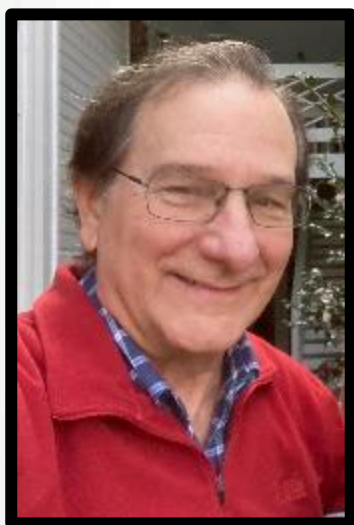




# Particle Pollution and Risk to Cardiovascular Health



**Wayne Cascio, MD, FACC**

*Director, Center for Public Health and Environmental Assessment*

*Office of Research & Development, US EPA*

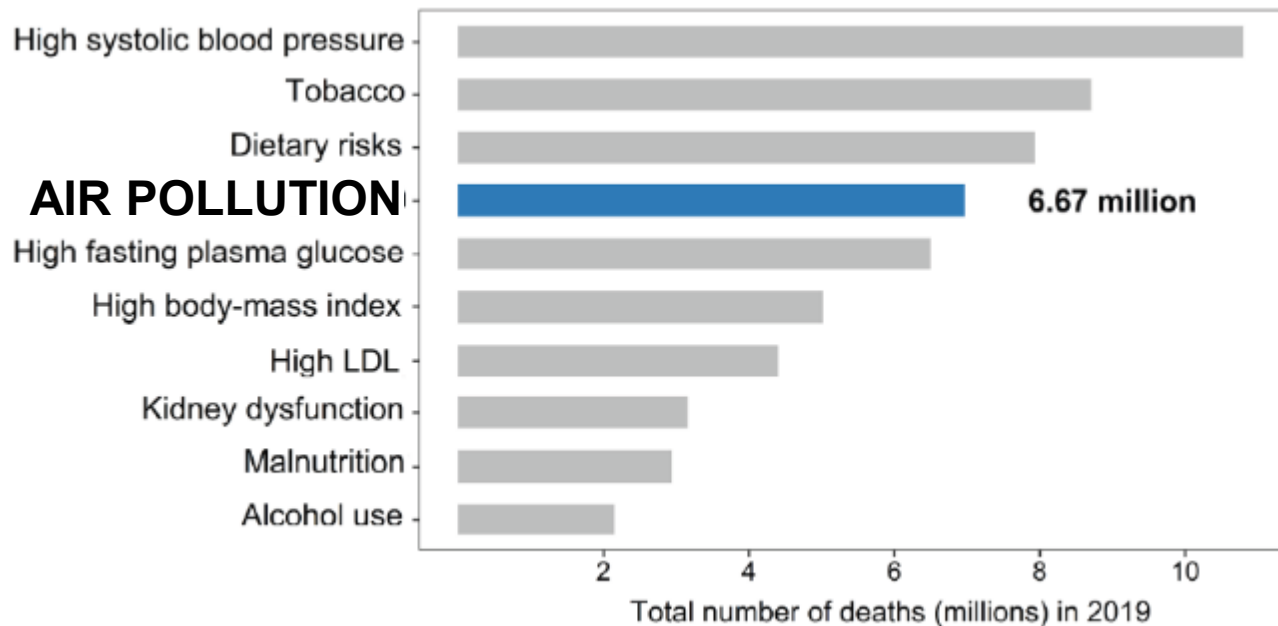
*Research Triangle Park, NC*

Virtual Presentation  
Chapel Hill, NC  
June 13, 2023

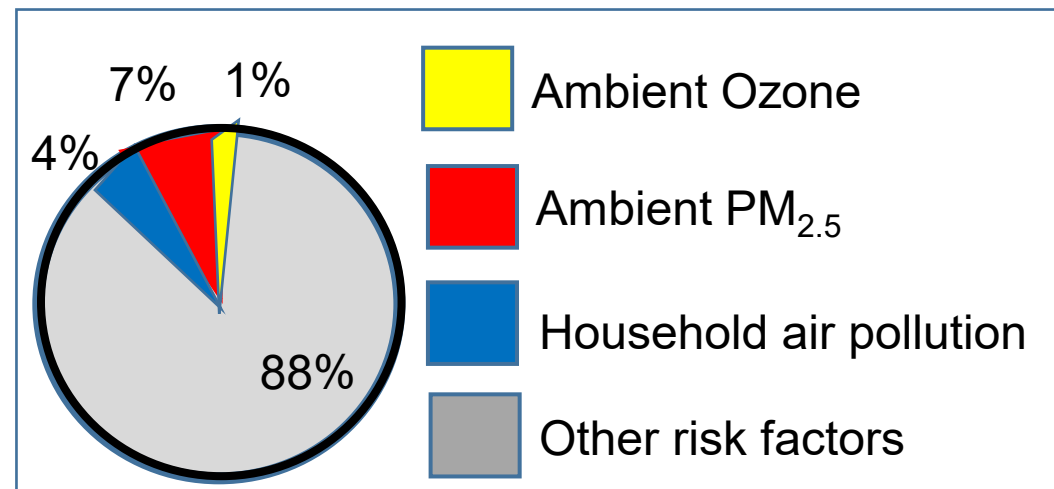
Missouri Million Hearts  
Missouri Dept. of Health and Senior Services



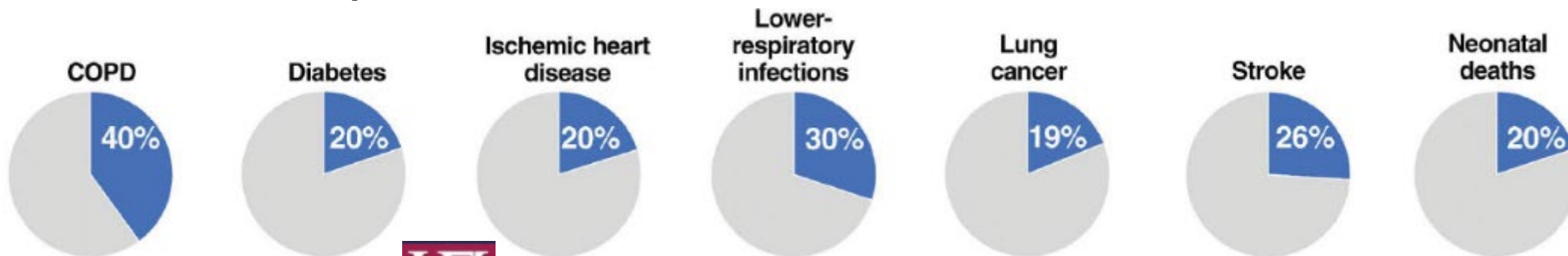
# Global Rank of Risk Factors by Total Deaths All Causes 2019



## % of Global Death due to Individual Pollutants



## % of Global Death from Specific Causes Due to Total Air Pollution





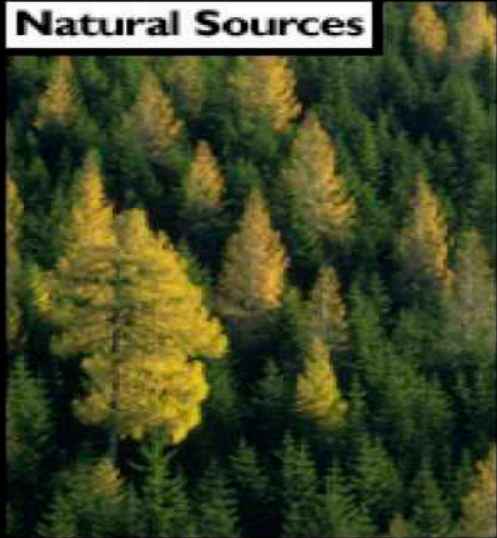
**Wood-Burning Stoves**



**Forest Fires**

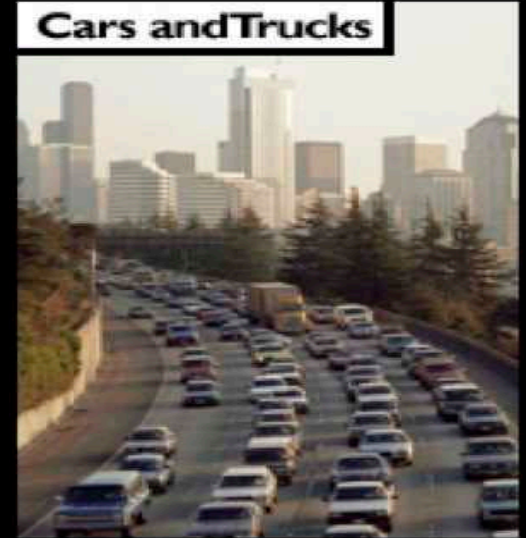


**Heavy Duty Diesel Engines**



**Natural Sources**

**Particulate Matter (PM)  
is derived from  
many different sources**



**Cars and Trucks**



**Non-Road Vehicles**



**Leaf Burning**



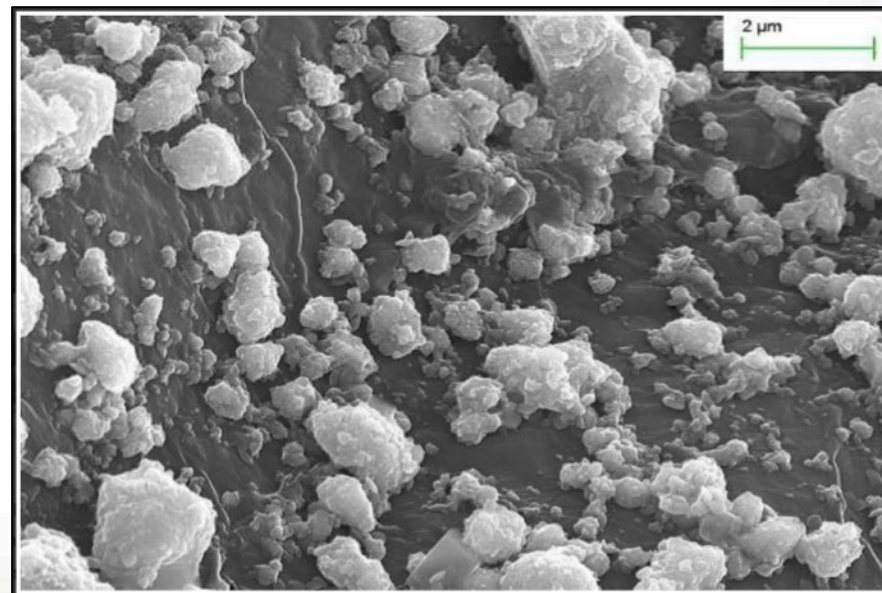
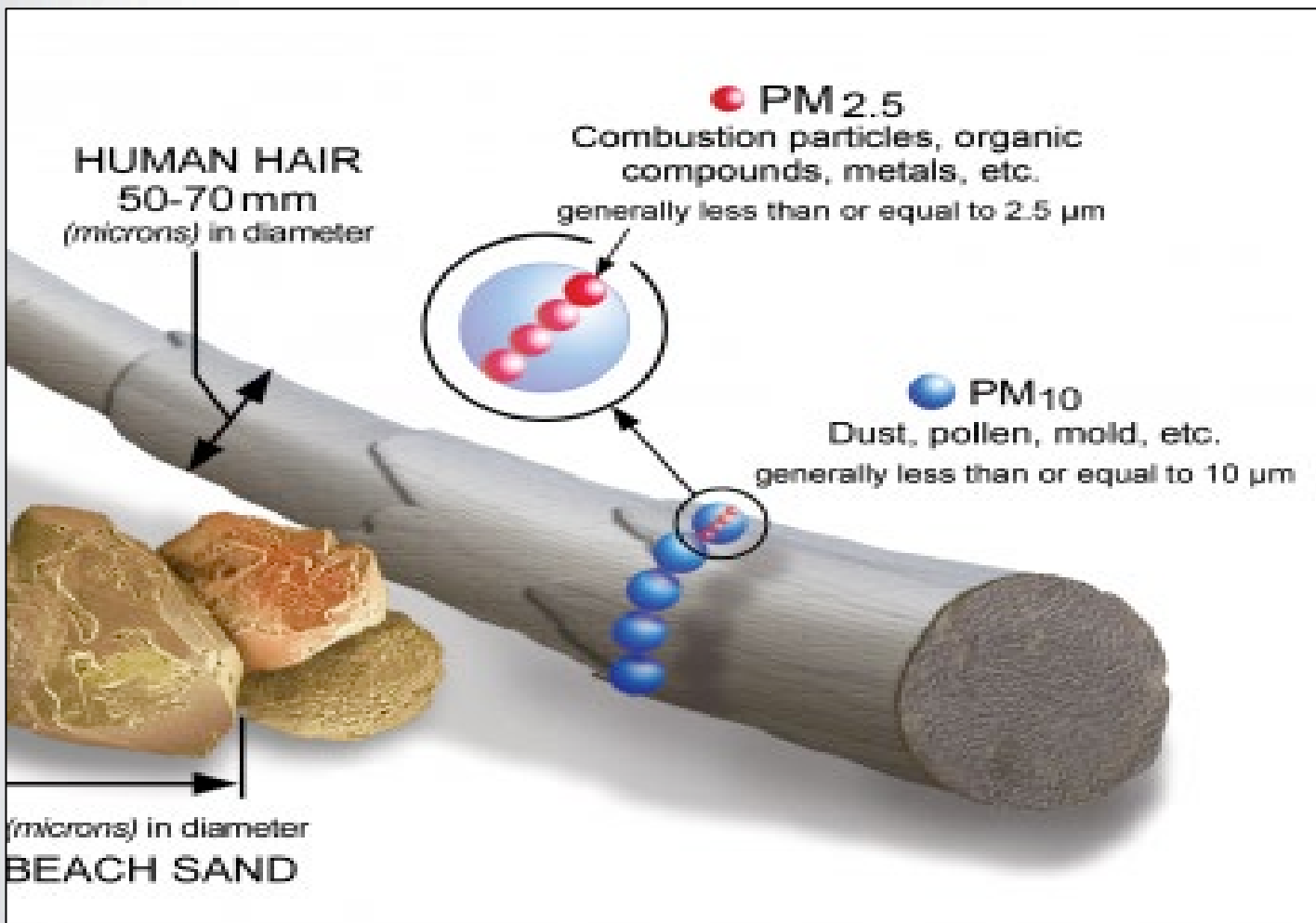
**Industrial Sources**



# What is Airborne Particulate Matter?

## Particulate Matter (PM) – “soot”

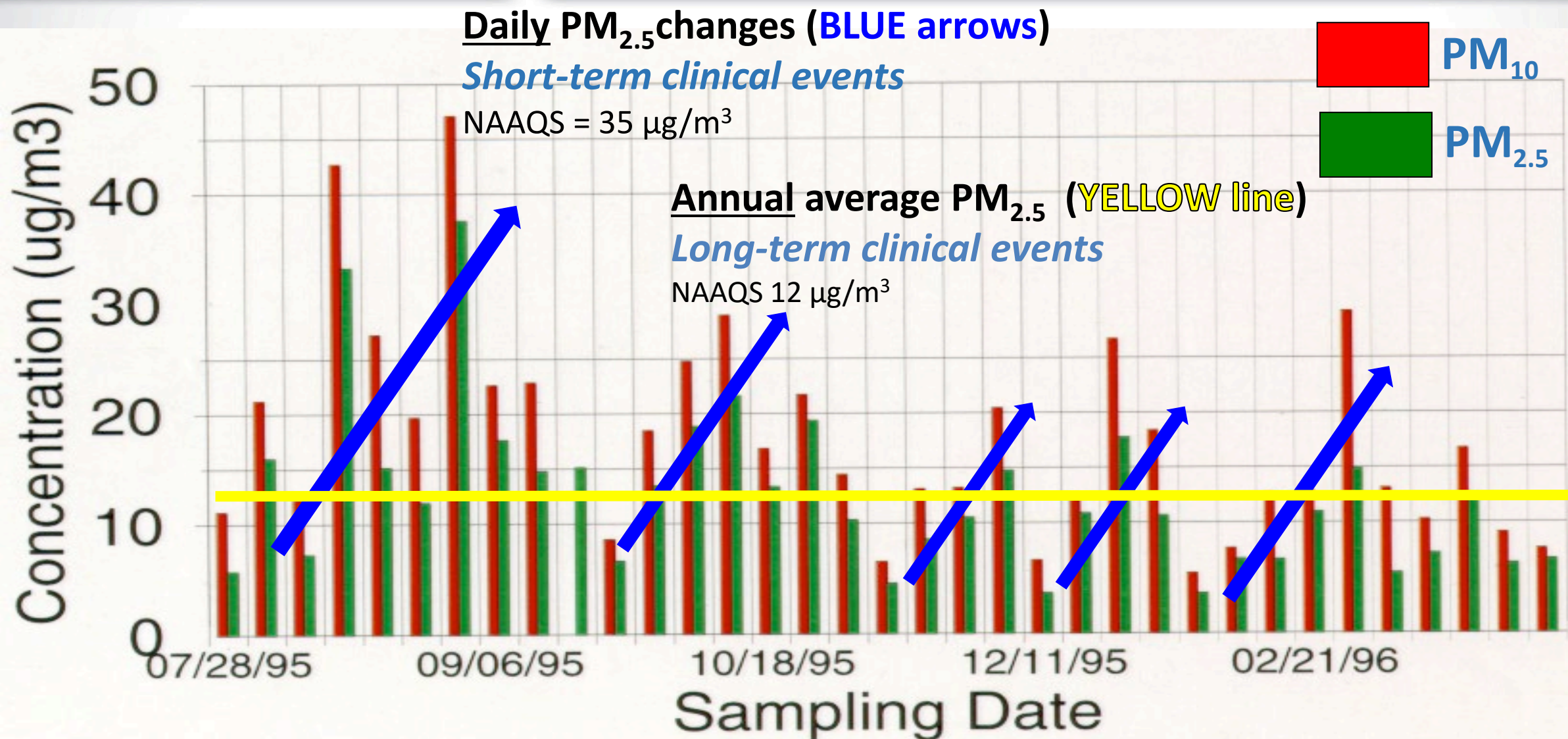
- from combustion sources
- mixture of solid particles and liquid droplets found in the air





# Daily Variability of $PM_{10}$ & $PM_{2.5}$

Chapel Hill, NC 1995-96





# *Short-term Air Pollutant Exposure Contribution to Cardiovascular Events*

## **AHA Scientific Statement**

### **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. Lueker, MD, MS, FAHA.

**Fine particulate matter (PM) or particle pollution can:**

- *Trigger heart attacks*
- *Trigger stroke*
- *Trigger arrhythmia*
- *Worsen heart failure*

**Heart disease patients should reduce their exposure to air pollution when levels are high**

European Heart Journal Advance Access published December 9, 2014



European Heart Journal  
doi:10.1093/eurheartj/ehu458

**CURRENT OPINION**

## Expert position paper on air pollution and cardiovascular disease

David E. Newby<sup>1</sup>, Pier M. Mannucci<sup>2</sup>, Grethe S. Tell<sup>3</sup>, Andrea A. Baccarelli<sup>4</sup>, Robert D. Brook<sup>5</sup>, Ken Donaldson<sup>6</sup>, Francesco Forastiere<sup>7</sup>, Massimo Franchini<sup>8</sup>, Oscar H. Franco<sup>9</sup>, Ian Graham<sup>10</sup>, Gerard Hoek<sup>11</sup>, Barbara Hoffmann<sup>12</sup>, Marc F. Hoylaerts<sup>13</sup>, Nino Künzli<sup>14,15</sup>, Nicholas Mills<sup>1</sup>, Juha Pekkanen<sup>16,17</sup>, Annette Peters<sup>18,19</sup>, Massimo F. Piepoli<sup>20</sup>, Sanjay Rajagopalan<sup>21</sup>, and Robert F. Storey<sup>22\*</sup>, on behalf of ESC Working Group on Thrombosis, European Association for Cardiovascular Prevention and Rehabilitation and ESC Heart Failure Association

- “Air pollution should be viewed as one of several major modifiable risk factors in the prevention and management of cardiovascular disease.”

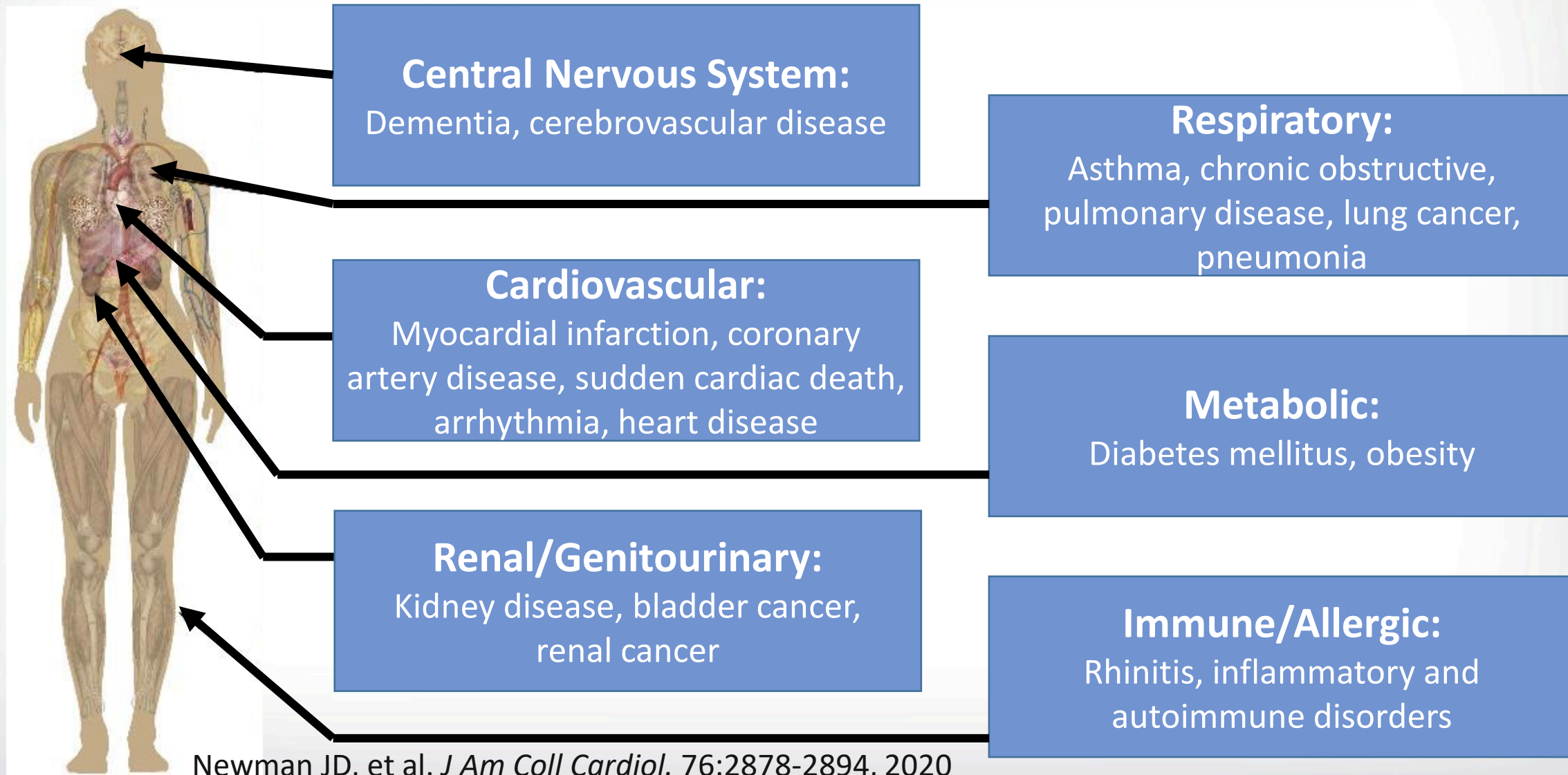
- “Health professionals, including cardiologists, have an important role to play in supporting educational and policy initiatives as well as counseling their patients.”





# ***Diseases Associated with Ambient Fine PM***

## **From Multiple Observational and Retrospective Studies**



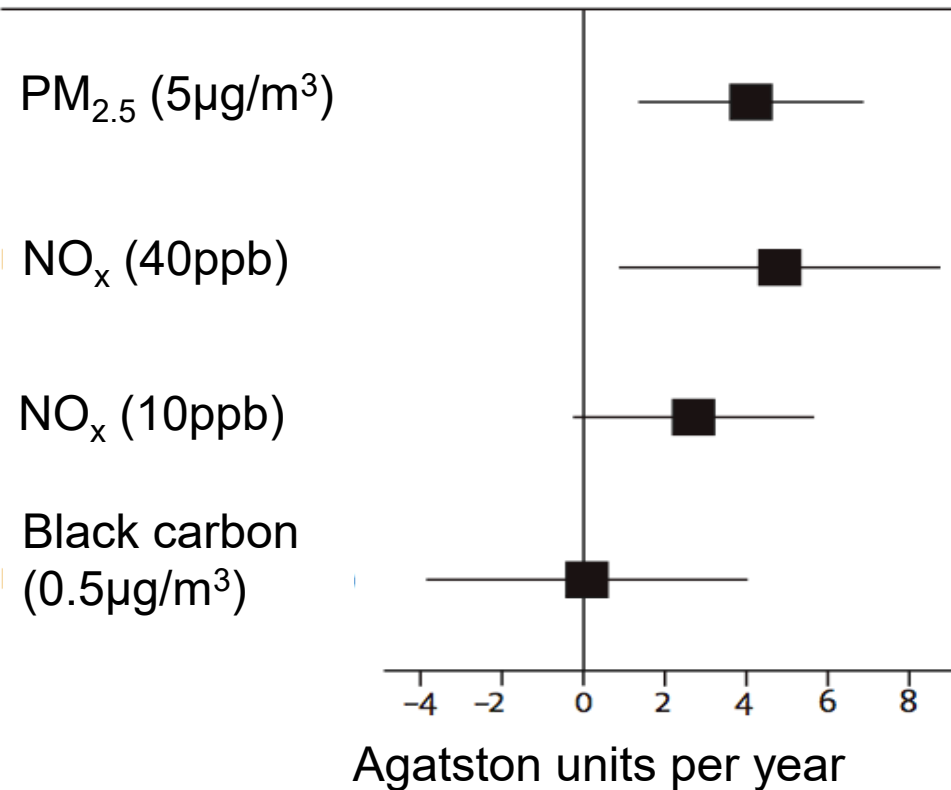
Newman JD, et al. *J Am Coll Cardiol.* 76:2878-2894, 2020



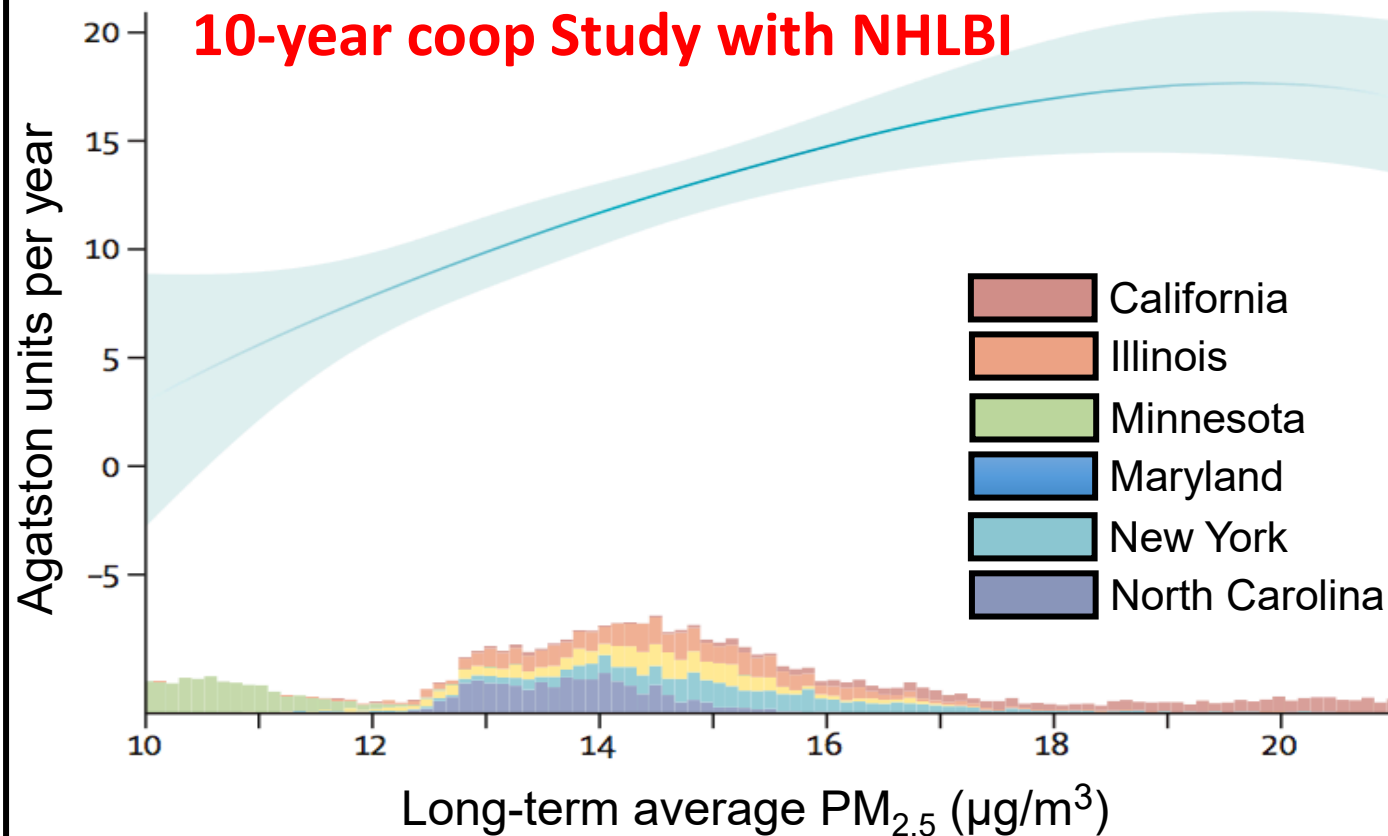


# Long-Term $PM_{2.5}$ & $NO_2$ Exposure Increases Coronary Artery Calcium

## Air Pollutants



## Multi Ethnic Study of Atherosclerosis - Air: 10-year coop Study with NHLBI



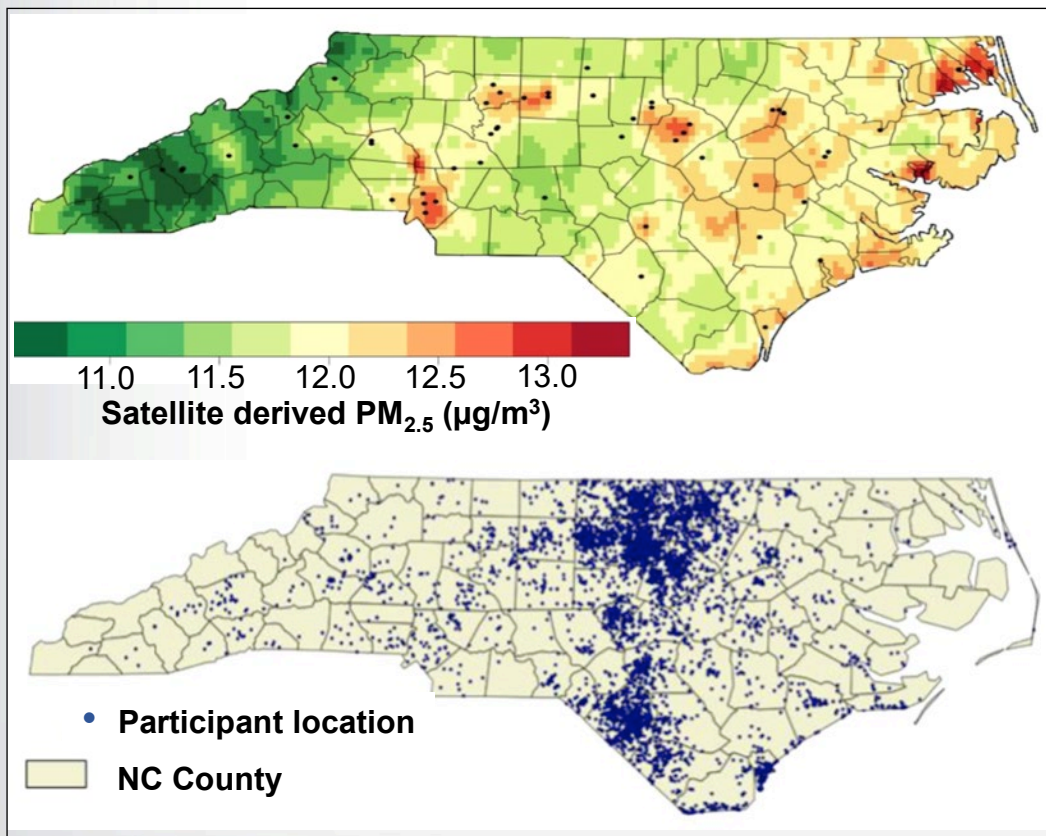
Long-term  $PM_{2.5}$  and  $NO_2$  increased coronary calcium, an indicator of atherosclerosis



# Health & Long-term Air Pollution Exposure

## Association between PM and Coronary Artery Disease

**5,679 patients who underwent coronary angiography at Duke University between 2002–2009 and resided in North Carolina\***



***1 µg/m<sup>3</sup> increase in annual average PM<sub>2.5</sub> was associated with an:***

- 11.1% relative increase in odds of significant CAD
- 14.2% increase in the odds of having had a heart attack during the previous year

***6,575 Ohio residents undergoing elective diagnostic coronary angiography\*\****

***1 µg/m<sup>3</sup> increase in annual average PM<sub>2.5</sub> was associated with an:***

- 17% relative increase in odds of 1-2 vessel, and 24% increase in ≥ 3 vessel CAD
- 14% increase in odds of having a heart attack within 3 years

\*McGuinn LA, et al. *Environ Res* 2016

\*\*Hartiala J, et al. *J Am Heart Assoc* 2016



# Air Pollution Worsens Vascular Risk Factors

## Risk Factors for Atherosclerosis and Air Quality

**ASCVD Risk Estimator Plus**

**Estimate Risk** | Therapy Impact | Advice

Current 10-Year ASCVD Risk ~% | Previous 10-Year ASCVD Risk ~%

### Patient Demographics

**Current Age** (circled) | Sex: Male | Female | Race: White | African American | Other

Age must be between 40-79

### Current Labs/Exam

**Total Cholesterol (mg/dL)** (circled) | **HDL Cholesterol (mg/dL)** (circled) | **LDL Cholesterol (mg/dL)** (circled) | **Systolic Blood Pressure (mm of Hg)** (circled)

Value must be between 130 - 320 | Value must be between 20 - 100 | Value must be between 30-300 | Value must be between 90-200

### Personal History

**History of Diabetes?** (circled) | On Hypertension Treatment? | **Smoker: Yes** (circled) | Former | No

**On a Statin?** (circled) | On Aspirin Therapy?

Yes | No | Yes | No | Yes | No | Yes | No

### Poor Air Quality:

**Age** – accelerates epigenetic aging markers

Ward-Caviness et al. Octotarget 2016

McCracken et al. *Environ Health Perspect* 2010

**Total Cholesterol** – increases cholesterol

Shanley et al. *Epidemiology* 2016

**HDL** – decreases HDL particle number

Bell et al. *Arterioscler Thromb Vasc Biol* 2017

**LDL** – oxidizes LDL and ox-LDL receptor

Gong et al. *Genome Biol.* 2007

Wu et al. *Chemosphere* 2015

**Systolic BP** – increases blood pressure

Giorgini et al. *Curr Pharm Des.* 2016

**Diabetes** – associated with type II diabetes

Renzi et al. *Environ Int* 2017

**Statin Therapy** – might protective

O'Neill et al. *Occup Environ Med* 2007

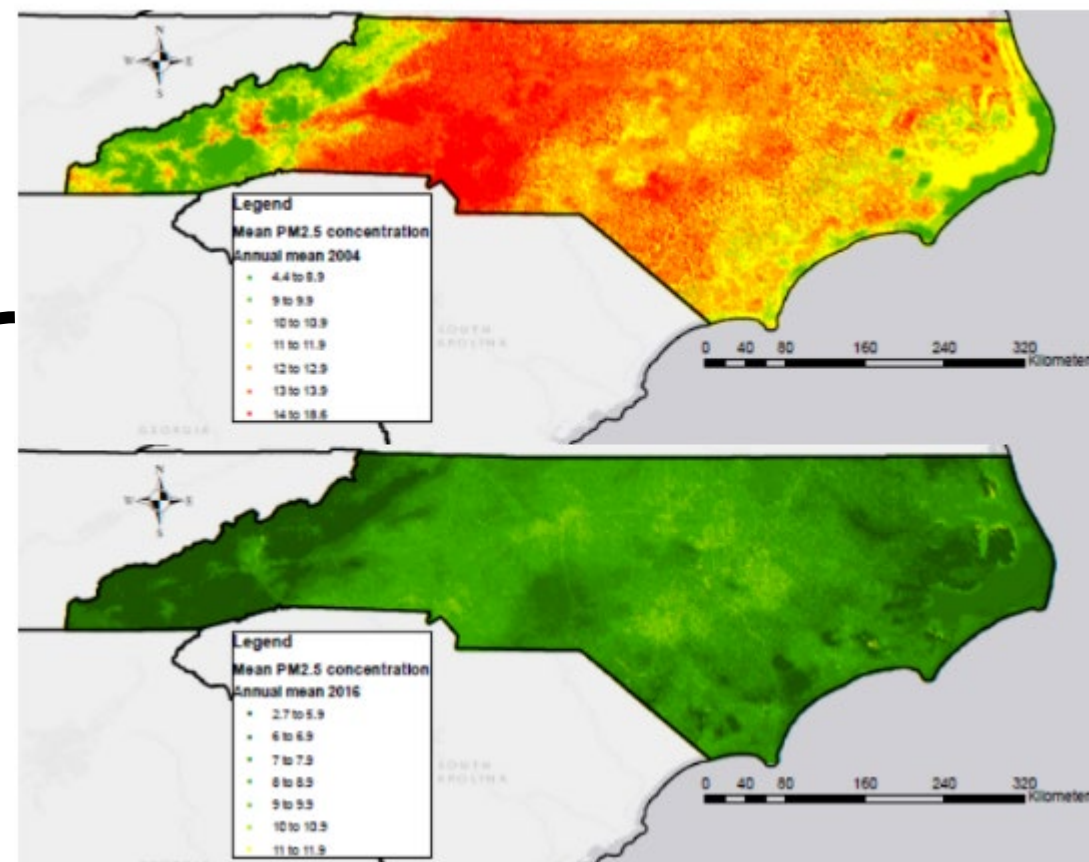
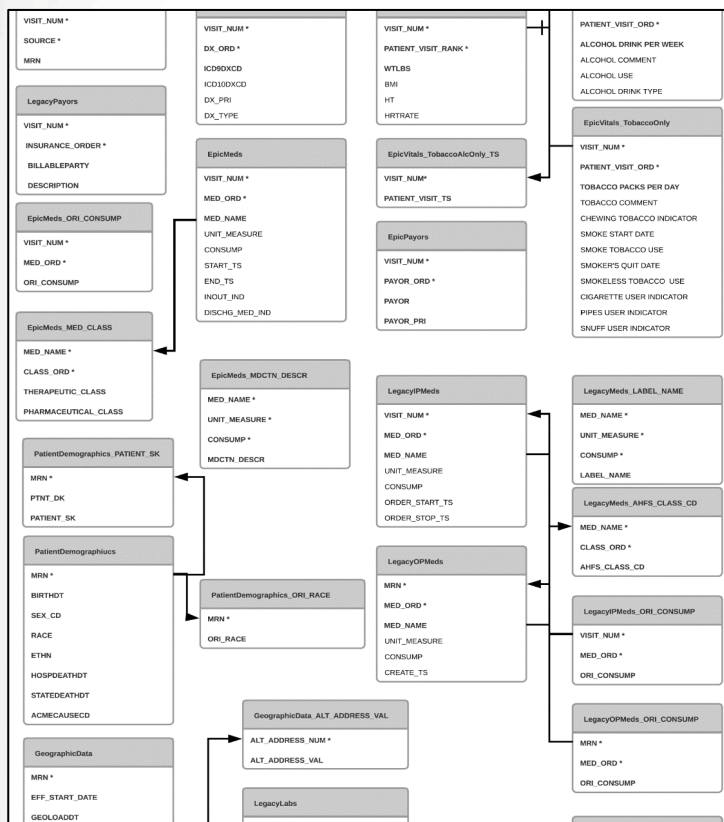
Alexeeff et al. *Environ Health Perspect* 2011



*What Cardiovascular Disease Population  
are We Likely to Benefit the Most by  
Reducing Personal PM Exposure?*



# EPA CARES Electronic Health Record Database



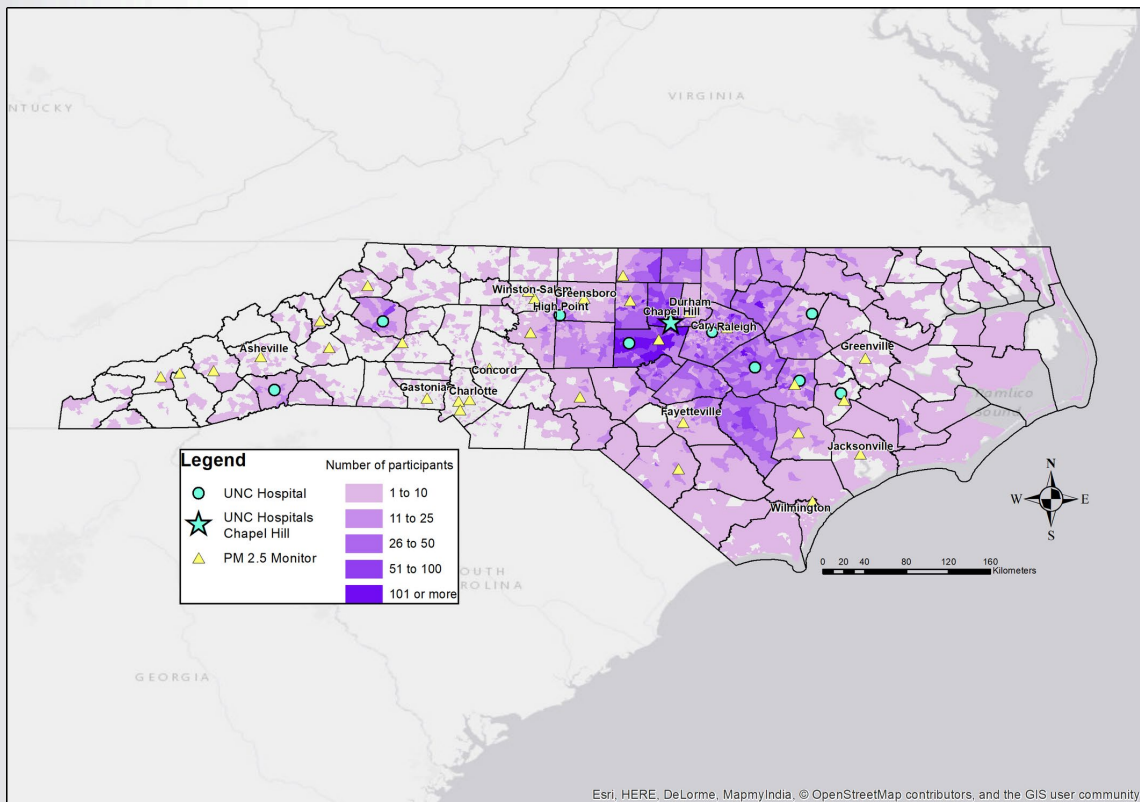
EPA CARES – A NC-centric resource for environmental health studies using EHRs  
> 100,000 individuals; > 50,000,000 observations



# Air Pollution and Heart Failure Mortality

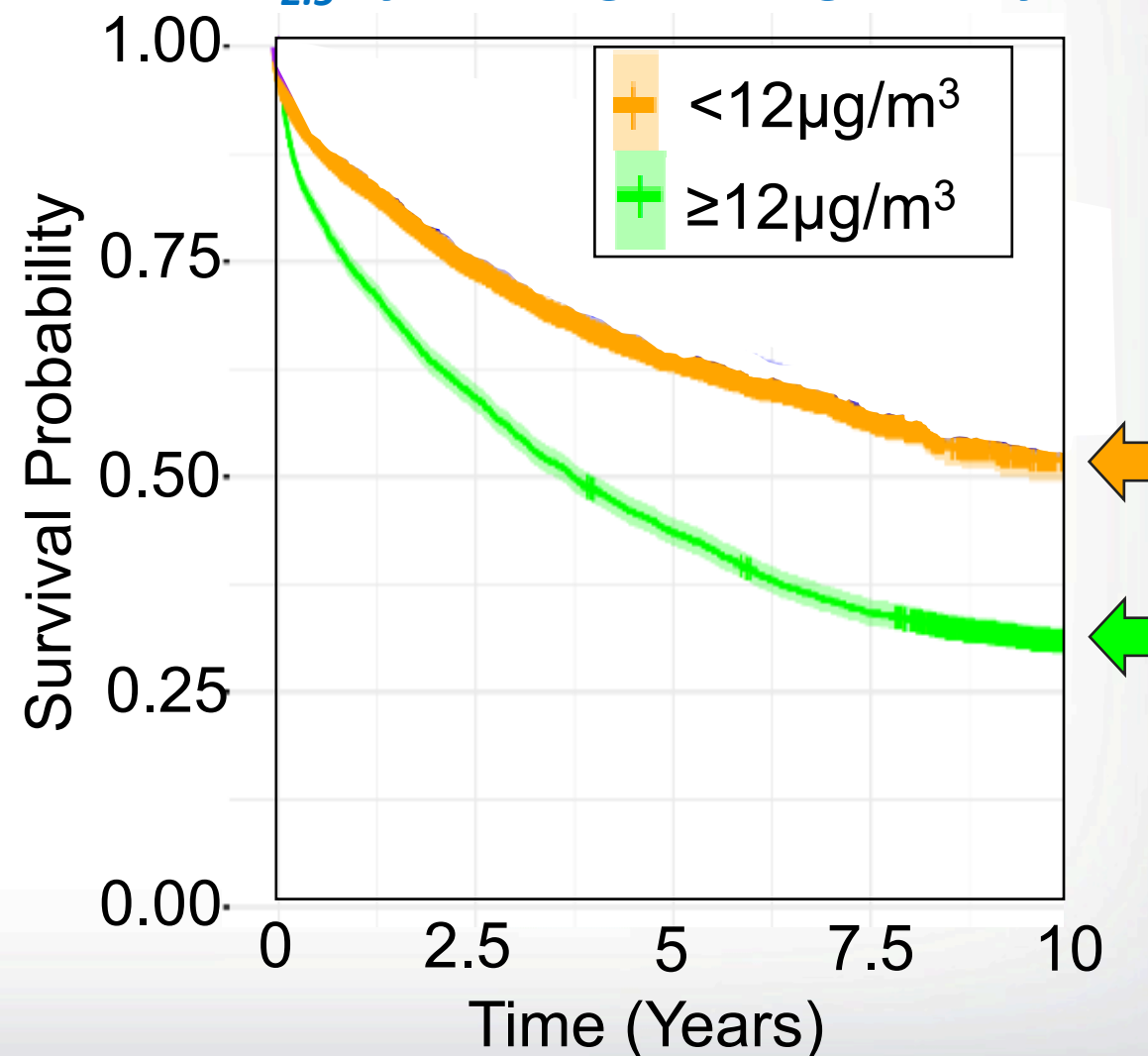
## Association with Age & Annual $PM_{2.5}$

### Heart Failure Patient in CARES Cohort



UNC-affiliated hospitals (blue circles) with the flagship hospital, located in Chapel Hill, NC, given as a blue star. EPA  $PM_{2.5}$  monitors are represented as yellow triangles

### $PM_{2.5}$ by HF Diagnosis Age $\geq 65$ years

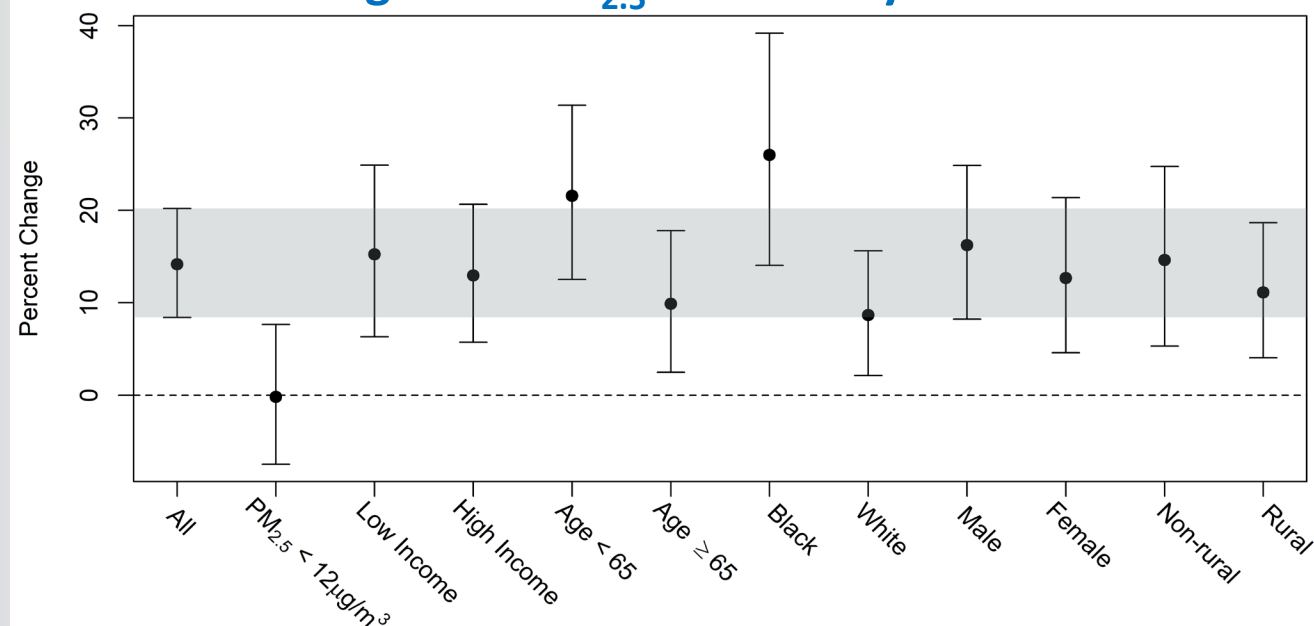






# *PM<sub>2.5</sub> Exposure and Heart Failure Hospital Readmissions*

## Long-term PM<sub>2.5</sub> and 30 Day Readmissions



Ward-Caviness CK, et al. Am Heart Assoc. 2021

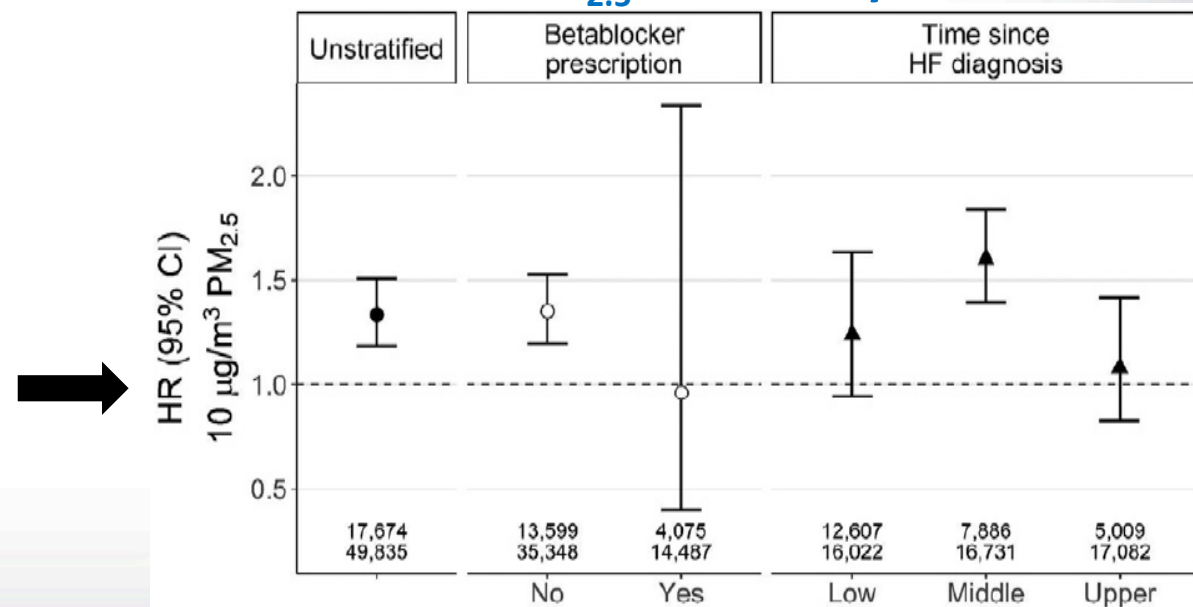
**What we did:** Short-term PM<sub>2.5</sub>-related readmission risks for HF patients

**What we learned:** PM<sub>2.5</sub> risks are highest in the days immediately after discharge, higher several months after diagnosis and potentially blocked by beta-blocker usage

**What we did:** N = 20,000 HF patients examined for 12 years for long-term PM<sub>2.5</sub>-related readmission risks

**What we learned:** PM<sub>2.5</sub> risks 40% greater for black patients. PM<sub>2.5</sub> risks seen for all types of hospital interactions – not just hospitalizations.

## Short-term PM<sub>2.5</sub> and 30 Day Readmissions



Wyatt LH, et al. Am Heart J. 2022

## *Populations At-Risk from PM<sub>2.5</sub>*

### **Susceptible populations include –**

- those with pre-existing cardiovascular disease
- those with pre-existing respiratory disease
- older adults
- those having lower socio-economic status
- children & the developing fetus

### **Populations suspected to be at greater risk –**

- those with chronic inflammatory diseases (e.g., diabetes, obesity)
- those with specific genetic polymorphisms (e.g., GSTM1)

*What can public health and the health care community do to reduce the adverse impact of air pollution?*





# *Improved Health Through Policy & Regulation*

## The Clean Air Act's (CAA) Six Criteria Pollutants

- **Primary air pollutants**

- CO
- CO<sub>2</sub>
- SO<sub>2</sub>
- PM - Suspended particles
- NO
- NO<sub>2</sub>
- Hydrocarbons

- **Secondary air pollutants**

- O<sub>3</sub>
- SO<sub>3</sub>
- HNO<sub>3</sub>
- H<sub>2</sub>SO<sub>4</sub>
- H<sub>2</sub>O<sub>2</sub>
- SO<sub>4</sub> salts
- PAHs

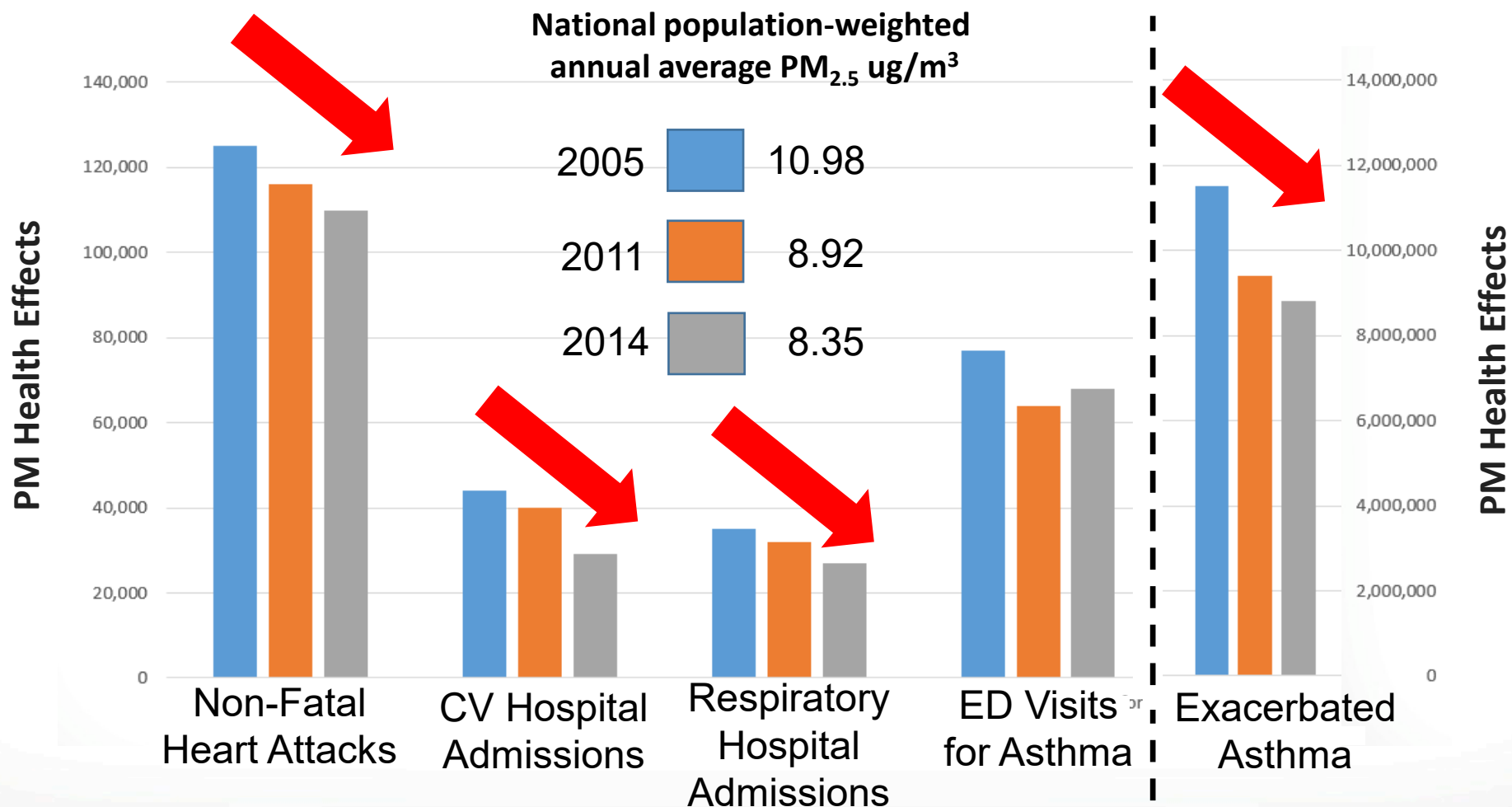
### CAA Criteria Pollutants

- PM - Suspended particles (PM<sub>2.5</sub>, PM<sub>10</sub>)
- O<sub>3</sub>
- NO<sub>x</sub>
- SO<sub>2</sub>
- CO
- Lead (Pb)



# Estimated $PM_{2.5}$ -Related Morbidity Effects

2005, 2011, 2014





## Public Education

Air Quality Index Available at AirNow.gov



- ***Color scale detailing how clean or polluted the air is***
- ***Local air quality conditions also often part of local weather reports***
- ***Where can it be found?***
  - Local TV, radio or newspapers
  - AirNow app
  - Email alerts at [www.enviroflash.info](http://www.enviroflash.info)

Descriptors	Cautionary Statement
Good 0 – 50	No message
Moderate 51 – 100	Unusually sensitive individuals
Unhealthy for Sensitive Groups 101 - 150	Identifiable groups at risk - different groups for different pollutants
Unhealthy 151 - 200	General public at risk; sensitive groups at greater risk
Very Unhealthy 201 - 300	General public at greater risk; sensitive groups at greatest risk





# The Environmental “Buckets” of Prevention Framework

## Total Population Community-Wide Prevention

**NAAQS**  
**Built-Environment**  
**Health Literacy**

- Attain & maintain NAAQS Stds
- Improve built-environment:
  - Places for physical activity
  - Create healthier near-road environments
- Improve overall CV health status

## Innovative Clinical Prevention



- Optimize clinical care of the at-risk priority population
- Increase awareness of health effects of PM among physicians, health care professionals, and the at-risk population
- Provide guidance to lower exposure & associated risk

## Traditional Clinical Prevention

**“evidence-based”  
clinical prevention  
management strategies**

- Long-term indoor air filtration lowered markers of oxidative stress and inflammation (*Chuang H-C, et al. Environ International 2017*)


**Public Health**

**Health Care**



# EPA's *Healthy Heart* Program

## Increasing Environmental Health Literacy



United States  
Environmental Protection  
Agency

Search EPA.gov

Environmental Topics ▾Laws & Regulations ▾Report a Violation ▾About EPA ▾


Related Topics: [Air Research](#)


CONTACT US

## Healthy Heart Toolkit and Research

### Heart Facts


- Heart disease and stroke are the first and fourth leading causes of death in the U.S.
- Air pollution can affect heart health and can trigger heart attacks and strokes that cause disability and death in those predisposed.
- One in three American adults has heart or blood vessel disease and is at higher risk from air pollution.





[Check your air quality to protect your health](#)

Recent Updates

EPA is raising awareness of heart disease and its link to air pollution and other environmental factors as a partner in [Million Hearts](#) , a

- *EPA's **Healthy Heart** program aims to prevent heart attacks and strokes by:*
- Raising public awareness about the role outdoor air pollution plays in cardiovascular health,
- and steps individuals can take to reduce their pollution exposure

<https://www.epa.gov/air-research/healthy-heart-toolkit-and-research>





# Engaging the Public

## Examples of EPA Products



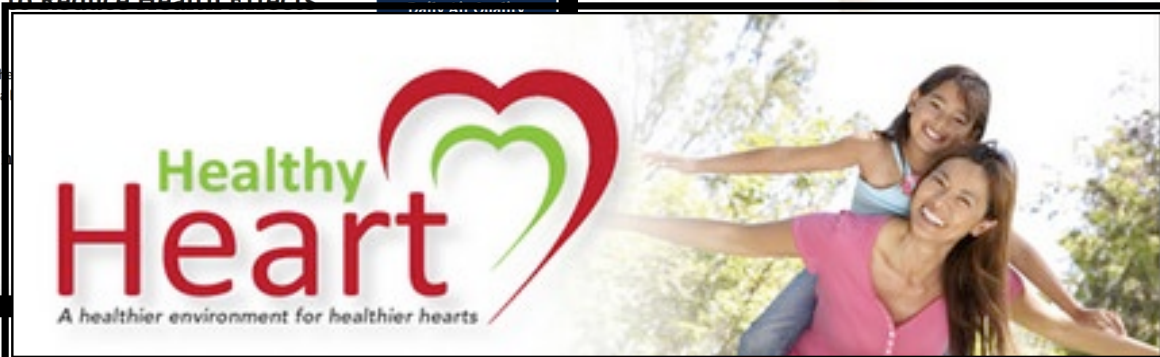
### Healthy Heart Toolkit and Research: Steps You Can Take

#### Steps You Can Take to Reduce Health Effects from Air Pollution

Studies show that air pollution can trigger health effects, especially for people who are at risk for these conditions. If you have exposure to high levels of air pollution.

When are air pollution levels

- Any time of year
- When weather is calm
- Near busy roads
- In urban areas
- In industrial areas
- When there is smoke



### Heart Disease, Stroke, and Outdoor Air Pollution

#### 1 Did you know that air pollution can trigger heart attacks, stroke, and other health effects?

Medical studies show that air pollution can trigger heart attacks, stroke, and irregular heart rhythms—especially in people who are already at risk for these conditions. Also, for people with a medical condition called heart failure, air pollution can further reduce the ability of the heart to pump blood the way that it should. Very small particles are the pollutants of greatest concern for triggering these effects. Particle pollution is found in haze, smoke, and dust—and sometimes in air that looks clean. This fact sheet tells you how you can:

- Get up-to-date information about your



#### 3 How can you protect your health?

### Particle Pollution and Your Patients' Health

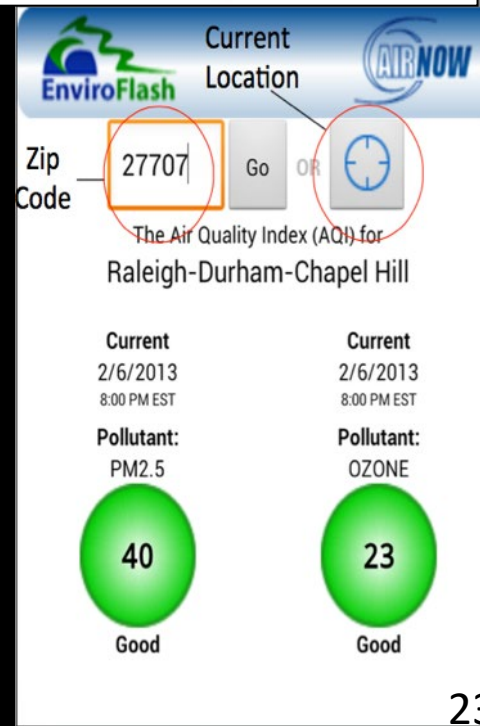
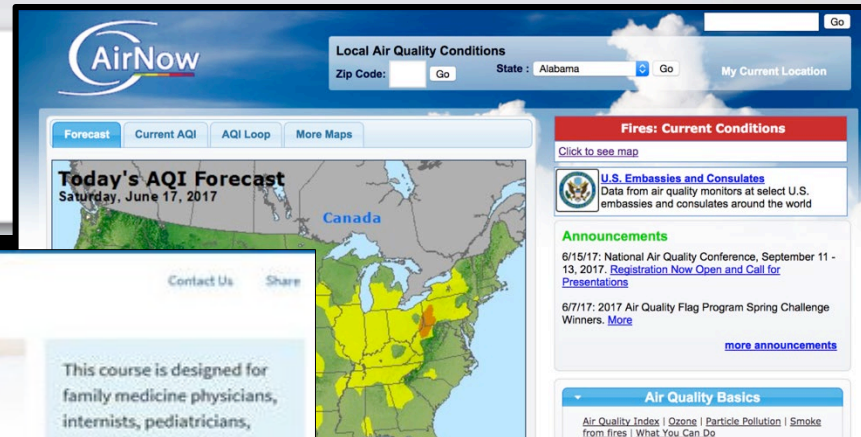
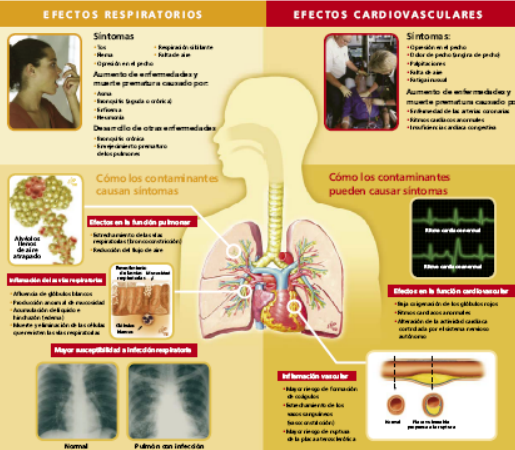
Helps health care providers advise their patients about particle pollution exposure.



This course is designed for family medicine physicians, internists, pediatricians, occupational and rehabilitation physicians, nurse practitioners, asthma educators, pulmonary specialists, cardiologists, and medical professionals.

Start the Course

### Contaminantes Comunes del Aire





## Partnering with HHS' Million Hearts® Recommendations Supported by EPA Science



Keeping People Healthy

Optimizing Care

Priority Populations

EPA contributes the **Healthy Heart** program to lower air pollutant exposures in at-risk populations in an effort to:

- *decrease heart attacks and strokes*
- *improve vascular disease outcomes*
- *decrease disability and healthcare expenditures*
- *decrease the societal burden of vascular diseases*





### Support includes: Counseling on risks of particulate matter

Goals	Effective Health Care Strategies
<b>Improve ABCS*</b> Targets: 80%	<i>High Performers Excel in the Use of...</i> <ul style="list-style-type: none"><li>• <b>Teams</b>—including pharmacists, nurses, community health workers, and cardiac rehab professionals</li><li>• <b>Technology</b>—decision support, patient portals, e- and default referrals, registries, and algorithms to find gaps in care</li><li>• <b>Processes</b>—treatment protocols; daily huddles; ABCS scorecards; proactive outreach; finding patients with undiagnosed high BP, high cholesterol, or tobacco use</li><li>• <b>Patient and Family Supports</b>—training in home blood pressure monitoring; problem-solving in medication adherence; counseling on nutrition, physical activity, tobacco use, <b>risks of particulate matter</b>; referral to community-based physical activity programs and cardiac rehab</li></ul>
<b>Increase Use of Cardiac Rehab</b> Target: 70%	
<b>Engage Patients in Heart-Healthy Behaviors</b> Targets: TBD	

\*ABCS - Aspirin when appropriate, Blood pressure control, Cholesterol management, Smoking cessation




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About Million Hearts®  
2027

Building Healthy  
Communities

Tobacco Use

Physical Inactivity

Particle Pollution

Optimizing Care

Focusing on Health Equity

## Particle Pollution and Heart Disease

Particle pollution—also called particulate matter (PM)—is made up of particles (tiny pieces) of solids or liquids in the air.<sup>1</sup> Research shows that short- and long-term exposure to particulate pollution are both linked to an increased risk of heart attacks and other forms of heart disease.<sup>2</sup>

### About Particle Pollution

Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small that you cannot see them in the air.<sup>1</sup> These small particles are called PM<sub>2.5</sub> and are 2.5 micrometers and

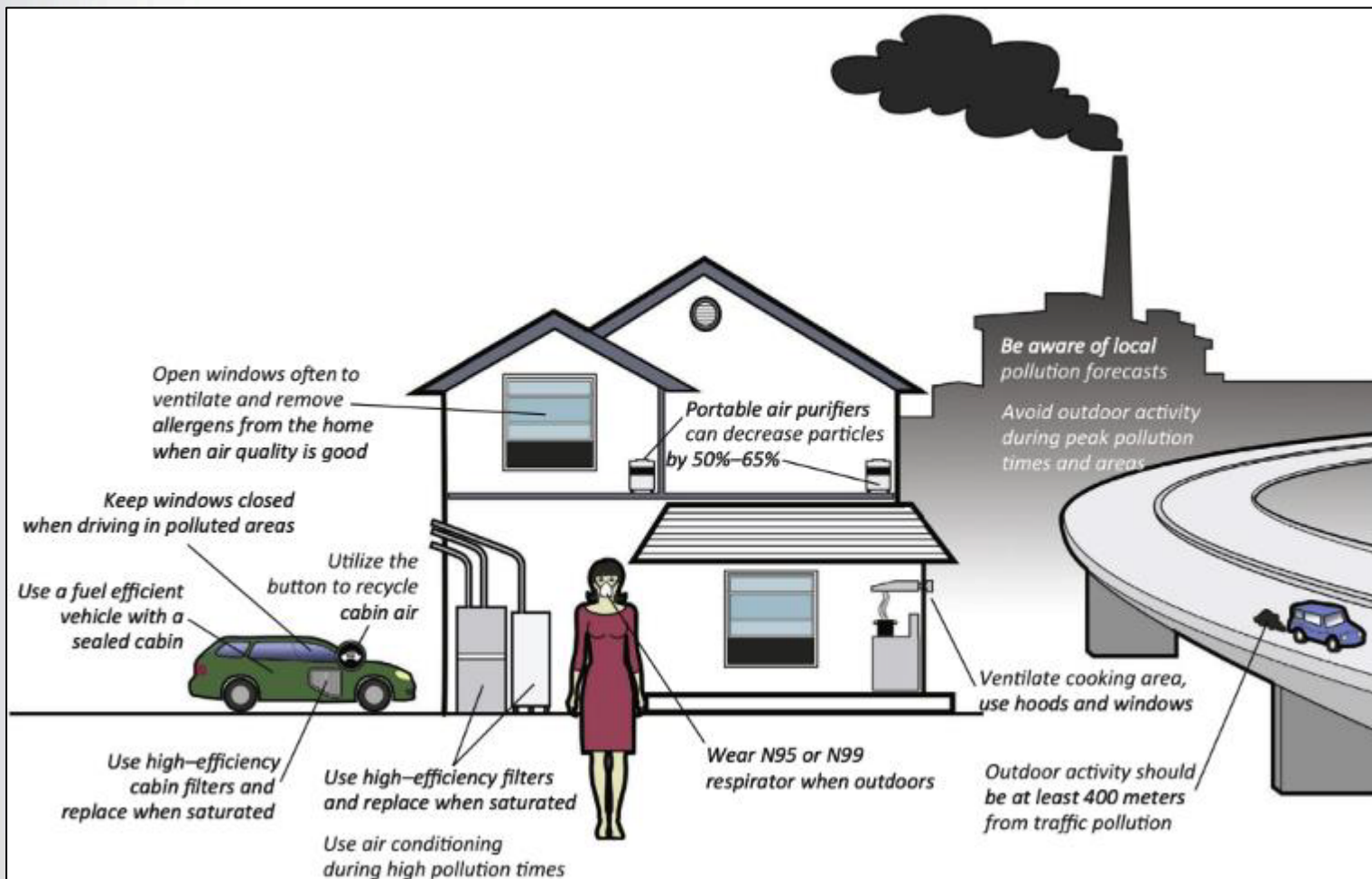


PM<sub>10</sub> is inhalable particles with diameters that are generally 10 micrometers and smaller; PM<sub>2.5</sub> are



# Reducing Particulate Matter Exposure

## Actions That Can be Taken by Individuals



- Portable air purifiers
- Open windows when air quality is good
- Use high-efficiency filters in the home
- Use air conditioning during periods of high pollution
- Keep windows closed when driving in polluted areas
- Use a vehicle with sealed cabin
- Use high-efficiency vehicle cabin filter
- Ventilate cooking area
- Wear N95 or N99 respirators outdoors
- Be aware of local pollution forecasts and avoid outdoor activity during peak pollution times and areas
- Outdoor activity 400m from traffic pollution

- **High attributable health burden**
- Particle pollution increases short- and long-term cardiovascular morbidity & mortality
- **Improvements in air pollution levels reduce health impacts and increase life expectancy**
- Many regions of US fail to meet EPA standards - >100 million exposed
- **EPA is working with the States to help communities meet NAAQS**
- Older-people, those with pre-existing heart & lung disease, & diabetes are at higher risk from air pollution



- **The electronic health record databases are opening up new opportunities to gain insight into the effect of PM on at-risk populations**
- **Importantly research is providing the evidence necessary to motivate public health and health care professionals to address risk reduction at the level of the population and individual**
- **Randomized controlled trials are needed to evaluate the efficacy of personal action to lower exposure and clinical risk and events**
- **Counseling patients at higher risk from PM to make personal interventions lower exposure by taking personal actions**

# Thank you

**Wayne E. Cascio, MD, FACC**  
**Director, Center for Public Health and Environmental Assessment**  
**Office of Research and Development**  
**U.S. Environmental Protection Agency**

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- No conflicts of interest
- The presentation represents the opinions of the speaker and does not necessarily represent the policies of the US EPA