Air Pollution and Heart Health

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Disclosure of Conflicts of Interest

- None to report
- The content of this presentation does not necessarily reflect the policy of EPA
PM is derived from many different sources

Natural Sources

Wood-Burning Stoves

Forest Fires

Heavy Duty Diesel Engines

Cars and Trucks

Non-Road Vehicles

Leaf Burning

Industrial Sources
High PM Levels Diminish Visibility

Low PM

Clear Day
PM$_{2.5}$ = 5 µg/m$^3$

High PM

Haze
PM$_{2.5}$ = 40 µg/m$^3$

Boston, MA June 1999
Health Effects
Associated with Different Size PM

The EPA regulates PM on the basis of mass in different size ranges

- Aerodynamic diameter
  - <10 µm (PM$_{10}$)
  - <2.5 µm (PM$_{2.5}$)
  - Annual: 15 µg/m$^3$
  - 24 hour: 35 µg/m$^3$
Ambient Particulate Matter
Daily Variability

Chapel Hill, NC

PM$_{10}$

PM$_{2.5}$
Composition of PM$_{2.5}$ at Urban and Rural Locations

- **East**
  - Organic carbon, sulfate & nitrate predominate

- **West**
  - Organic carbon, nitrate and black carbon predominate

- Levels are highly variable on all scales
  - Between continents
  - Between countries
  - Between regions
  - Between cities
  - Within cities

*Bhatnagar, A. Circ Res 2006*
Three-Year Average 24-hour PM$_{2.5}$ Concentration by County: 2005-2007

Number of people residing within counties that reported county-wide average concentrations within the specified ranges (in millions)

- $\geq 20.1 \mu g/m^3$ [1 county]
- $18.1 - 20.0 \mu g/m^3$ [7 counties]
- $15.1 - 18.1 \mu g/m^3$ [53 counties]
- $12.1 - 15.0 \mu g/m^3$ [242 counties]
- $\leq 12.0 \mu g/m^3$ [237 counties]
- No data
Living in Areas with High Air Pollution Associated with Shorter Life Expectancy

An Association between Air Pollution and Mortality in Six U.S. Cities
Douglas W. Dockery, C. Arden Pope, Xiqing Xu, John D. Spengler, James H. Ware, Martha E. Fay, Benjamin G. Ferra, Jr., and Frank E. Speizer

- Linear relationship after control for traditional risk factors
Findings Replicated by Large American Study and Others

- >500,000 adults from 151 metropolitan areas
- Followed prospectively and controlled for traditional risk factors

American Cancer Society Cohort
Pope et al 2002

Pope and Dockery 2006
Strongest Associations For Cardiovascular Endpoints

No effect line

RR (95% CI)

- All Cardiovascular plus Diabetes
- Ischemic heart disease
- Dysrhythmias, Heart failure, Cardiac arrest
- Hypertensive disease
- Other Atherosclerosis, aortic aneurysms
- Cerebrovascular
- Diabetes
- Other Cardiovascular
- Respiratory Diseases
- COPD and allied conditions
- Pneumonia, Influenza
- All other respiratory
Living in a More Polluted Area Associated with Increased CVD

Figure 1. Level of Exposure to Fine Particulate Matter and the Risk of Death from Cardiovascular Causes in Women.
Proposed Biological Mechanisms

1. Systemic Oxidative stress and Inflammation
   - Cellular inflammatory response (↑ activated WBCs, platelets, MPO)
   - ↑ Cytokine expression levels (↑ IL1β, IL6, TNFα)
   - ↑ ET, histamine, cell microparticles, oxidized lipids; ↓ anti-oxidants
   - Adipokines (PAI-1, Resistin)
   - Acute phase response (↑ Clotting factors, Fibrinogen, CRP)
   - Blood: ↑ Platelet aggregation
   - Heart: ↓ HRV, ↑ Heart rate, ↑ Arrhythmia potential
   - Vasculature: EC dysfunction/vasoconstriction, ↑ ROS (e.g. NOX)
   - Atherosclerosis progression/vulnerability, ↑ Thrombogenicity (e.g. tissue factor)

2. ANS imbalance
   - ↑ SNS / ↓ PSNS

3. PM or constituents in the circulation
   - UFP, soluble metals, Organic compounds

- Blood: ↑ Platelet aggregation
- Vasculature: Vasoconstriction, Endothelial dysfunction, PM-mediated ROS, ↑ BP, ↑ Atherosclerosis, EC dysfunction/vasoconstriction, ↑ ROS (e.g. NOX), Atherosclerosis progression/vulnerability, ↑ Thrombogenicity (e.g. tissue factor)
- Blood: ↑ Platelet aggregation
- Heart: ↓ HRV, ↑ Heart rate, ↑ Arrhythmia potential
- Vasculature: EC dysfunction/vasoconstriction, ↑ ROS (e.g. NOX), Atherosclerosis progression/vulnerability, ↑ Thrombogenicity (e.g. tissue factor)

Acute oxidative stress & inflammation
- Activation of lung ANS reflex arcs
- Pulmonary oxidative stress & inflammation
- PM and/or constituents transmitted into blood
- Bronchioles/Alveoli

Sub-acute & Chronic
“Systemic spill-over”

Perhaps chronic

3. PM or constituents in the circulation
Particulate Matter Air Pollution and Cardiovascular Disease
An Update to the Scientific Statement From the American Heart Association

Robert D. Brook, MD, Chair; Sanjay Rajagopalan, MD; C. Arden Pope III, PhD; Jeffrey R. Brook, PhD; Aruni Bhatnagar, PhD, FAHA; Ana V. Diez-Roux, MD, PhD, MPH; Fernando Holguin, MD; Yuling Hong, MD, PhD, FAHA; Russell V. Luepker, MD, MS, FAHA; Murray A. Mittleman, MD, DrPH, FAHA; Annette Peters, PhD; David Siscovick, MD, MPH, FAHA; Sidney C. Smith, Jr, MD, FAHA; Laurie Whitsel, PhD; Joel D. Kaufman, MD, MPH; on behalf of the American Heart Association Council on Epidemiology and Prevention, Council on the Kidney in Cardiovascular Disease, and Council on Nutrition, Physical Activity and Metabolism

“The overall evidence is consistent with a causal relationship between PM$_{2.5}$ exposure and cardiovascular morbidity and mortality.”

“PM$_{2.5}$ is deemed a modifiable factor that contributes to CV morbidity and mortality.”
Populations and clinical groups having increased vulnerability to the adverse health effects of air particle pollution include:

- Aged adults
- Children
- Cardiovascular disease
  - Heart failure
  - Ischemic heart disease
  - Arrhythmia
- Diabetes
- Pulmonary disease
  - Asthma
  - COPD
- Genetic polymorphisms
  - e.g. GSTM-1
• Cardiovascular disease is the #1 cause of death in the U.S.

• The cardiovascular health effects of air particle pollution have been known for several decades, but only recently have the details become better defined

• Air particle pollution is characterized by the mass of the particles. It is ubiquitous and the levels and constituents differ by local and regional sources

• While air pollution levels have fallen substantially over the past 30 years levels remain high enough to adversely impact health
Air Pollution and Heart Disease
Summary

• Thousands of papers published on air pollution and health

• Short-term exposures associated with the triggering/exacerbation of cardiovascular disease and clinical events

• Long-term exposures associated with increased risk of cardiovascular death and atherosclerotic progression

• Physiological pathways may include inflammation, autonomic changes, and vascular changes

• Persons predisposed to these endpoints may be at increased risk of air pollution