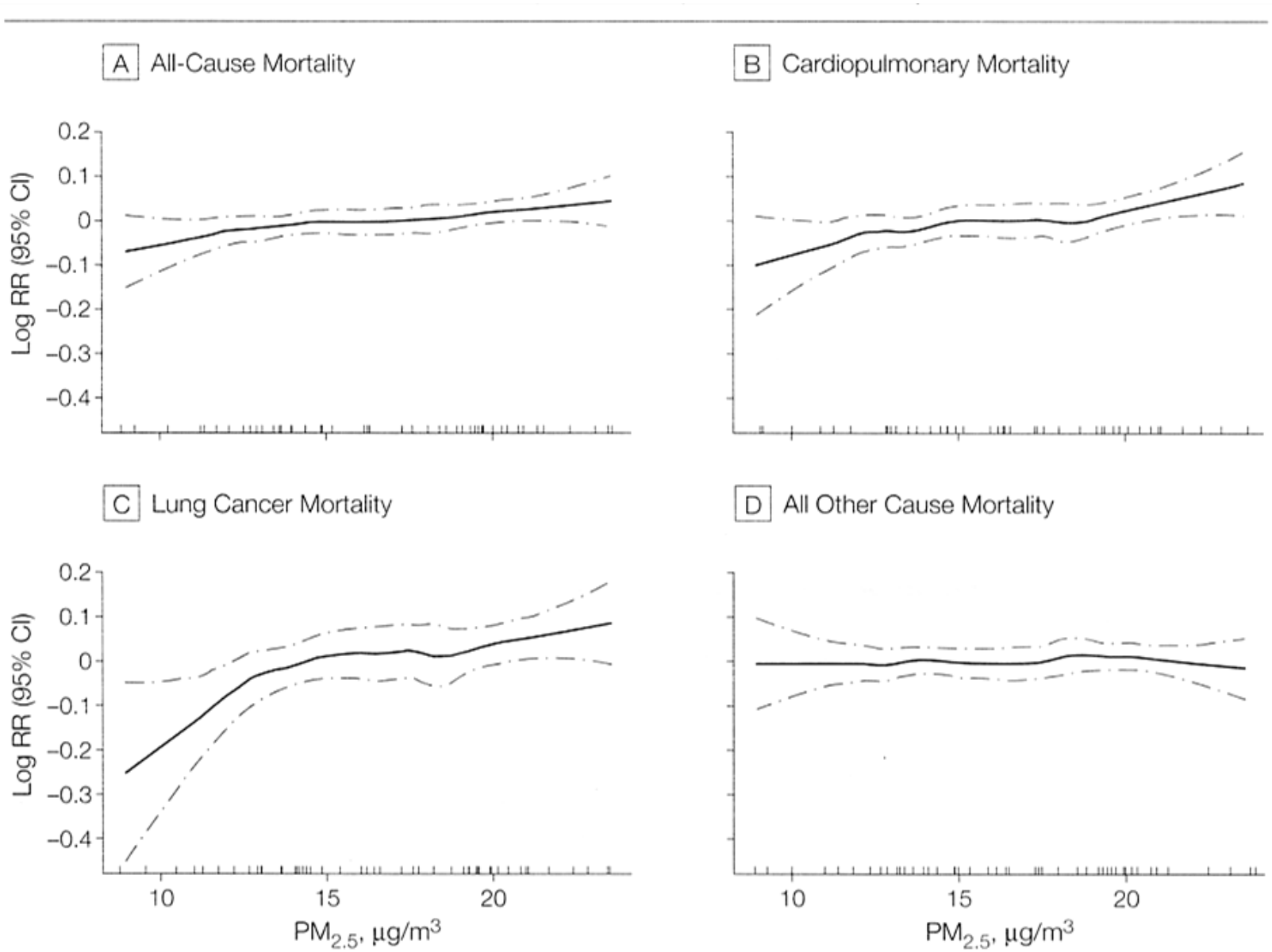
JAMA®
The Journal of the American Medical Association
March 6, 2002

Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution

C. Arden Pope III, PhD
Richard T. Burnett, PhD
Michael J. Thun, MD
Eugenia E. Calle, PhD
Daniel Krewski, PhD
Kazuhiko Ito, PhD
George D. Thurston, ScD



Increased levels of fine PM ➡ increased risk of death.



The Six-Cities and ACS studies have undergone extensive peer review and analyses. Their results are reproducible and remarkably robust.

HEI

SPECIAL REPORT

HEALTH EFFECTS INSTITUTE

July 2000

Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality

A Special Report of the Institute's Particle Epidemiology Reanalysis Project

HEI

RESEARCH REPORT

HEALTH EFFECTS INSTITUTE

Number 140
May 2009

PRESS VERSION

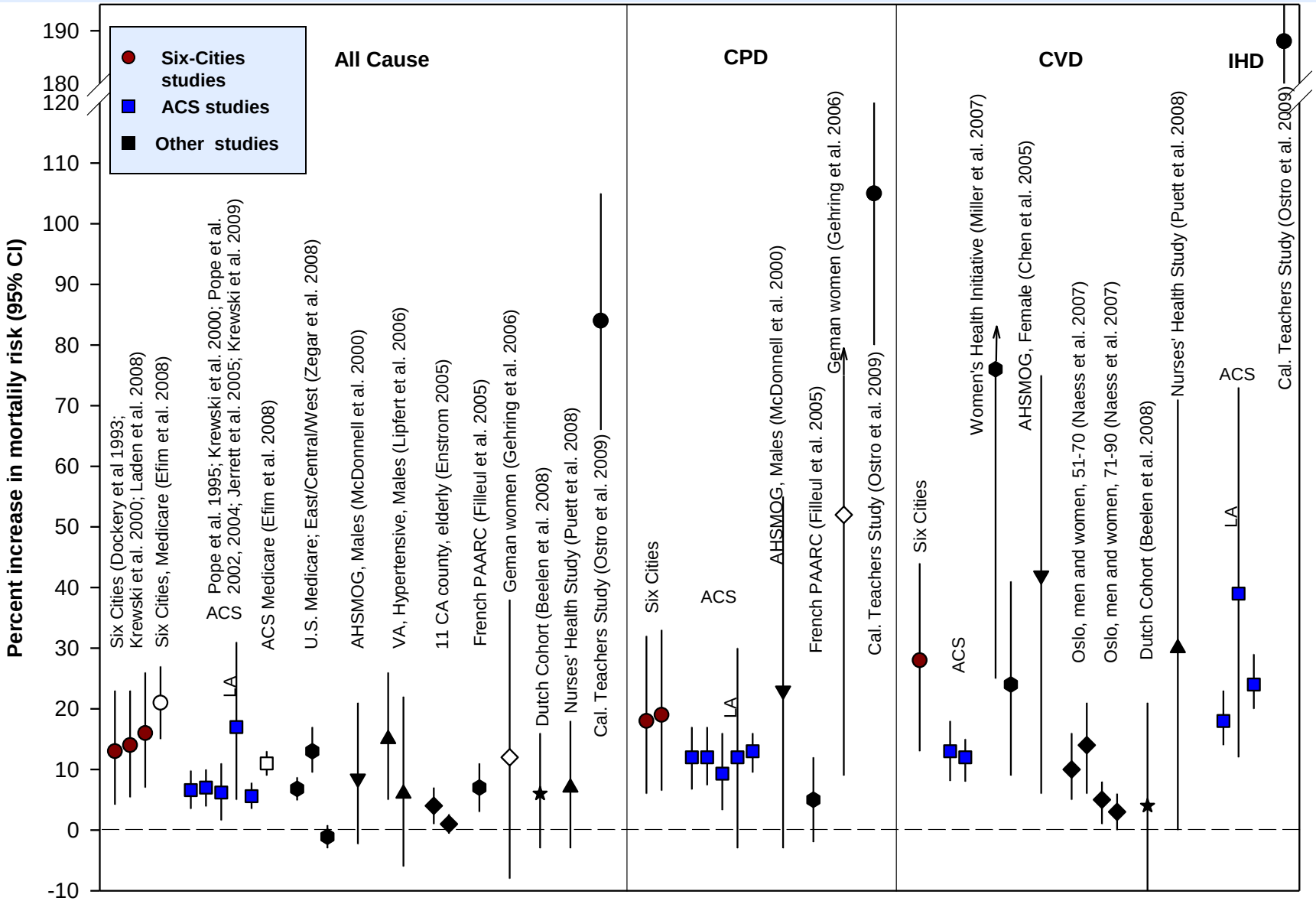
Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality

Daniel Krewski, Michael Jerrett, Richard T. Burnett, Renjun Ma, Edward Hughes, Yuanli Shi, Michelle C. Turner, C. Arden Pope III, George Thurston, Eugenia E. Calle, and Michael J. Thun

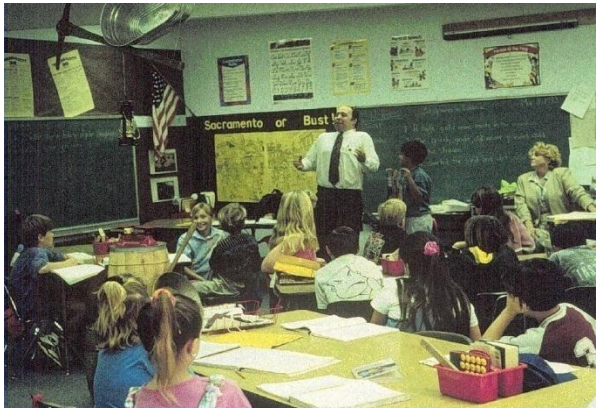
with Bernie Beckerman, Pat DeLuca, Norm Finkelstein, Kaz Ito, D.K. Moore, K. Bruce Newbold, Tim Ramsay, Zev Ross, Hwashin Shin, and Barbara Tempalski

Includes a Commentary by the Institute's Health Review Committee

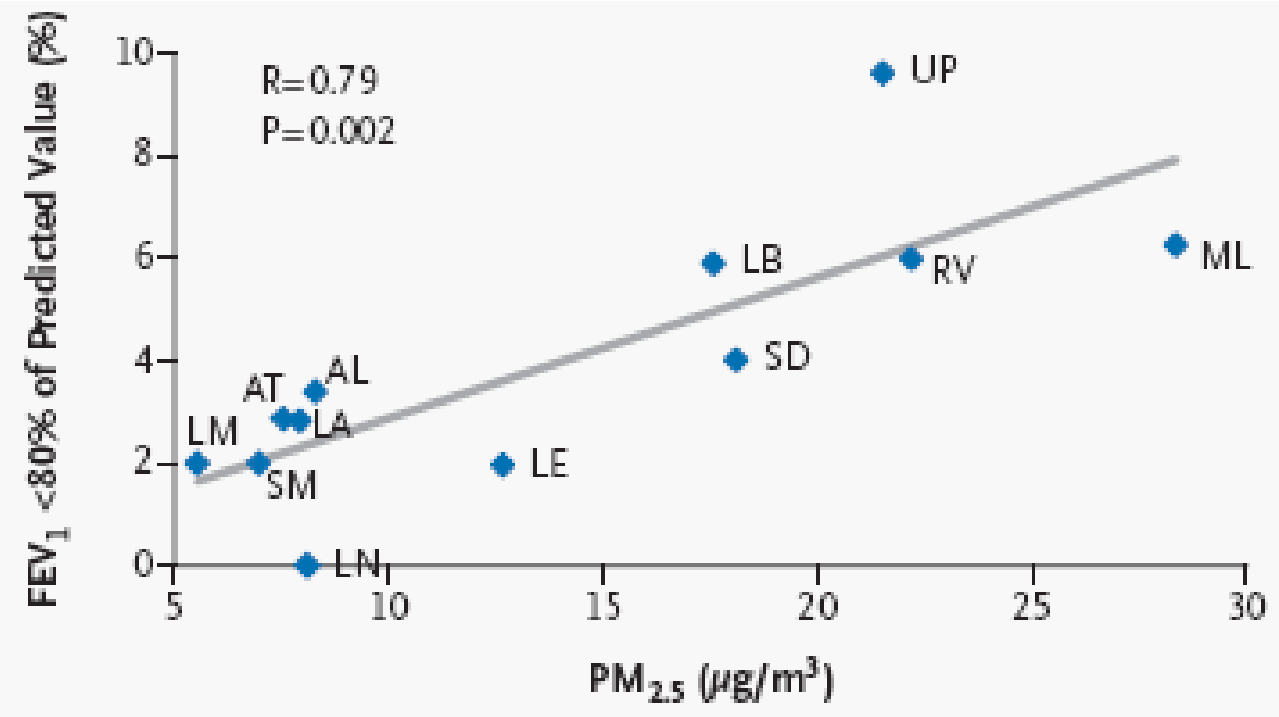
Other cohort studies have shown associations between exposure to fine PM and increased risk of cardiovascular death.



Southern California Children's Health Study, has shown that **air pollution impacts lung development in children.**



THE LANCET **Gauderman et al. 2007**



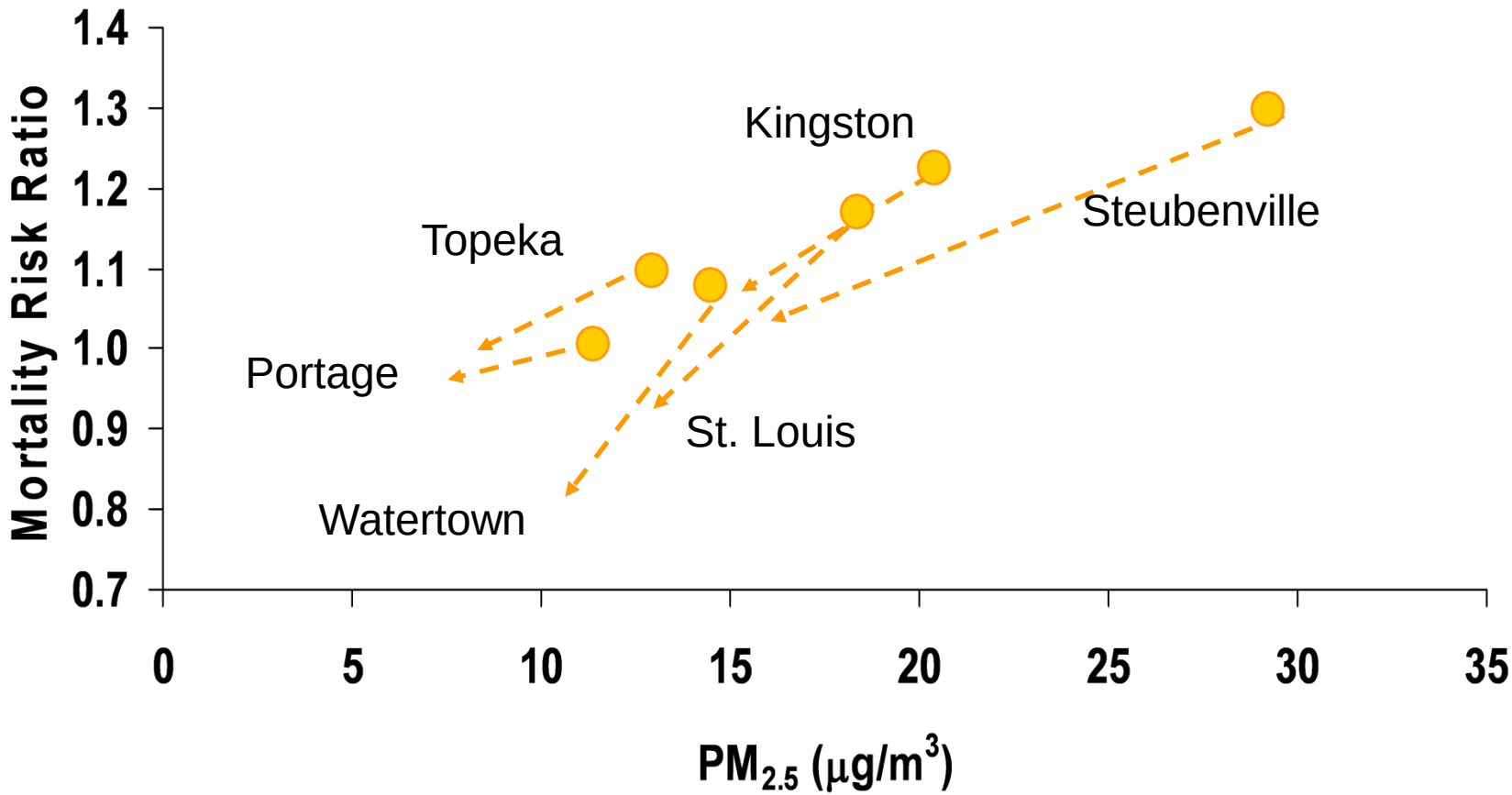
Children living in cities with higher air pollution showed greater deficits in lung function growth.

We know that short and long-term exposure to air pollution contribute to cardiopulmonary disease and death.

The next critical step has been to determine whether reducing air pollution results in substantial and measurable **improvements in human health.**

Follow up analysis of the Six-Cities cohort:

Air pollution reductions ⟶ reduced risk of death



Reduction in fine particulate air pollution:
Extended follow-up of the Harvard Six Cities Study

Laden, Schwartz, Speizer, Dockery, 2006

AMERICAN JOURNAL OF Respiratory and Critical Care Medicine

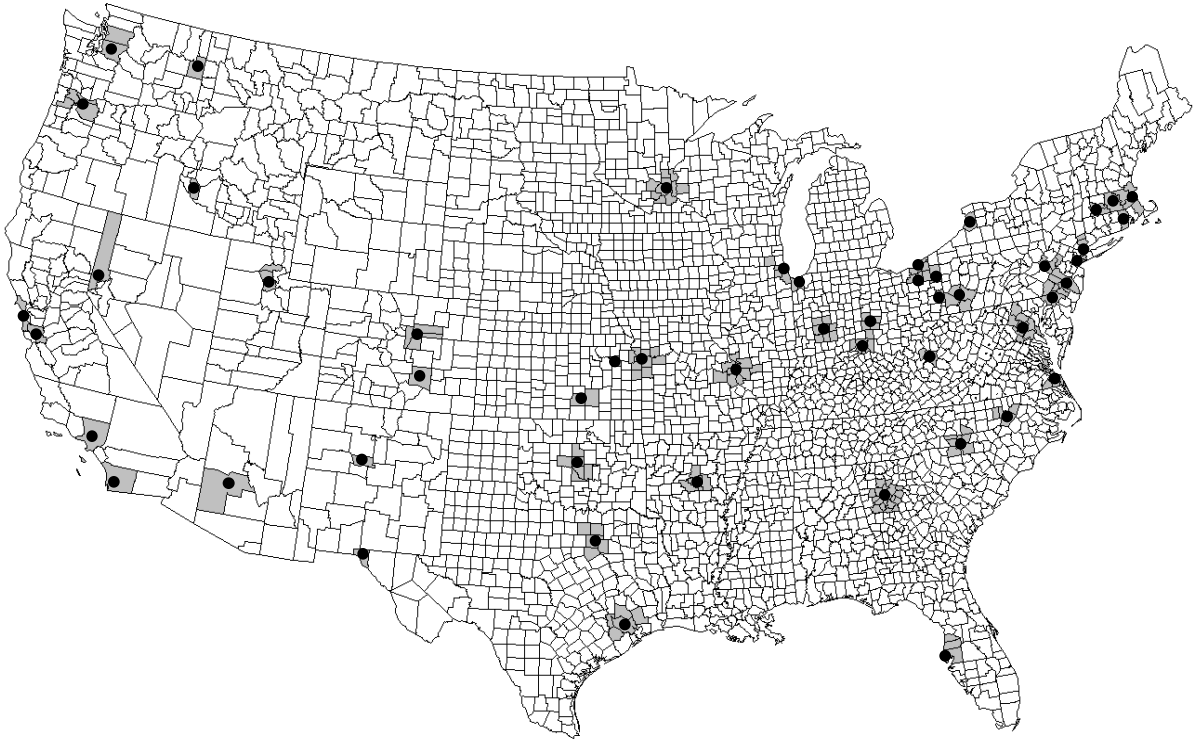
Do cities with bigger improvements in air quality have bigger improvements in health, measured by life expectancy?

The NEW ENGLAND JOURNAL of MEDICINE

January 22, 2009

Fine-Particulate Air Pollution and Life Expectancy in the United States

C. Arden Pope, III, Ph.D., Majid Ezzati, Ph.D., and Douglas W. Dockery, Sc.D.

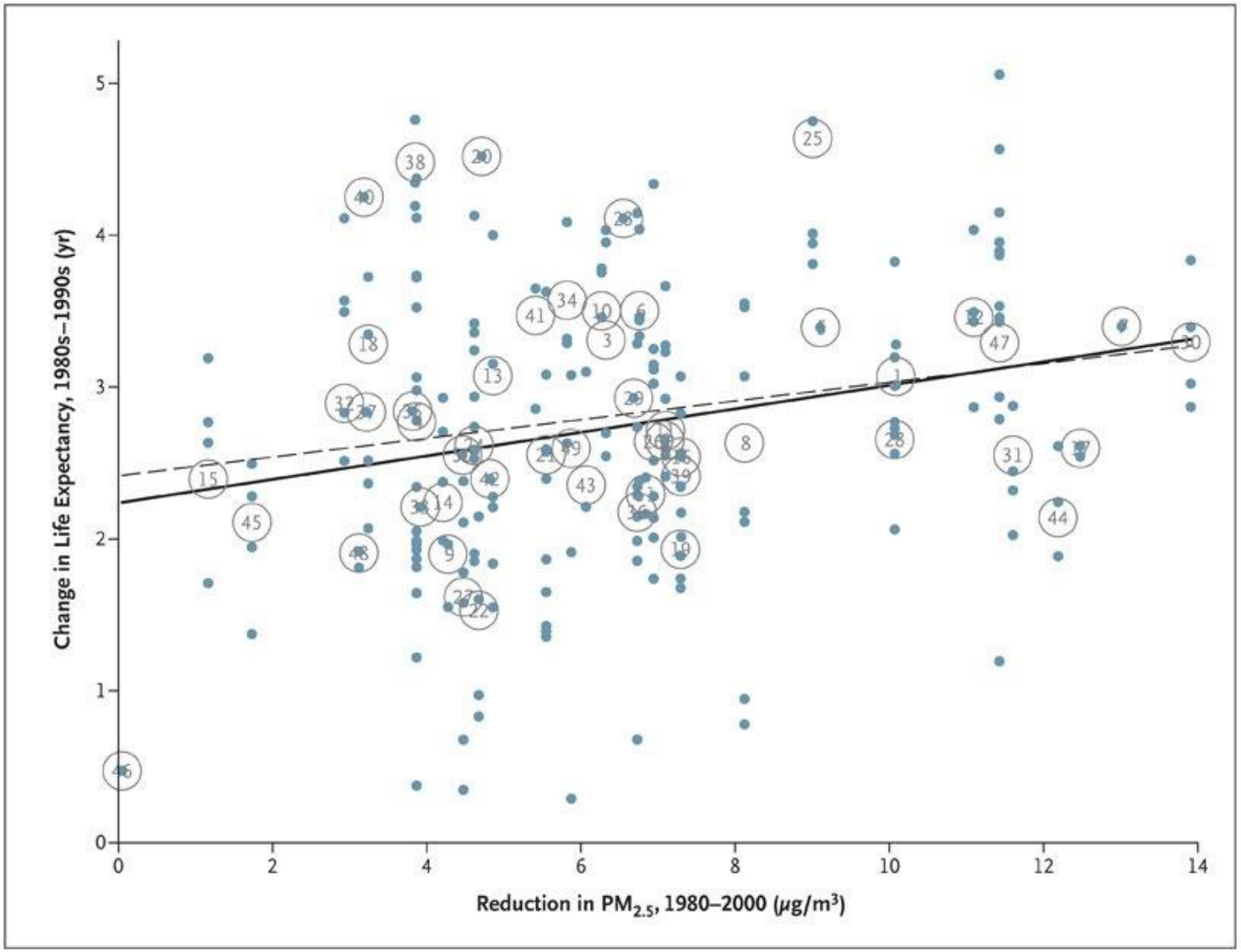


- Matching $PM_{2.5}$ data for 1979-1983 and 1999-2000 in 51 Metro Areas

- Life Expectancy data for 1978-1982 and 1997-2001 in 211 counties in 51 Metro areas

- Evaluate changes in Life Expectancy with changes in $PM_{2.5}$ for the 2-decade period of approximately 1980-2000.

YES. On average, the greater the reduction in air pollution, the greater the increase in life expectancy.



A 10 μg/m^3 decrease in $PM_{2.5}$ was associated with a **7.3 (± 2.4) month** increase in life expectancy.

Table 2. Results of Selected Regression Models, Including Estimates of the Increase in Life Expectancy Associated with a Reduction in $PM_{2.5}$ of 10 μg per Cubic Meter, Adjusted for Socioeconomic, Demographic, and Proxy Indicators for Prevalence of Smoking.*

Variable	Model 1	Model 2	Model 3	Model 4	Model 5†	Model 6‡	Model 7‡
				years			
Intercept	2.25±0.21§	0.80±0.19§	1.78±0.27§	1.75±0.27§	2.02±0.34§	1.71±0.51§	2.09±0.36§
Reduction in $PM_{2.5}$ (10 μg/m^3)	0.72±0.29¶	0.83±0.20§	0.60±0.20§	0.61±0.20§	0.55±0.24¶	1.01±0.25§	0.95±0.23§
Change in income (in thousands of $)	—	0.17±0.02§	0.13±0.02§	0.13±0.01§	0.11±0.02§	0.15±0.04§	0.11±0.02§
Change in population (in hundreds of thousands)	—	0.08±0.02§	0.05±0.02§	0.06±0.02§	0.05±0.02§	0.04±0.02	0.05±0.02¶
Change in 5-yr in-migration (proportion of population)‖**	—	0.19±0.79	1.28±0.80	—	—	−0.02±1.83	—
Change in high-school graduates (proportion of population)‖	—	0.17±0.56	−0.11±0.53	—	—	−0.90±0.86	—
Change in urban residence (proportion of population)‖	—	−0.76±0.32¶	−0.40±0.25	—	—	0.03±1.88	—
Change in black population (proportion of population)‖††	—	−1.94±0.58§	−2.74±0.58§	−2.70±0.64§	−2.95±0.78§	−5.06±2.12§	−5.98±1.99§
Change in Hispanic population (proportion of population)‖††	—	1.46±1.23	1.33±1.10	—	—	2.44±2.22	—
Change in lung-cancer mortality rate (no./10,000 population)	—	—	−0.07±0.02§	−0.06±0.02§	−0.07±0.03¶	0.01±0.03	0.02±0.03
Change in COPD mortality rate (no./10,000 population)	—	—	−0.07±0.02§	−0.08±0.02§	−0.09±0.03§	−0.15±0.06§	−0.19±0.05§
No. of county units	211	211	211	211	127	51	51
R^2‡‡	0.05	0.47	0.55	0.53	0.60	0.76	0.74

This increase in life expectancy persisted even after controlling for socio-economic, demographic, or smoking variables

Summary

1. **Short-term exposure** to air pollution exacerbates cardiovascular and pulmonary disease. It increases the risk of becoming symptomatic, requiring medical attention, or even dying.

2. **Longer-term exposures** result in even larger increased risk of respiratory and cardiovascular disease and death and may contribute to the initiation and progression of disease.

3. **Public policy efforts** to reduce air pollution in the U.S. have resulted in improved human health.

2007 Report to Congress on the Benefits and Costs of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities

2007

Office of Management and Budget
Office of Information and Regulatory Affairs

I don't have estimates of economic benefits and costs specific to Utah, but:

- Responsible clean air efforts make large contributions to human health and reduce pollution-related health costs.
- Given the desires to live in clean healthy environments, efforts to control air pollution in Utah, also contribute to responsible economic growth and development.