Overview of EPA's Air Research Program and Role of EPA's Particulate Matter (PM) Research Centers

SAB PM Center Advisory Panel
October 1-2 2008

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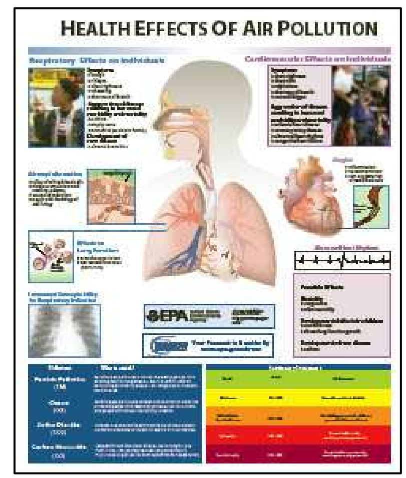
Office of Research & Development
USEPA



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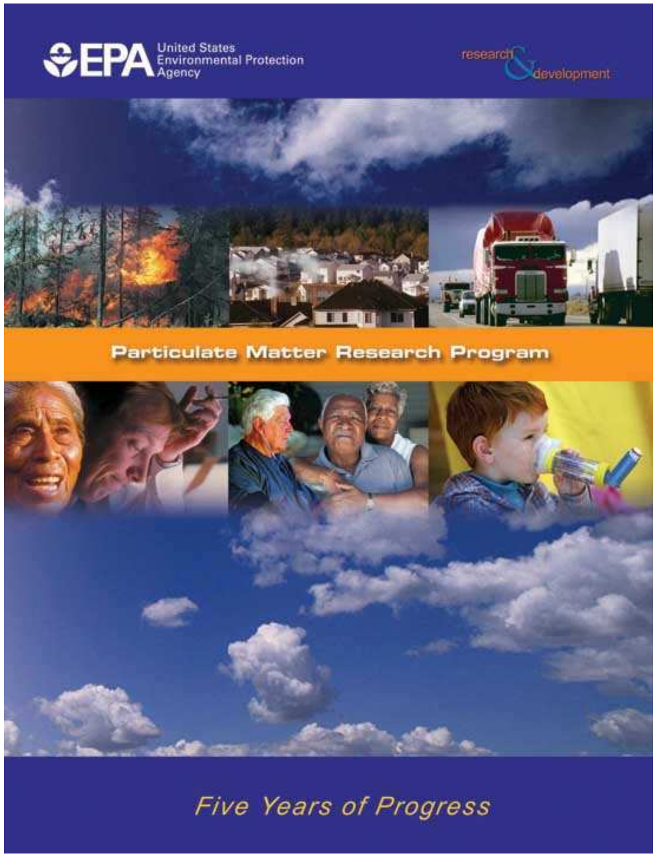
Overview

- Background
  - Brief history of the Air (PM) program & Centers
  - Air program structure & coordination
- Value of Centers to EPA Research Program
  - Complements intramural program
  - Cutting edge science
- Making a difference
  - Science highlights
  - Enhancing public health
- Conclusion



ORD Clean Air Research Program

The Clean Air research program utilizes interdisciplinary, problem-oriented approaches that are coordinated and leveraged to better understand and reduce the risks associated with air pollution.

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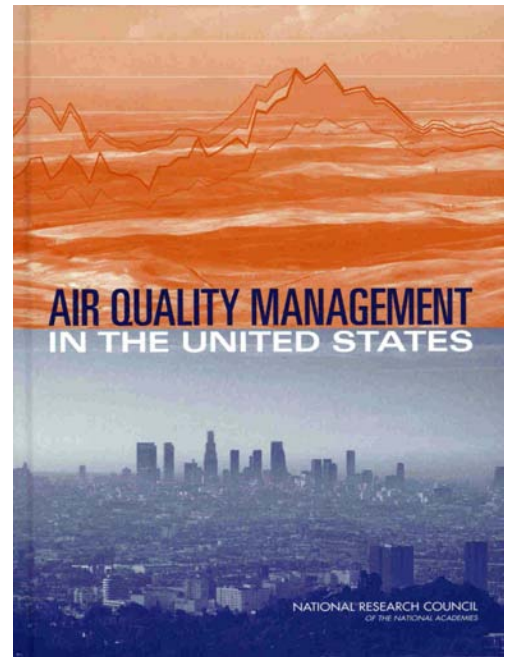
1998: New Emphasis on PM

- **Congress increased the EPA PM Research Program budget by $22.4 million per year with mandates:**
  - Redirect & expand intramural program
  - Establish NAS / NRC expert panel on research priorities
  - Expand STAR PM Grants Program
    - Up to 5 PM Centers
    - Develop RFA’s on pressing science issues
  - Coordination across federal agencies

NRC Reports: Research Priorities for Airborne Particulate Matter

- Important research needs identified
- Recommended a multi-year portfolio of the highest priority research topics

1998 1999 2001 2004



2004

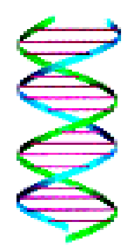
NRC PM Research Priorities

PM Research Needed to Minimize Health Risks

1. Outdoor Measures vs. Personal Exposure
2. Exposure of Susceptible Populations to PM Components
3. Characterization of Sources
4. Air Quality Model Development & Testing
5. Assessment of Hazardous PM Components
6. Dosimetry & Fate of Deposited PM
7. Combined Effects of PM and Gaseous Pollutants
8. Susceptible Subpopulations
9. Mechanisms of Injury
10. Analysis & Measurements

11. Technical Support– Atmospheric Measurements and Methods
12. Source to Health Outcome

The Clean Air Research Program

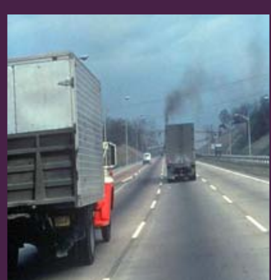


Epidemiology → **Clinical and Animal Toxicology Studies** → **Molecular**

Intramural Program ⟷ **EPA STAR Program (PM Centers)**

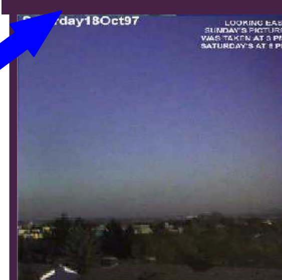
EPA Partners:
- *Other Federal/State Agencies*
- *Health Effects Institute*
- *Academia*
- *Industry laboratories*

Emission Source Characterization



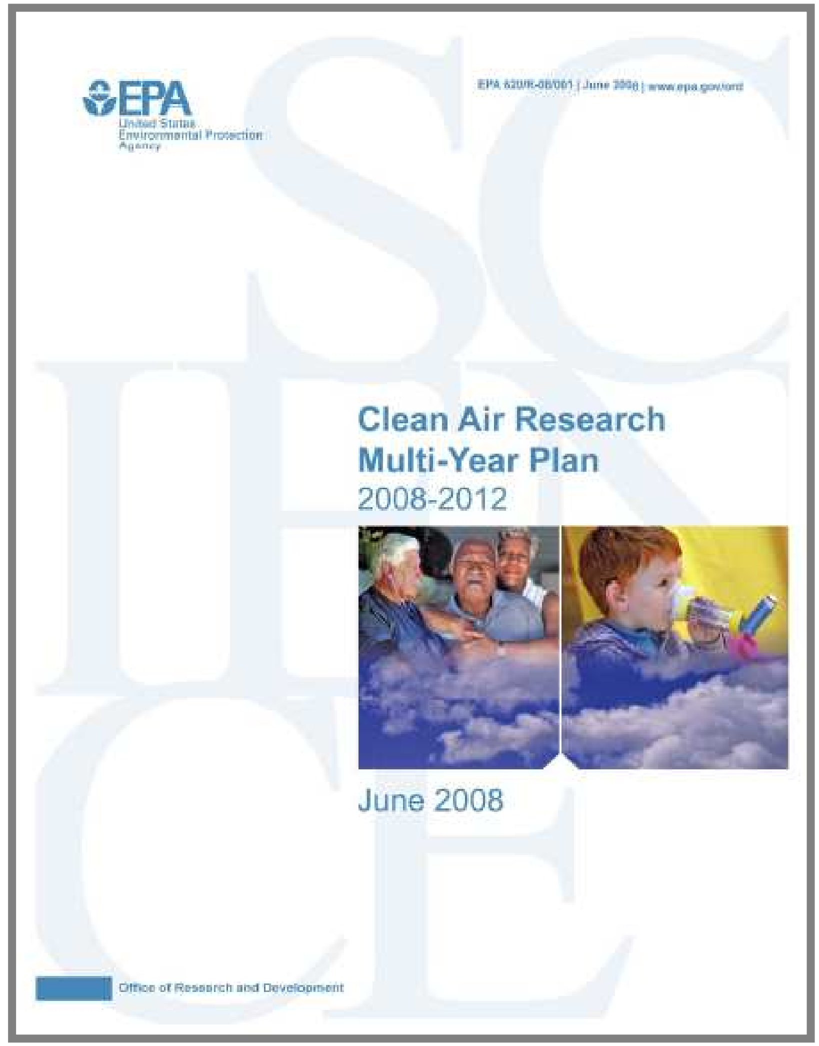
EPA Monitoring Network

Exposure, Atmospheric Measurement and Models



2008 Revised Multi-Year Plan

- PM, ozone and air toxics integrated into one *Clean Air MYP*
- Emphasis on program coordination and leveraging
- Emphasis on interdisciplinary science
- Gradual shift to a <u>multi-pollutant</u> research theme
- Regulatory support with public health outcome



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Long Term Goals

LTG 1 - **Reduce uncertainty in the science that supports <u>standard setting</u> and <u>air quality management decisions.</u>**

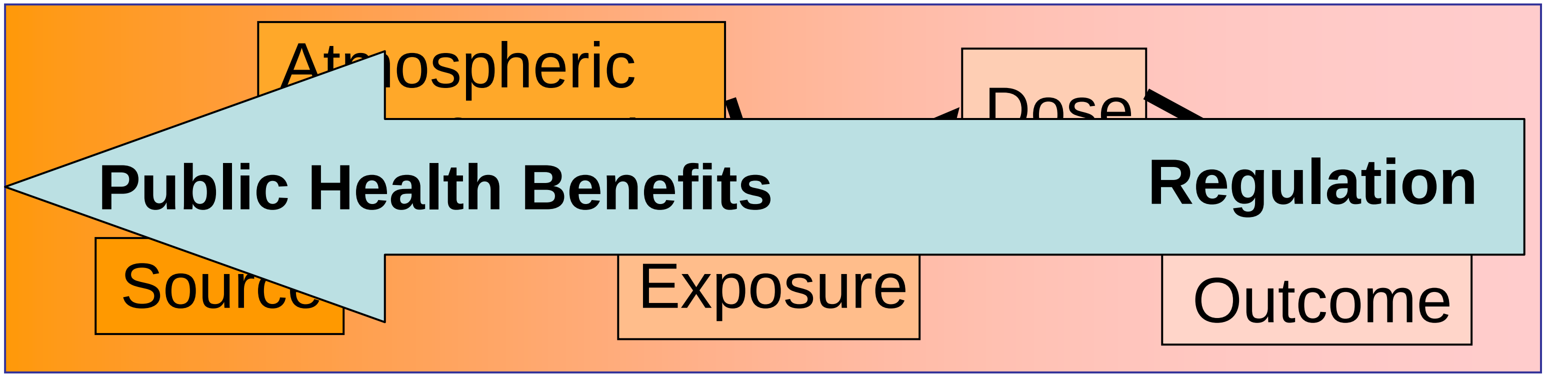
- Inform regulatory decision-making (NAAQS, AT)
- Support implementation of regulations with tools (methods and models) and information to OAR, Regions, States, tribes.

LTG 2 - **Reduce uncertainties in linking health and environmental outcomes to air pollution sources.**

- Launch a multi-pollutant research program
- Identify specific source-to-health linkages, with initial emphasis on "near roadway" impacts
- Demonstrate effectiveness of the science and its

Source to Health Outcomes

Source to Health Outcome approach recognizes health outcomes are linked to sources via interconnected biological, chemical, and physical behaviors



- Greater degree of integration across disciplines
- Improved understanding of entire problem
- Yield efficient and effective regulation
- Link to public health outcomes

Timeline of PM Centers Program

- 1999 – First PM Centers funded
  - ➢Harvard; NYU; Southern California; Rochester; Northwest
- 2002 – SAB interim review of PM Centers Program
- 2005 – Current PM Centers funded
  - ➢Harvard; Johns Hopkins; Southern California; UC Davis; Rochester
- 2005 – ORD Air (PM/O_3) Program Review by:
  - – Board of Scientific Counselors (BOSC)
  - – Performance Assessment Rating Tool (PART)
- 2007 – ORD Mid-cycle BOSC
- 2008 – SAB advice on future Air Centers Program
- 2009 – Scheduled ORD Air Program BOSC
- 2009 – Release new Air Research Centers RFA

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First PM Center Directors

Petros Koutrakis

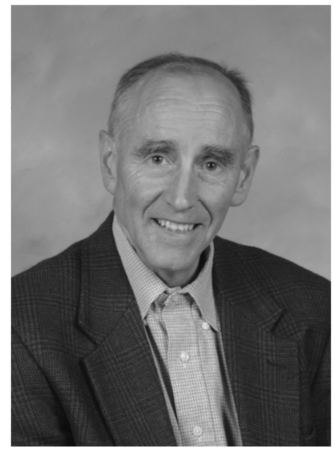
Harvard University PM Research Center

John Froines

Southern California Particle Center

Jane Koenig

Northwest Research Center for Particulate Air Pollution and Health



Günter Oberdörster

University of Rochester PM Research Center

Morton Lippmann

New York University PM Center

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Major Conclusions of 2002 SAB PM Center Report

- The Centers Program has produced benefits beyond those normally found in individual investigator-initiated grants and is likely to continue to provide such benefits
- Overall the PM Centers & individual grants programs should be maintained in roughly the same proportion
- There are clear advantages to maintaining a diverse research portfolio
  - Ensures that the widest range of investigators contribute ideas to the PM program
  - Provides opportunities for cross-fertilization within the science community
- The Agency should continue to support both intramural and extramural components of an overall PM research effort

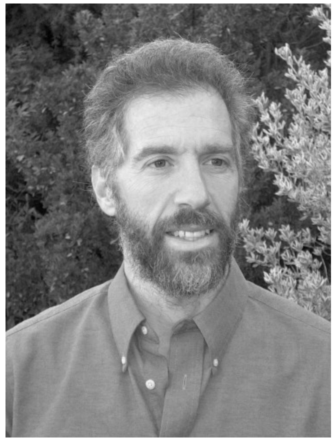
Current PM Center Directors

Petros Koutrakis

Harvard University PM Research Center

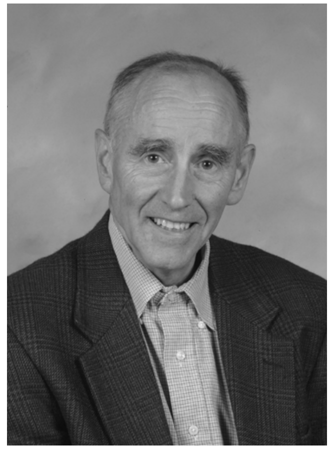
John Froines

Southern California Particle Center



Tony Wexler

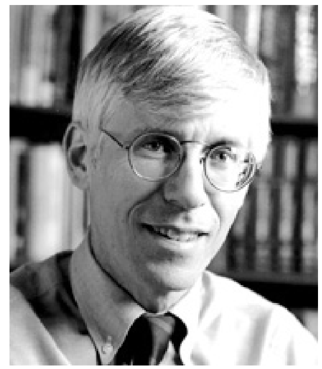
San Joaquin Valley Aerosol Health Effects Center at UC Davis



Günter Oberdörster

University of Rochester PM Research Center

Francesca Dominici



Jonathan Samet

Johns Hopkins University PM Research Center

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Why EPA Values the PM Centers Program

- Complements Intramural Program
- Cutting Edge Science in Multitude of Disciplines

♦ Science that Makes a Difference ♦

- Important Science Advances from 1998 to 2008
- Implications of the Science Extend Beyond “Regulations”
  - New directions in science and public health practice

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Complements Intramural Program

- Provides the core of ORD's air pollution epidemiology program – EPA has one intramural air epidemiologist
- Possesses the intellectual and institutional flexibility to respond and expand as the science evolves (leveraging)
- Provides a balanced rationale for EPA's intramural program to target highly programmatic needs
- Attracts investigators with needed ["new"] expertise (notably cardiovascular but also oxidant biochemistry, engineering)

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Complements Intramural Program

(continued)

- Expands ORD's capacity to do science that is fundamentally strong yet programmatically relevant
- Yields synergies with STAR grants and intramural PIs and projects
- Develops novel technologies – e.g., to allow controlled exposures of humans & animals to ultrafine, fine, and coarse PM
- Moves the focus toward identifying and understanding the sources and composition of PM as these relate to health outcomes

Cutting Edge Science

- Many highly cited publications
  - Original Centers have produced over 500 publications
  - Current Centers over 100 publications so far
  - Peak in publications not until ~5 years after initial funding
  - Published in high impact scientific and medical journals, e.g. *NEJM, Science, Lancet, Circulation, JAMA*
- Paper of the Year
  - EHP 2008 “Nanotoxicology: An Emerging Discipline Evolving from Studies of Ultrafine Particles”

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Scientific Leadership

- **Chair/Membership on national scientific advisory committees**
  - NRC Committee on Research Priorities for Airborne Particulate Matter
  - Science Advisory Board for the U.S. EPA
  - Clean Air Scientific Advisory Committee
  - Board of Scientific Counselors of the National Toxicology Program
  - Health Effects Institute Research Committee
- **Editorial boards of leading scientific journals**
  - Journal of the Air & Waste Management Association
  - Atmospheric Environment
  - Aerosol Science and Technology
  - Environmental Health Perspectives
  - Inhalation Toxicology
- **Awards/honors received**
  - Surgeon General's Medallion
  - Prince Mahidol Award, from the King of Thailand, for work on air pollution
  - Outstanding contributions in Aerosols in Medicine (AAAR and ISAM)
  - Named among Top 1% Authors Worldwide in Engineering (ISI)
- **Leadership positions in professional societies**
  - American Chemistry Council
  - American Thoracic Society
  - American Association for Aerosol Research
- **Collectively hold more than 20 U.S. patents in the field of aerosol instrumentation**

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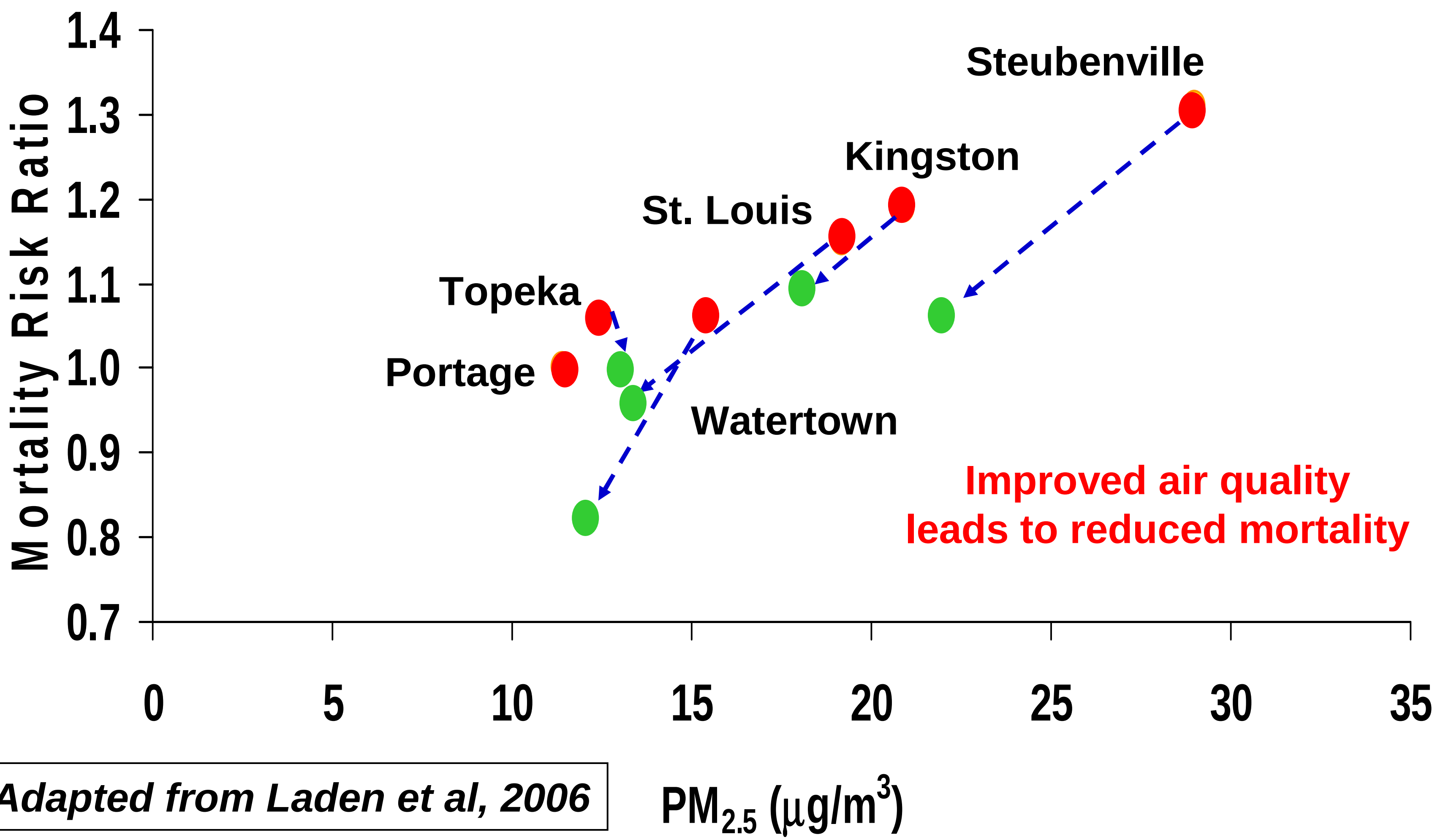
Epidemiology / Human Studies

- Ambient fine PM concentrations provide "reasonable" estimates of exposure in time-series analyses - *Sarnat et al. 2000, 2002*
- No apparent threshold for PM effects - *Schwartz et al., 2002*
- "Harvesting" unlikely - *Schwartz, 2001*
- East – West coast differences in PM hospitalization seems to reflect composition - *Bell et al., in press*
- Long-term PM linked to cardiovascular events, lung cancer, and cardiovascular mortality - *Pope et al, 2002, 2004; Miller et al., 2007*
- Cardiovascular effects and mortality linked to PM and select components - *Peters et al., 2001; Franklin et al., 2008; Peng et al., 2008*
- Vascular dysfunction tied to PM - *Delfino et al., 2008*
- Some evidence that intervention can mitigate responses - *Schwartz et al., 2005*

Reductions in PM Reduces Risk

(Six Cities Cohort Follow-up)

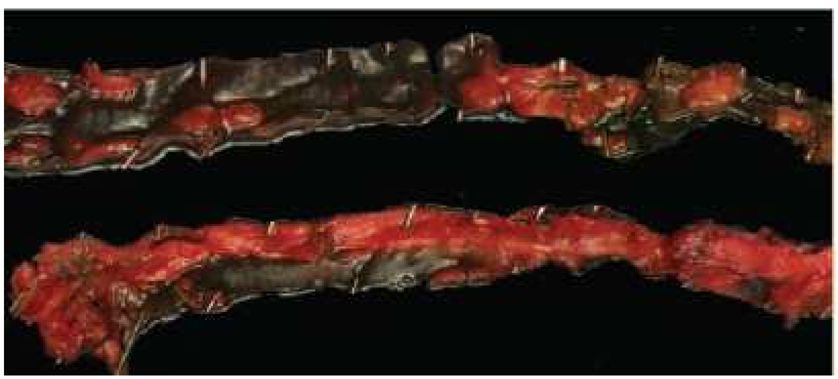


Adapted from Laden et al, 2006

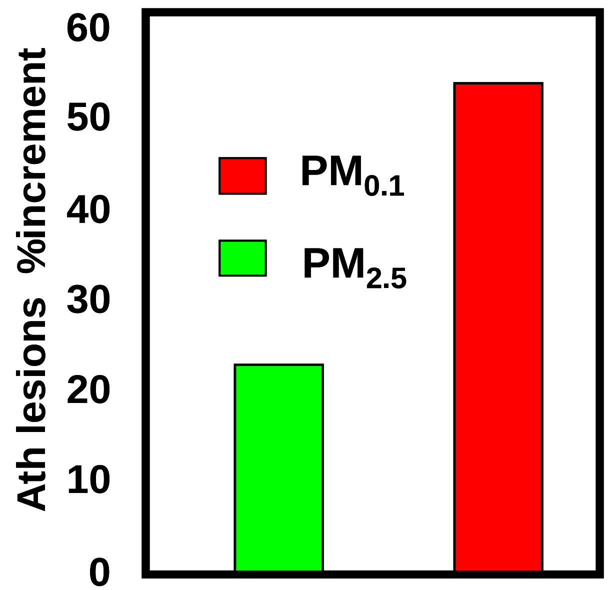
Environmental Cardiology

- *Workshop on Cardiovascular Effects Associated with Air Pollution,* Rochester, March 2001 - *Utell et al., 2002*
  - AHA recognition – *Circulation* (Brook et al., 2004)
- HRV changes (humans & animals)

  Adar et al., 2007; Nadziejko et al. 2002; Chen et al., 2005
- Cardiac function (ECG) changes – *Godleski et al., 2006*
- Systemic Inflammation – *Frampton et al., 2006; Delfino et al., 2005*
- Atherosclerosis – *Lippmann et al., 2005; Corey et al., 2006; Araujo et al., 2008*



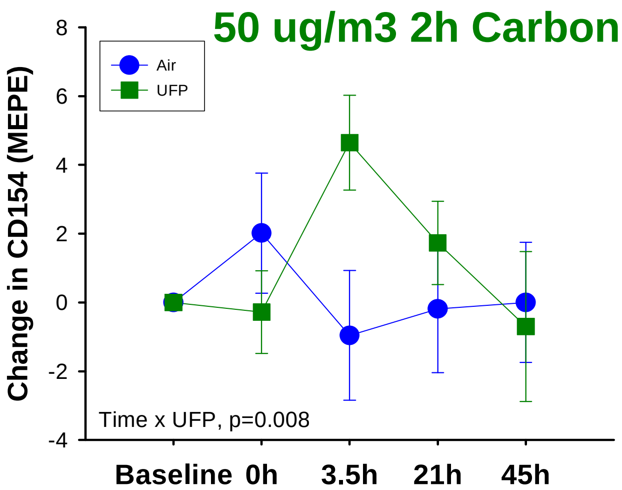
Chen and Nadziejko, 2005

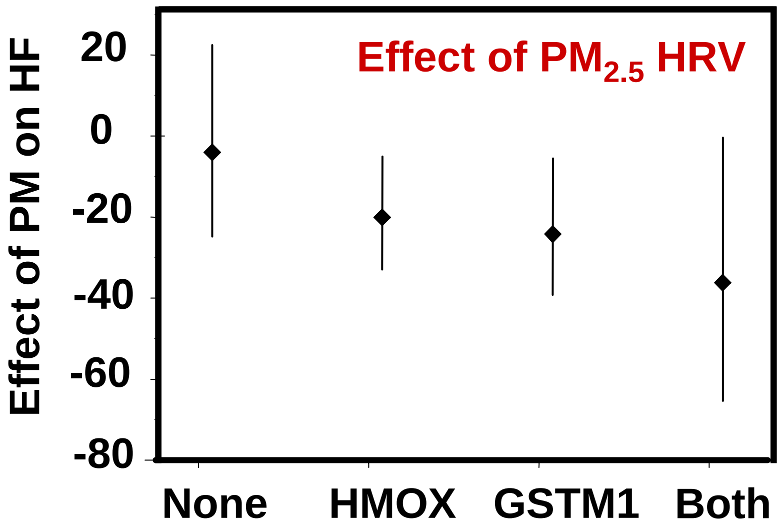


Araujo et al., 2008

Mechanisms and Susceptibility

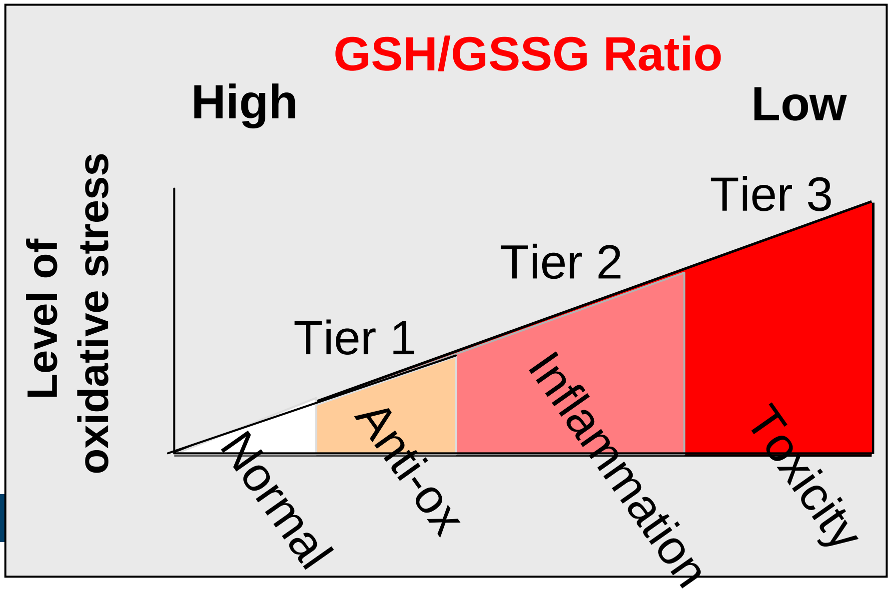
- Children – *Delfino et al., 2008; Koenig et al., 2005 (many)*
- Elderly – *Park et al, 2008; Baccarelli et al., 2008*
- Cardiopulmonary disease – *Liu et al., 2003; Wellenius et al., 2005; Jansen et al., 2005*
- Diabetes – *Zanobetti & Schwartz, 2001;* ***Frampton et al., 2008***
- Animal Models – *Elder et al, 2000, 2002, 2004; Kleinman et al., 2005; Last et al., 2004*
- Gene-Environment – *Schwartz et al., 2005; Gong et al., 2007;* ***Chahine et al., 2007***

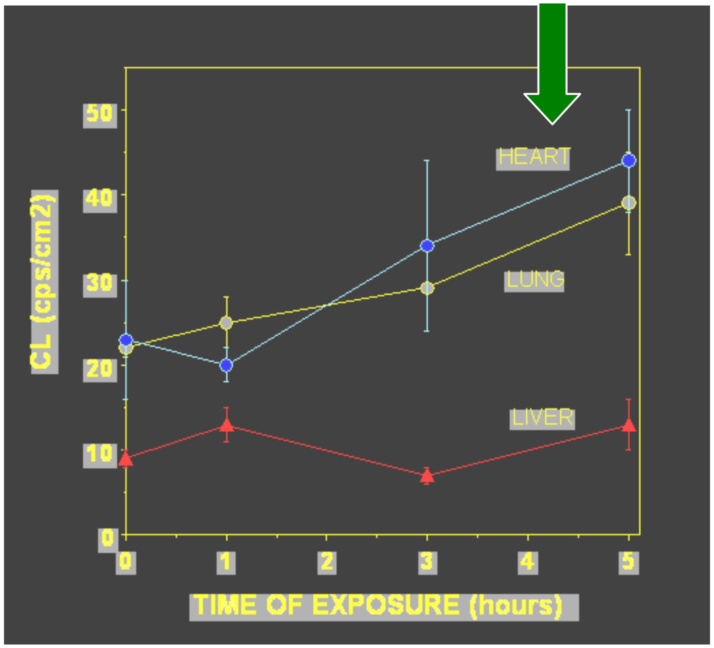




Mechanisms/Oxidative Stress

- Particles contain pro-oxidant components (cross-over with uF) – *Cho et al., 2005; Zhou et al., 2003*
- Stratified Oxidative Stress Hypothesis – ***Nel et al 2006***
- Oxidant pathways (*in vitro*) – *Hatzis et al., 2006*
- Oxidant pathways (*in vivo*) – ***Gurgueira et al., 2002***; *Delfino et al., 2005*
- Mitochondrial mediation – *Li,et al, 2003*
- Systemic oxidants and inflammation – *Delfino et al., 2008*





Ultrafine Particles

- Major sources include: vehicular emissions and secondary photochemical formation – *Kim et al., 2002*
- High organic and metal content may confer higher toxicity (Surface area / oxidant) – ***Li et al., 2003; *** *Zhou et al., 2003*
- High spatial heterogeneity / dispersion with distance from roadways – ***Zhu et al., 2002***

Near Road Distribution

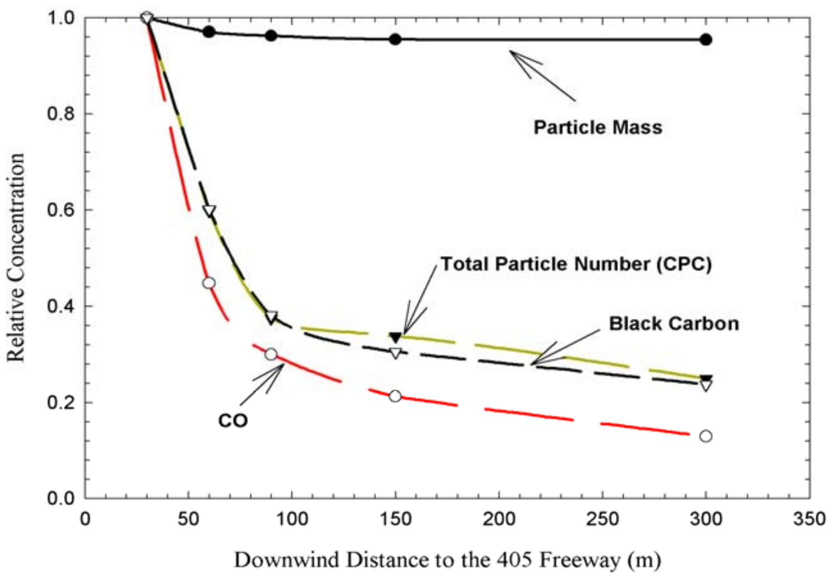


Table 5
Contrasting features of coarse, fine, and ultrafine particles[a]

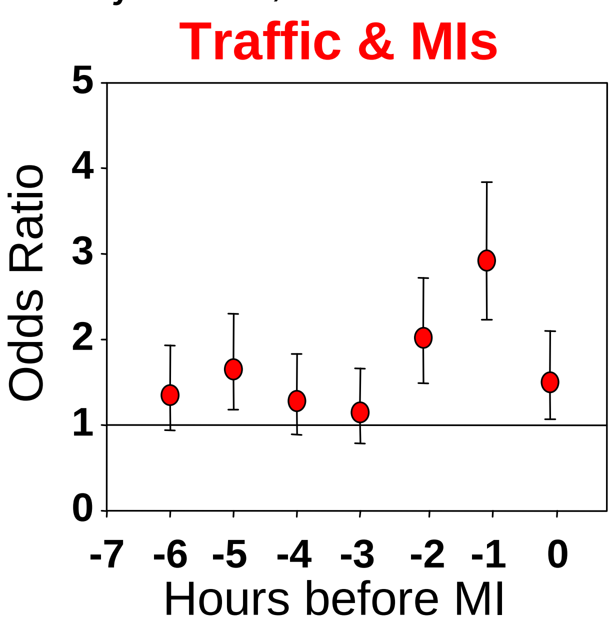
Parameters	Particle mode		
	Coarse (PM_{10})	Fine ($PM_{2.5}$)	Ultrafine
Size	2.5–10 μm	2.5–0.15 μm	<0.15 μm
Organic carbon content	+	++	+++
Elemental carbon content	+	++	+++
Metals as % of total elements	+++	++	+
PAH content	+	+	+++
Redox activity (DTT assay)	+	++	+++
HO-1 induction	+	++	+++
GSH depletion	+	+++	+++
Mitochondrial damage	None	Some	Extensive

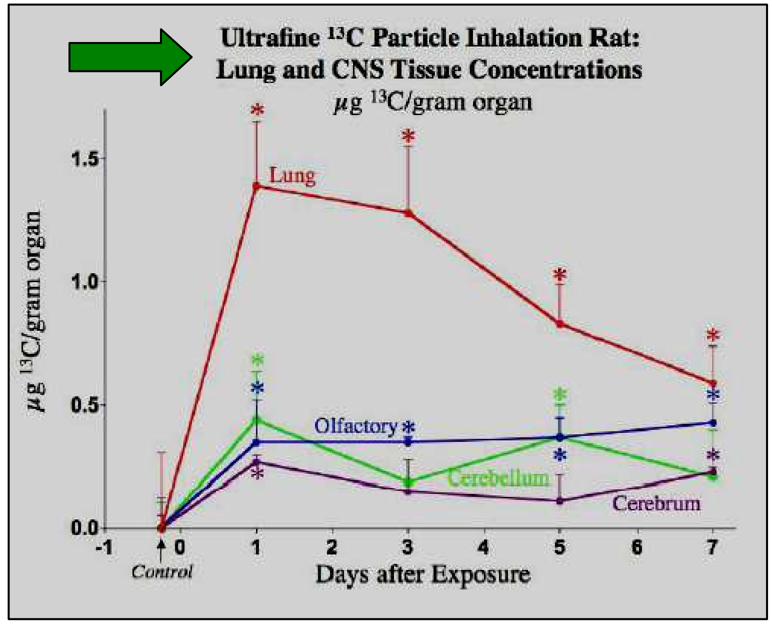
[a] [85].

Composition by size mode

Ultrafine Particles
(continued)

- Traffic impacts on health – ***Peters et al., 2004***; *Gauderman et al., 2005, 2007; Elder et al.2004, 2006; Kleinman et al., 2005*
- Translocation to CNS – *Elder et al, 2007;* ***Oberdörster 2004***
- Effects on CNS – *Veronesi et al., 2005; Kleinman et al., 2008*
- Systemic inflammation – *Frampton et al., 2006; Elder et al., 2004; Araujo et al., 2008*





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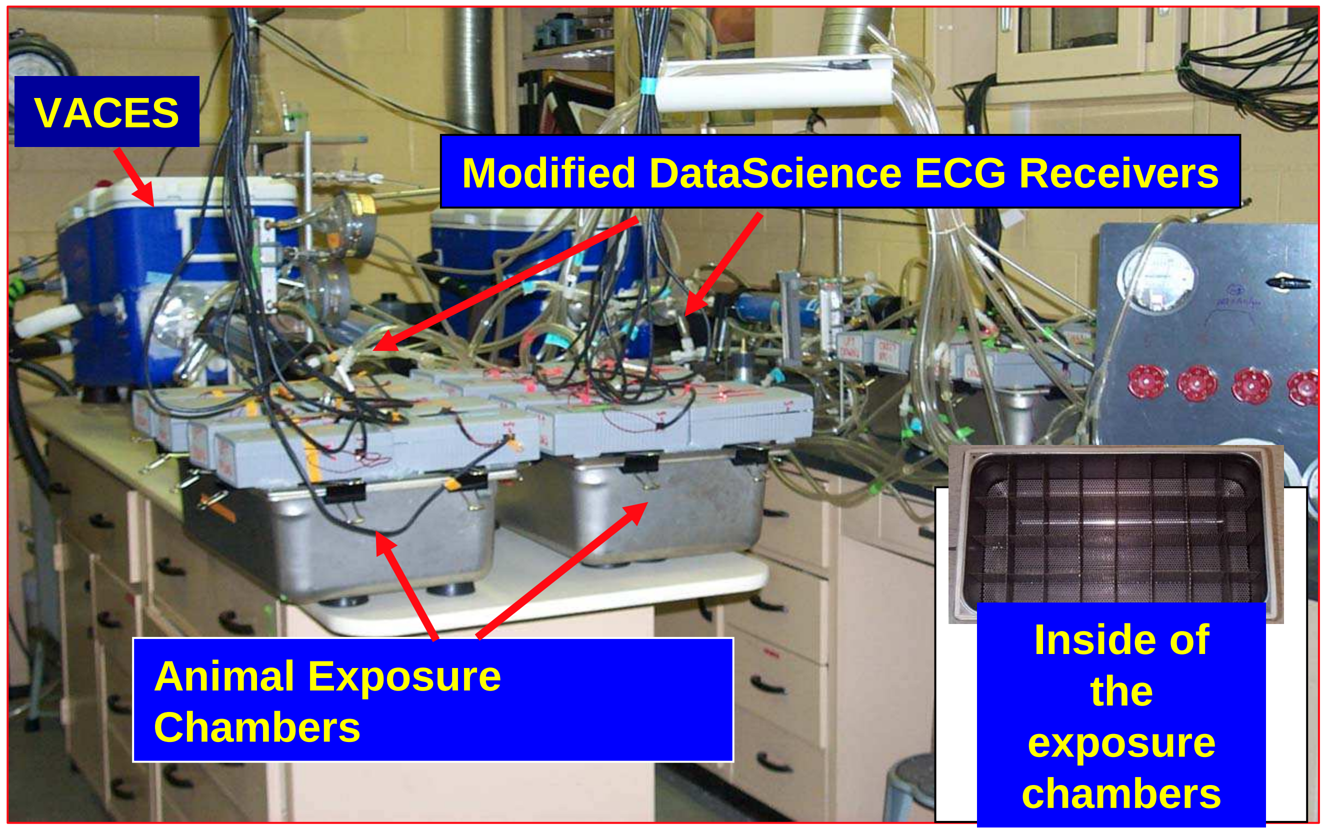
Advances in New Technology

- Coarse Concentrator – *Demokritou et al., 2002a*
- Ultrafine Concentrator – *Kim et al., 2000; Gupta et al., 2004*
- Chem Vol (sampler) – *Demokritou et al., 2004*
- Personal PM sampler – *Misra et al., 2002; Demokritou et al., 2002b*



Health Effects of PM Sources

- Source apportionment workshop (2004) – *Thurston et al., 2005*
- Source apportionment / health linkage – *Ito et al., 2006; Mar et al., 2006*
- Traffic / near road studies – throughout centers
- Agricultural PM – *Smith et al., 2003*
- On-road exposures of rats in a mobile emissions laboratory (MEL) – *Elder et al., 2004, 2007*
- Power plants (TERESA), tunnels, shipping ports, airports – *Ruiz et al., 2007; Geller et al., 2005; Arhami et al., in press; Westerdahl et al., 2008*



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What We Knew About PM Exposure & Human Health Effects in 1997

- Growing data base showing adverse health effects, including premature death associated with PM
- Correlations appeared stronger with $PM_{2.5}$ (fine)
- Some groups appeared to be at unusual risk
- Long-term exposure associated with shortened life-span
- <u>Controversy:</u> ‘Biologic Plausibility’ uncertainty with major questions about personal exposures and effects
- <u>Yet - The Findings were Compelling</u>: EPA revised the PM National Ambient Air Quality Standards (NAAQS)
    - New $PM_{2.5}$ standards

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*Epidemiological Perspective**

1997: Top 9 Reasons Not to Regulate PM2.5

- Time Series Associations confounded
- Exposure uncorrelated with ambient
- All Harvesting
- Thresholds
- No Mechanism/Biological Plausibility
- Only due to Some Particles, will Regulate Wrong Ones
- Don't know who is Susceptible
- Only 2 Cohort Studies/Faked
- Don't know if lower PM2.5 means fewer deaths

***J. Schwartz – PM Center Public Meeting, Washington, DC, 2004**

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Ten Years of Progress (2008)

- Research strengthened confidence that PM causes adverse health effects – “biologic plausibility”
- Supported use of ambient fine PM concentrations to evaluate exposure in time-series epidemiologic analyses
- Greater recognition that PM hazardous components (physical and chemical) are key to impacts on human health
- Better understanding of source and PM formation processes, especially for the organic fraction
- Size matters – all modes seem to have “unique” properties and associated toxicities
- Broadened the focus of PM effects beyond the lungs, effects on CV system perhaps of greatest concern; also CNS, birth outcomes
- New insights on susceptibility issues (launching G-E)
- Supported revisions of NAAQS and has moved air pollution into the realm of public health practice

Entry into Public Health Practice

- Air pollution is not just a respiratory issue, impacts have been identified systemically – notably cardiovascular but also potentially CNS and birth outcomes
- Clinicians alerted to the risks of air pollution via the:
  - AHA Scientific Statement: *Air Pollution and Cardiovascular Disease - A Statement for Healthcare Professionals From the Expert Panel on Population and Prevention Science of the American Heart Association,* Circulation*, 2004*
  - *American Academy of Pediatrics Policy Statement, Ambient Air Pollution: Health Hazards to Children,* Pediatrics, *2004*
  - AIRNow emphasizes cardiac risk as well as pulmonary cautions
  - AHA video news release on cardiovascular responses to air pollution
    - EPA abstract (Detroit studies) 1 of 2 selected from 1800

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Entry into Public Health Practice
(continued)

- Public Health Literature: "*Preventing Chronic Disease: Public Health Research, Practice and Policy*" 2008, CDC authors, citing air pollution as a top-6 risk factor for cardiovascular disease

- National Heart Lung and Blood Institute contacts EPA to help assess the feasibility of an air pollution intervention study to reduce cardiovascular deaths.

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Evolving Air Pollution Landscape

- **Multipollutant assessment**
  - OAQPS - Broad-based and source (sector)-targeted regulation
  - Source to Health-Outcome Paradigm – more effective regs?
  - Less studied (diffuse) sources – ports, airports, CAFOs, fires
  - "Post-Sulfur" air environment – C / N dominance
  - Biofuels – new chemistry / nitrogen
  - Urbanization
  - Complexities of exposure (potential for remote technologies?)
  - Host factors and susceptibility – 'omic technologies?
  - Accountability – 'quantifying' that we are making a difference?
- **Air Pollution – Climate interactions**
  - Influence of Climate (global issues)
  - How will CO_2 be regulated?