Particulate Matter Research Program:

Five Years of Progress

What Have We Learned About PM Since 1997?

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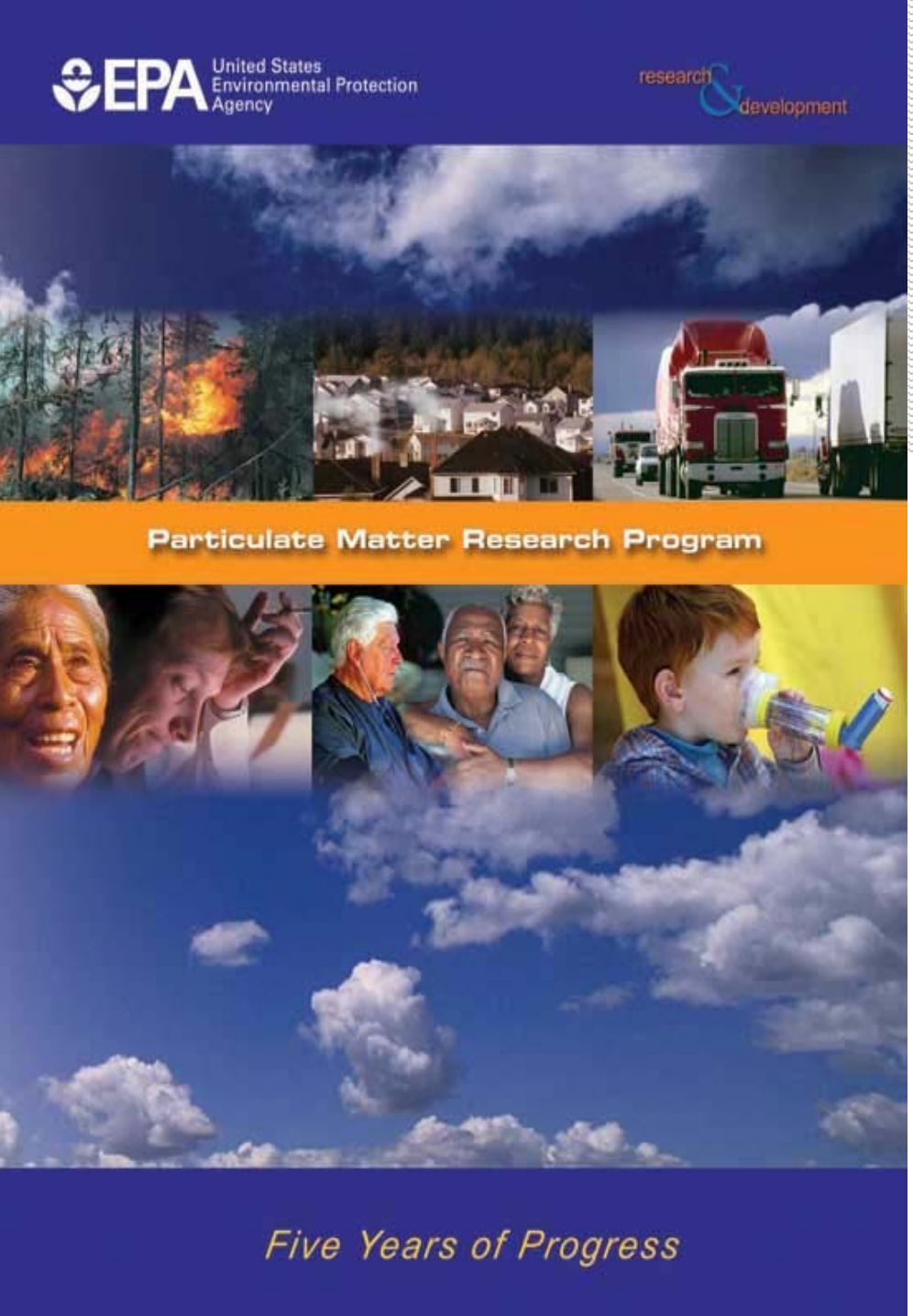
Presentation to Stakeholders

9 September 2004



Presenting:

EPA Research and Development's Particulate Matter Accomplishments Report

This report highlights the research conducted and funded by ***EPA Research and Development's*** particulate matter (PM) research program since 1997 and provides a status report on what we know about PM and insights into what we need to know as we move into the future.

PM Research Supports EPA's Clean Air Goal

- Through intensified research, EPA has established a sound scientific basis for setting national ambient air quality standards and in support of state and tribal programs to meet the standards.
  - *Reconfirmed the links between exposure to $PM_{2.5}$ and serious human health problems and discovered that $PM_{2.5}$ affects the heart*
  - *Provided new evidence on where and how individuals are exposed to $PM_{2.5}$, including outside and indoors*
  - *Provided more sophisticated measurement and air modeling tools*
- Major scientific achievements, but important uncertainties and questions remain.

EPA PM Research Program

Epidemiology

Clinical and Animal Toxicology Studies

Molecular

Intramural Program ⟷ **EPA STAR Program**

EPA Partners:
- *Other Federal Agencies*
- *Health Effects Institute*
- *National Research Council*
- *Academia*
- *Industry laboratories*

Emission Source Characterization

Exposure, Atmospheric Measurement and Models

Supersites and EPA Monitoring Network

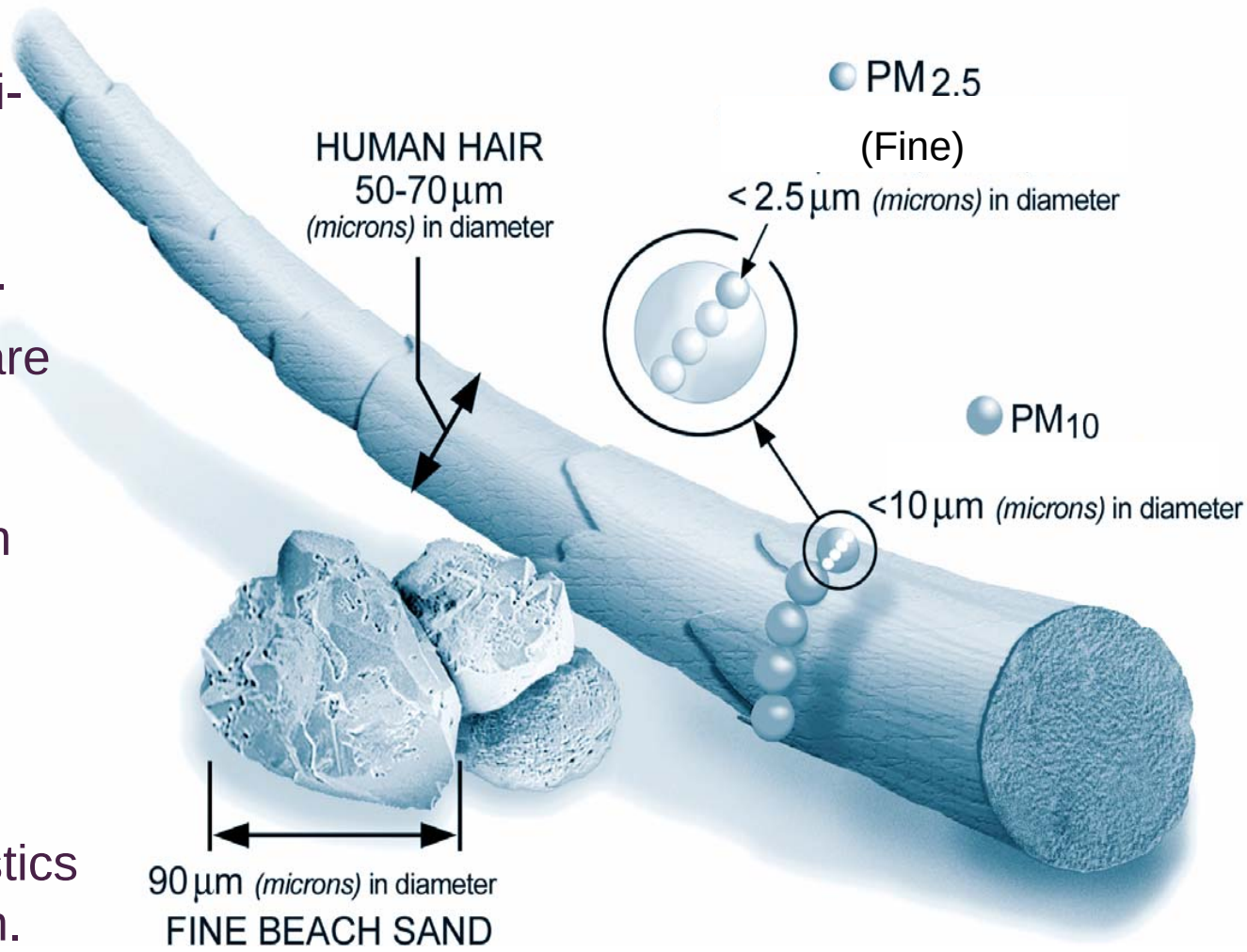
EPA Leadership in Particulate Matter Research

- EPA's PM research program is a model of science leadership.
  - *Internationally recognized in-house research program*
  - *Extensive coordination of planning and research efforts by other institutions*
- EPA PM research is closely coordinated with the national air monitoring network, including Supersites.
- In 1998, EPA established five university based-PM research centers that have produced results important to air pollution policy.

Northwest Research Center for Particulate Air Pollution and Health
Southern California Center for Airborne Particulate Matter
Harvard Center for Ambient Particle Health Effects
NYU School of Medicine PM Center
Rochester PM Center

What is Particulate Matter (PM)?

- PM is a complex mixture of solid, semi-volatile and aqueous materials of various sizes found in the air.
- When inhaled, they are associated with premature death and disease in the human population.
- The size and composition of the particles may be important characteristics with respect to health.



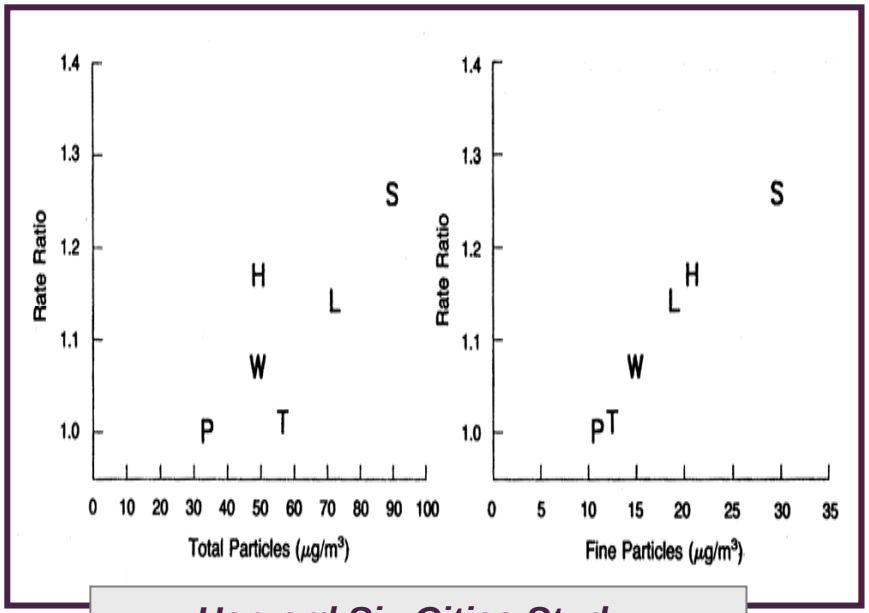
Ambient PM is Derived from Varied Sources

Fine particles can be emitted directly or formed in the air from gases.

1997: What Was Known About PM Exposure and Human Health Effects?

- Adverse health effects, including premature death, were associated with PM.
- Correlations with mortality were stronger with fine PM matter than with larger particulates.
- Long-term exposure was associated with shortened life span.
- Controversial: There were uncertainties about biological plausibility, no evident mechanisms of action; and important questions about exposures and effects.
- Findings compelling: EPA revised the PM National Ambient Air Quality Standards (NAAQS).

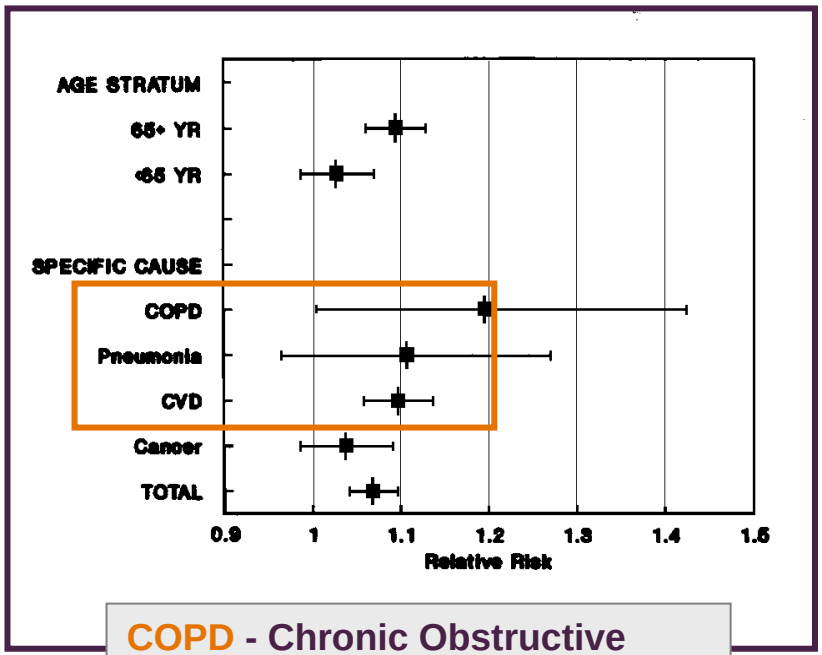
Epidemiology Evidence Compelling, But Uncertain



Harvard Six Cities Study:
Steubenville, Harriman, St. Louis, Watertown, Topeka, Portage

Fine PM is strongly associated with human health effects. Risk of dying increases linearly as fine PM levels increase.

If someone has a preexisting heart or lung problem, research shows that they may be at greater risk from exposure to particulate matter.



COPD - Chronic Obstructive Pulmonary Disease
CVD - Cardiovascular Disease

EPA and NRC's Collaboration on the PM Research Program

- In three reports, the National Academy of Sciences' National Research Council (NRC) identified important PM research priorities.
- In 1998's Congressional appropriations, funding for PM research was doubled and EPA was mandated to develop research planning strategies with the NRC.
- The reports recommended a multi-year research portfolio targeted to address the highest priority research questions. EPA has aligned its research program to address the NRC recommendations.
- A fourth NRC report has been delivered to EPA and discusses progress to date.

Key Research Questions

- Could low concentrations of PM actually cause such marked effects by themselves?
- Who is susceptible, and why?
- How are ambient PM and actual personal exposure linked?
- Are specific sources or PM attributes linked to adverse effects?
- How do we know what sources to control to reduce public health risks?

Key Research Questions

- Could low concentrations of PM actually cause such marked effects by themselves?
  - *Insights: EPA studies identified plausible biological mechanisms, greatly strengthening confidence that the epidemiology findings are "real"*
  - *Challenges: Much uncertainty remains regarding the biological mechanisms underlying heart and lung effects associated with PM exposures*

Key Research Questions

- Who is susceptible, and why?
  - *Insights: EPA clinical studies found that pre-existing pulmonary disease results in "hot spots" of PM deposition, explaining why some groups are at enhanced risk*
  - *Challenges: More information about potential for enhanced effects in susceptible populations (e.g., infants, children, diabetics) is needed*

Key Research Questions

- How are ambient PM and actual personal exposure linked?
  - *Insights: EPA demonstrated linkage between ambient $PM_{2.5}$ and personal exposure to ambient $PM_{2.5}$, improving confidence in interpretation of epidemiological findings*
  - *Challenges: Very limited understanding of exposure of most-susceptible groups to most-important PM components*

Key Research Questions

- Are specific sources or PM attributes linked to adverse effects?
  - *Insights: Greatly improved understanding of PM components in urban areas (Supersites) and contributing sources*
  - *Challenges: Limited availability of methods to monitor key PM constituents (e.g., organic fraction) and to identify sources contributing most to health risks*

Key Research Questions

- How do we know what sources to control to reduce public health risks?
  - *Insights: Improved models developed to predict future ambient PM levels for state/tribal control strategy development*
  - *Challenges: Limited availability of tools to optimize management of PM in conjunction with other air pollutants (multi-pollutant)*

Findings: Short-term Epidemiology

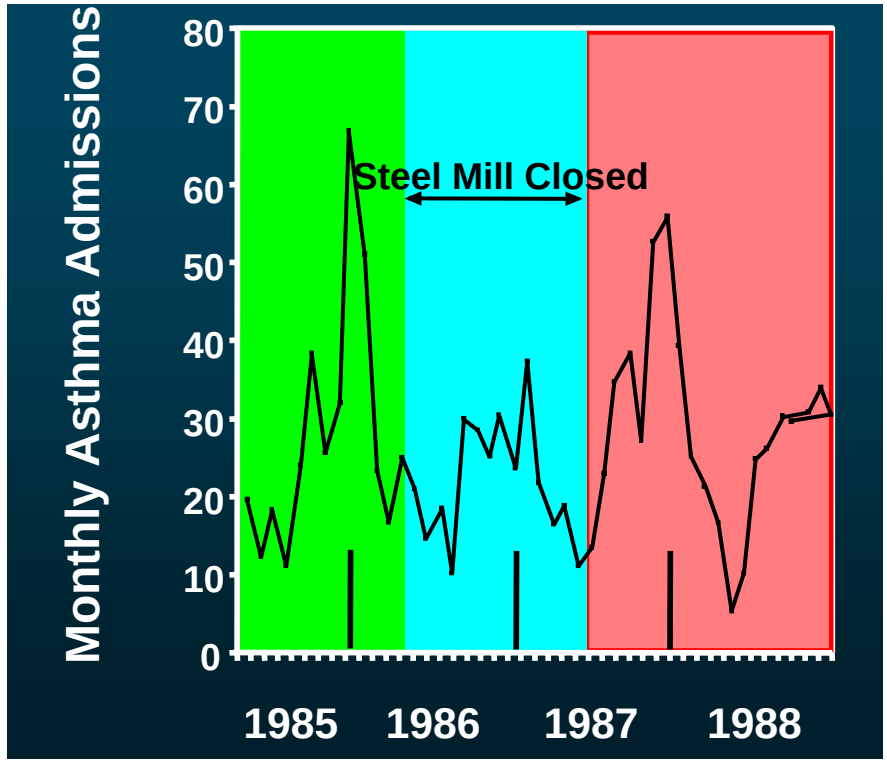
- Uncertainties raised: influence of weather, other pollutants, etc.
- Health Effects Institute (HEI), funded by EPA and industry, supported multi-city study (The National Morbidity, Mortality, and Air Pollution Study "NMMAPS")
  - *Showed consistent increase in mortality, not sensitive to inclusion of other pollutants; strengthened confidence in epidemiologic results*
- Statistical issues identified in use of widely-used software (GAM)
  - *EPA supported reanalysis of key studies; PM association persisted in the majority of studies; risk estimate smaller in some, major uncertainties reduced*
- Next Steps: research on effects of short-term exposure to PM
  - *Working with partners to design multi-pollutant, multi-city studies*
  - *Examine role of PM attributes, sources for various effects*
  - *New funding for PM centers*

Findings: Long-term Epidemiology

- Prospective cohort studies (Harvard Six City, American Cancer Society) that employed improved statistical methodologies reported long-term exposure to PM associated with mortality
  - *Uncertainties remain, including confounding by other variables*
  - *HEI-funded reanalysis essentially replicated the original results, addressed criticisms*
- Next steps: research on effects of long-term exposure to PM
  - *STAR Program - $30 Million Prospective Epidemiology Study*
  - *Five other EPA-sponsored studies using existing cohorts*

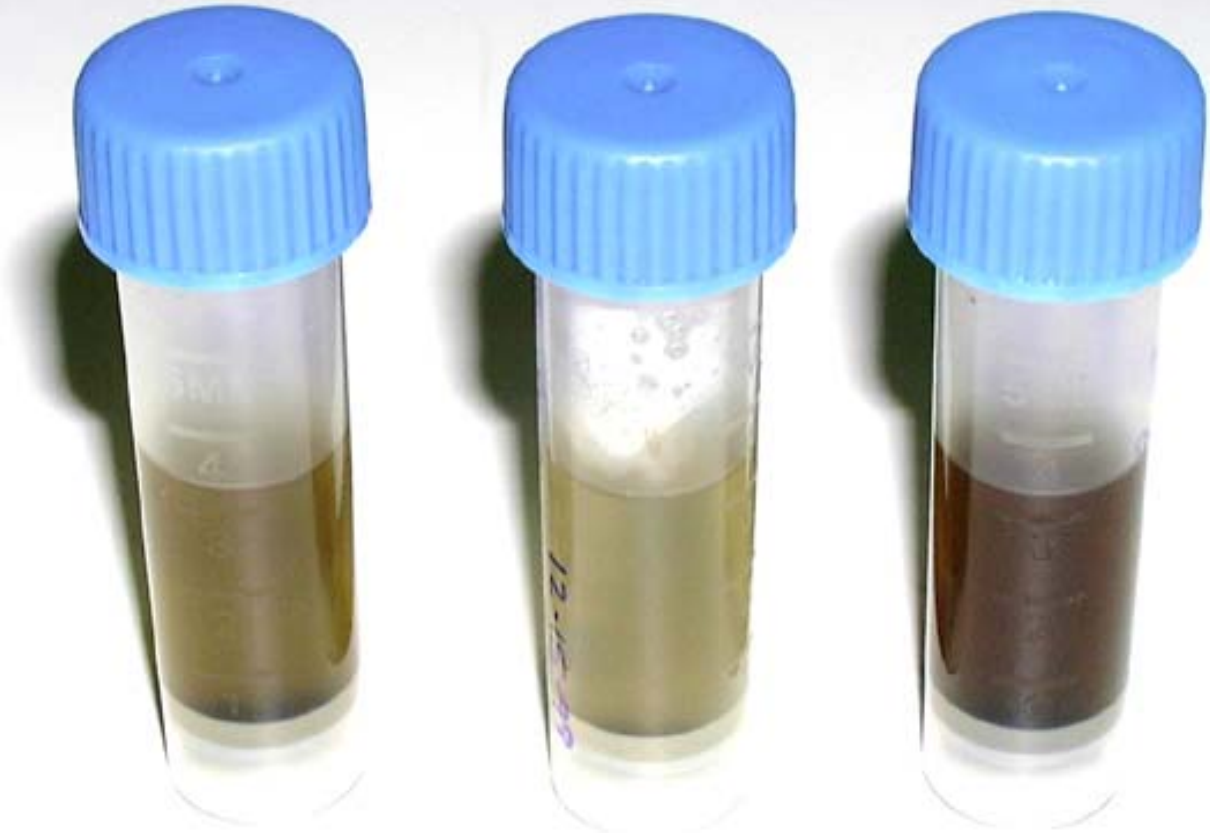
Findings: Biological Plausibility

Scientific evidence (epidemiology, clinical, toxicology) has strengthened our confidence that PM and some PM components produce adverse effects in humans.



The epidemiology studies showed health outcomes tracking the steel mill closure and PM levels.

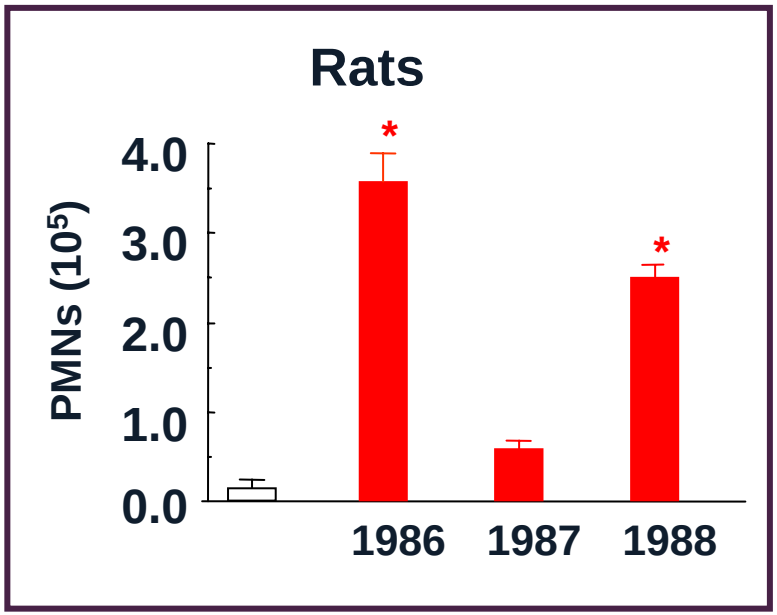
Utah Valley Extracts

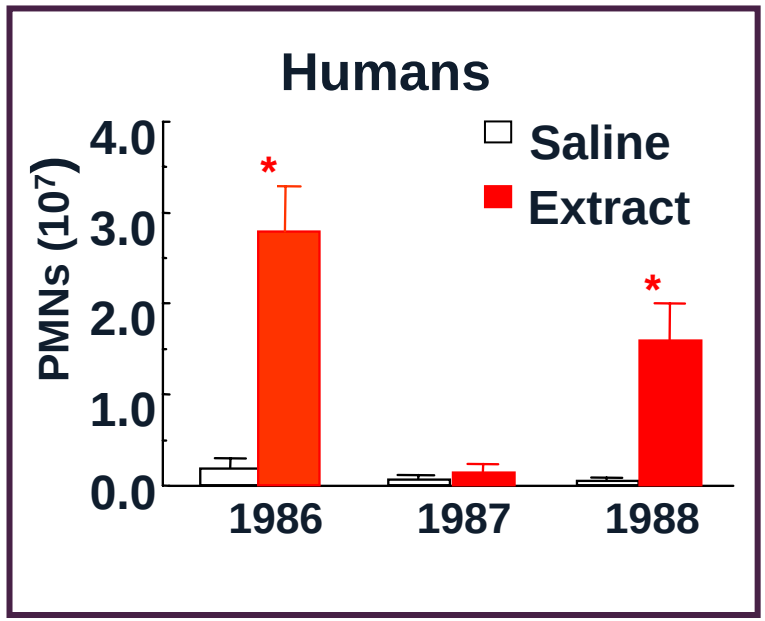


1986	1987	1988
STEEL MILL: Open	Closed	Open

Clinical and Toxicology Studies

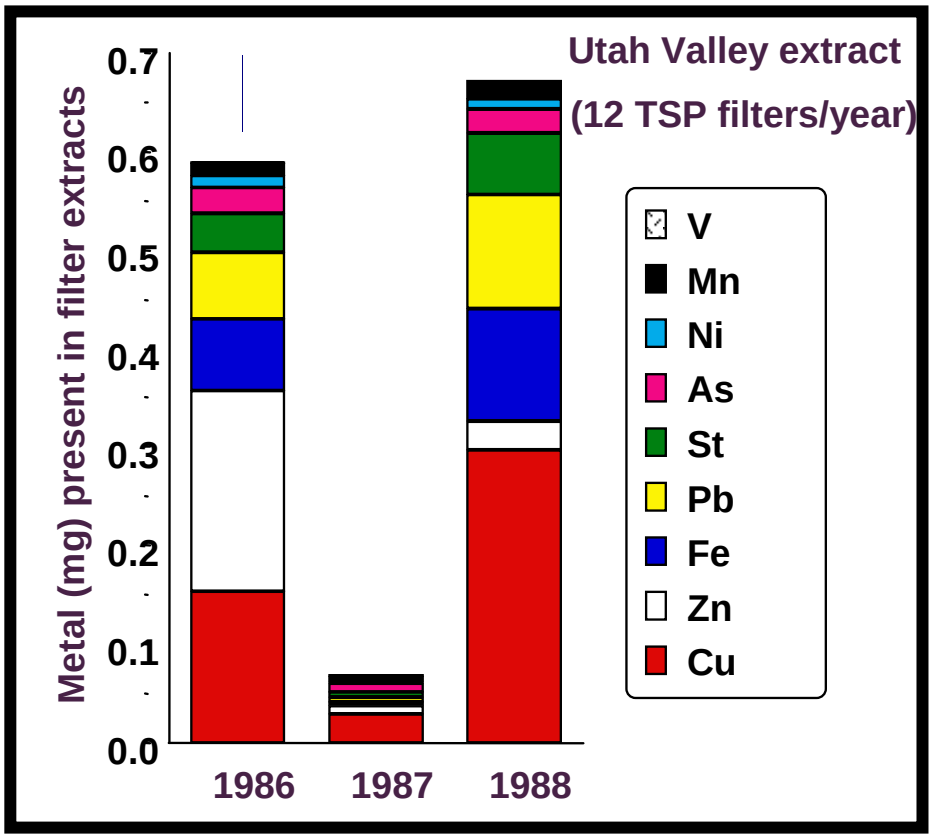
- Extracts of the Utah Valley particles were tested in humans, animals, and *in vitro* cell cultures.
- Consistent effects in humans and laboratory animals demonstrate PM toxicity.

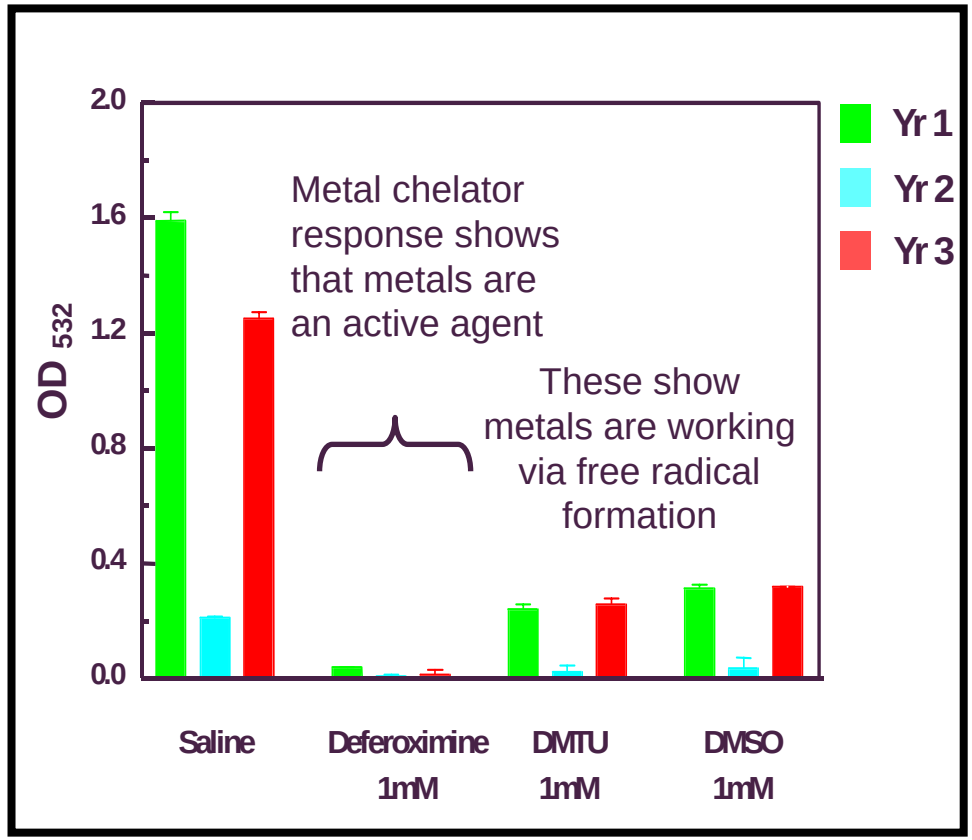




PMN – marker of pulmonary inflammation

The Composition of the PM Indicates the Role of Metals in Producing Toxicity

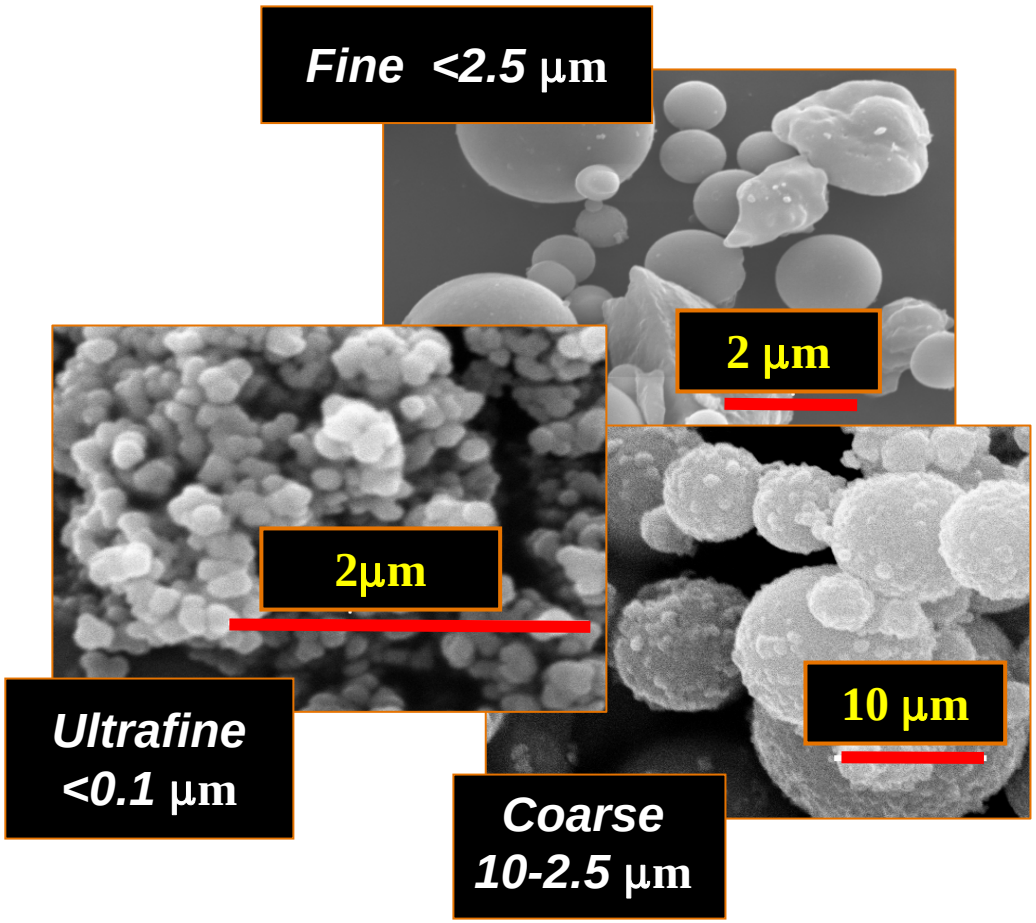


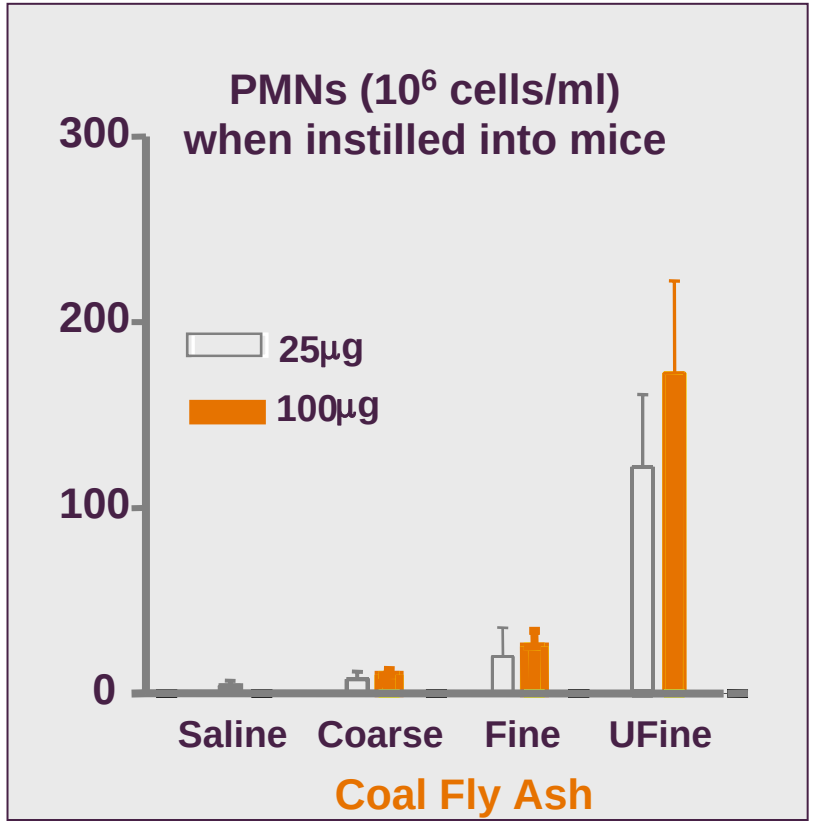


Utah Valley dust shows significant metal composition

In vitro study shows Utah Valley dust generates reactive oxidants

Relating Fraction Size to Lung Toxicity



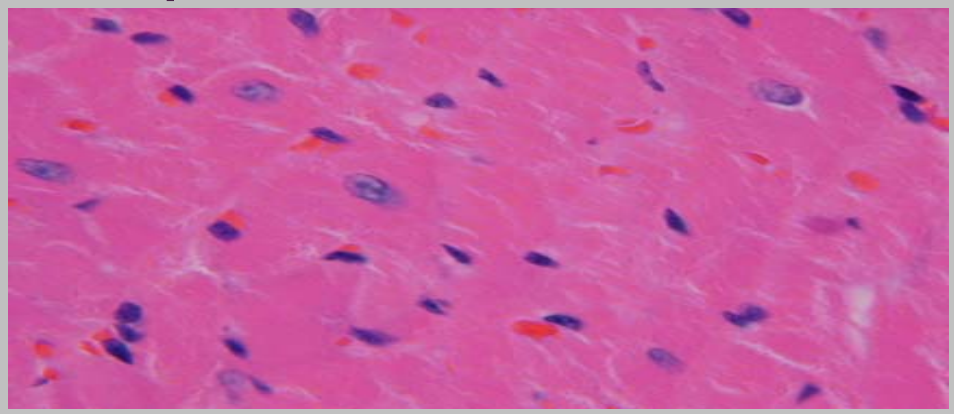


PMNs - a marker of pulmonary inflammation

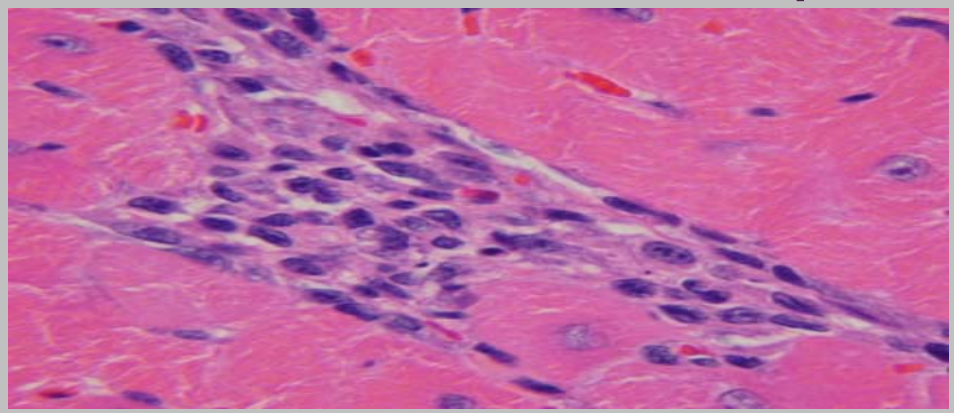
Findings: Mechanisms of Damage

Direct evidence of cardiac tissue changes:

Air-exposed



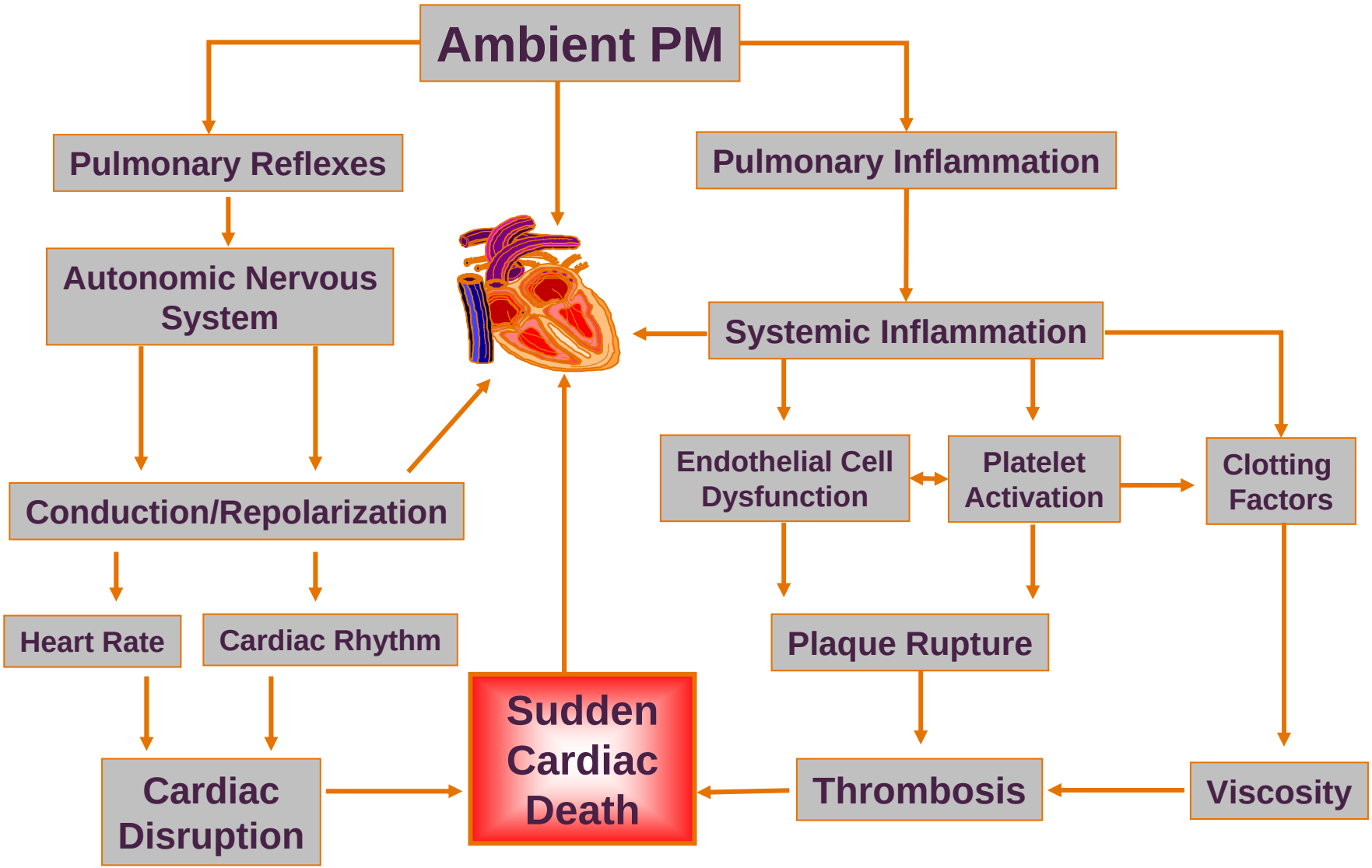
PM-exposed



Rat heart tissue after exposure to PM-associated zinc

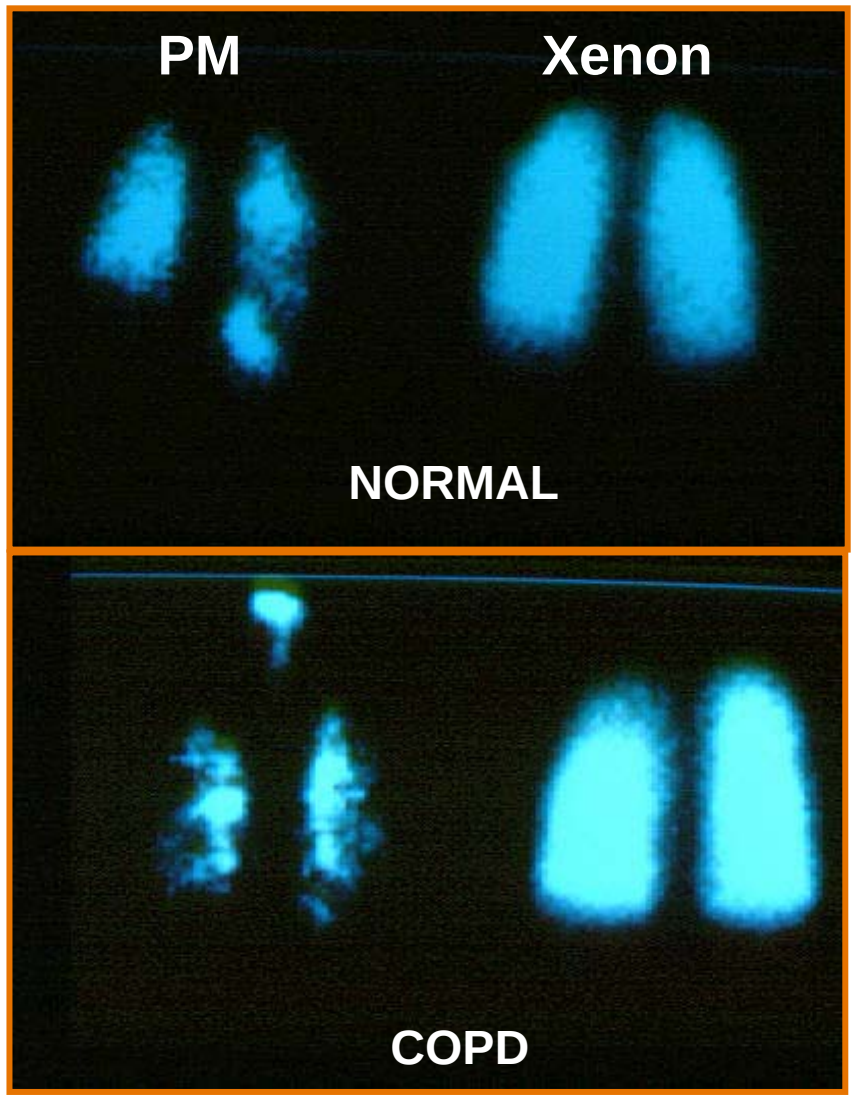
- PM exposure can lead to heart problems, not just lung illness; major shift in scientific understanding.
- Changes in heart rhythm and heart tissue have also been observed in humans.

Potential Mechanisms of PM Effects on Cardiopulmonary System



Findings: Susceptibility

- People with pre-existing heart- or lung-related disease are more likely to experience continued or more serious problems after exposure to PM.
- People with Chronic Obstructive Pulmonary Disease (COPD) can have up to 10 times as many particles in certain locations in their lungs, creating “hot spots” that may increase their susceptibility to PM-related health effects.



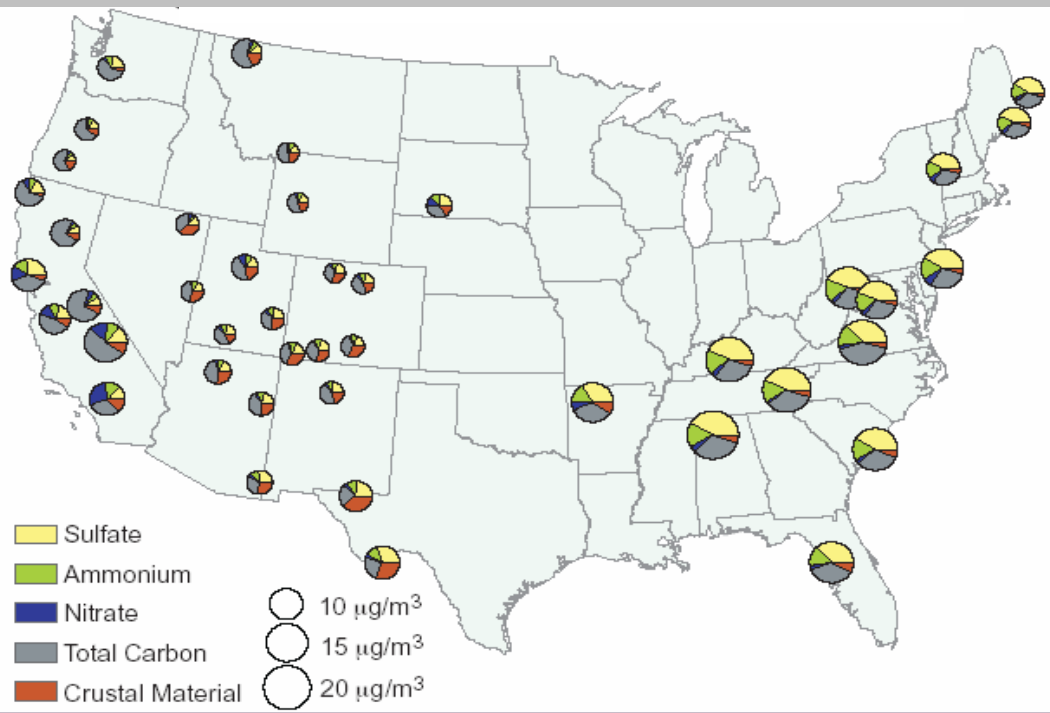
Findings: Exposure

- Demonstrated linkage between ambient $PM_{2.5}$ and personal exposures to ambient $PM_{2.5}$.
- Personal exposures to $PM_{2.5}$ mass are similar for healthy and susceptible populations.
- Conclusion: Ambient monitors are a valid surrogate for personal exposure to $PM_{2.5}$ mass in epidemiological studies.

Findings: Atmospheric Sciences

- Research supports state and tribal programs to attain PM standards.
- Multi-pollutant computer model developed to use source emissions to predict ambient PM levels.
- Methods developed to collect and analyze ambient PM fractions and species.
- State of the art methods developed to measure emissions from diverse sources.

Carbonaceous material, sulfate, nitrate, and ammonium are major components of Rural $PM_{2.5}$



Great Strides in Addressing Critical Questions

- Research has strengthened our confidence that PM causes adverse health effects
- Improved understanding of the importance of PM characteristics on human health
- Broadened focus from pulmonary effects to cardiovascular system effects
- Demonstrated that the $PM_{2.5}$ ambient monitoring system is valid for use in epidemiology studies
- Developed new tools to support state implementation of standards

PM Research is Science Foundation for EPA Decision-Making

PM research has significant regulatory benefits and impacts:

- Indicates that fine PM standards are important to protect public health
- Strengthens confidence in the scientific basis for the PM standards
- EPA's science program has produced critically important findings included in the PM Air Quality Criteria Document used to support the current revision of the PM National Ambient Air Quality Standards

Great Strides -- Significant Questions Remain

The National Research Council

Research Priorities for Airborne Particulate Matter: IV. Continuing Research Progress (2004)

"Much has been learned from the research investment in 1998, and evidence gained by the investment is already being used in decision-making, which will continue even in the face of uncertainty. However, much is still to be learned…Continued enhancement of [this] air pollution and health research effort will undoubtedly yield substantial benefits for years to come…in [the] effort to improve air quality and public health."

Key Research Challenges for the Years Ahead:

- *Effects of long-term exposure to PM*
- *Biological mechanisms explaining susceptibility*
- *PM attributes and source apportionment*