Million Hearts 2022:

Understanding the Links between Environmental Pollutant Exposure and Cardiovascular and Cerebrovascular Events

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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***

Air Pollution: A Leading Cause of the Global Burden of Disease

In 2015 ambient $PM_{2.5}$ ranked fifth as a risk factor for global mortality -

Exposure to $PM_{2.5}$ caused:

- 4.2 million deaths
- 103.1 million disability-adjusted life-years (DALYs)

Between 1990-2015 deaths increased in association with $PM_{2.5}$ from:

- 3·5 million to 4.2 million

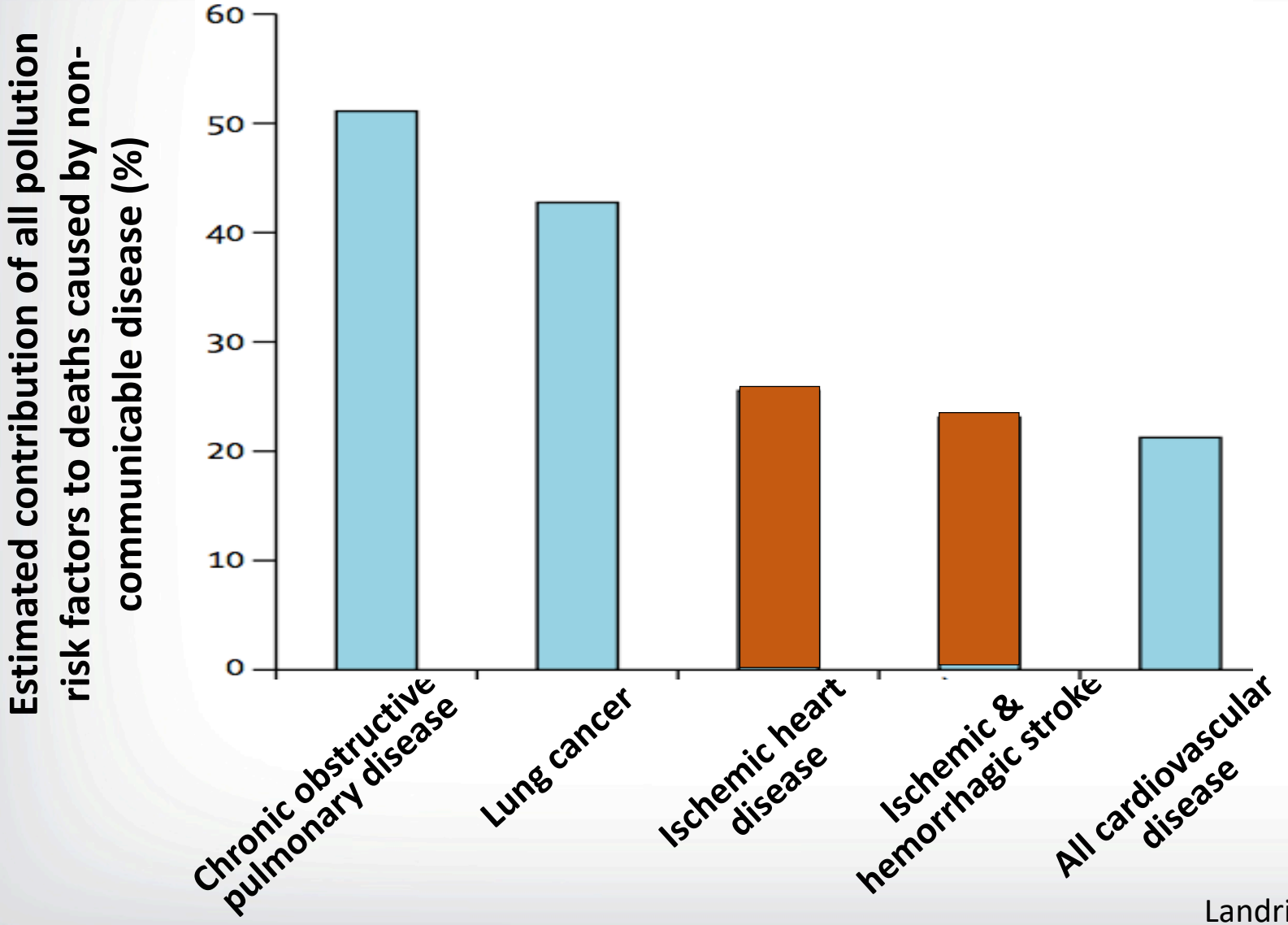
Ozone exposure contributed to morbidity and mortality -

In 2015 ozone exposure is estimated to have accounted for:

- 254,000 deaths
- 4.1 million DALYs from chronic obstructive pulmonary disease

Cohen AJ, et al. Global Burden of Disease, Injuries, and Risk Factors Study 2015. *Lancet* 2017

Estimated Contribution of All Pollution to Deaths Caused by Non-Communicable Diseases, 2015



All pollution contributes to:

- over 20% of ischemic heart disease
- over 20% of ischemic and hemorrhagic stroke
- 20% of all cardiovascular disease

Landrigan PJ et al. *Lancet* 2018; 391: 462–512

Despite Progress in the U.S. Air Pollution Continues to Impact Population Health

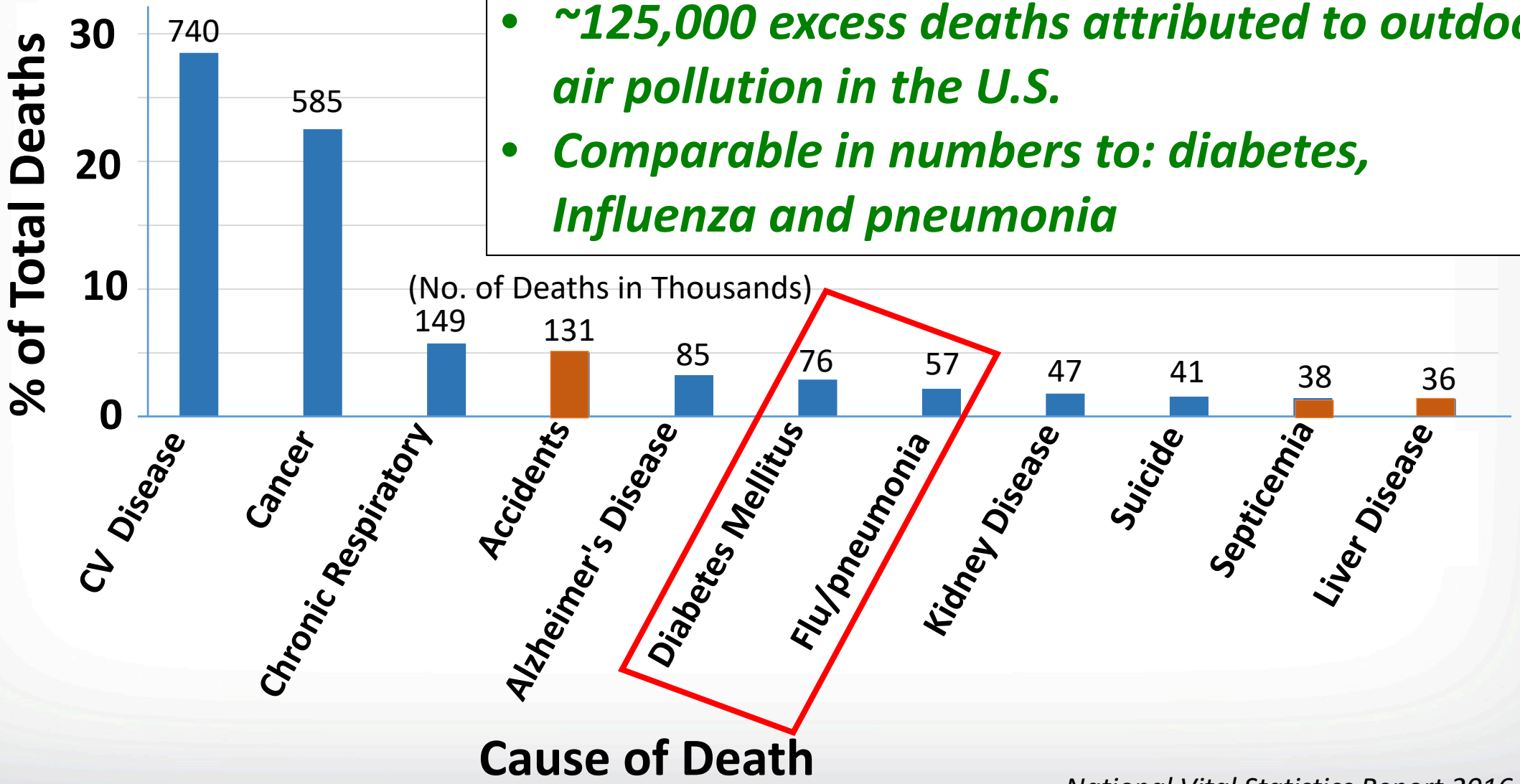
Air Pollution Remains a Significant U.S. Public Health Concern

- Estimated excess mortality **125,000 deaths/year**
- Over **20 million school days and work days lost**
- Over **1 million life-years lost**
- **122.5 million people living in counties with one or more pollutants exceeding the NAAQS in 2016**

Fann N. et al. Risk Anal 2012; Fann et al. *Environ Sci Tech* 2013; US EPA

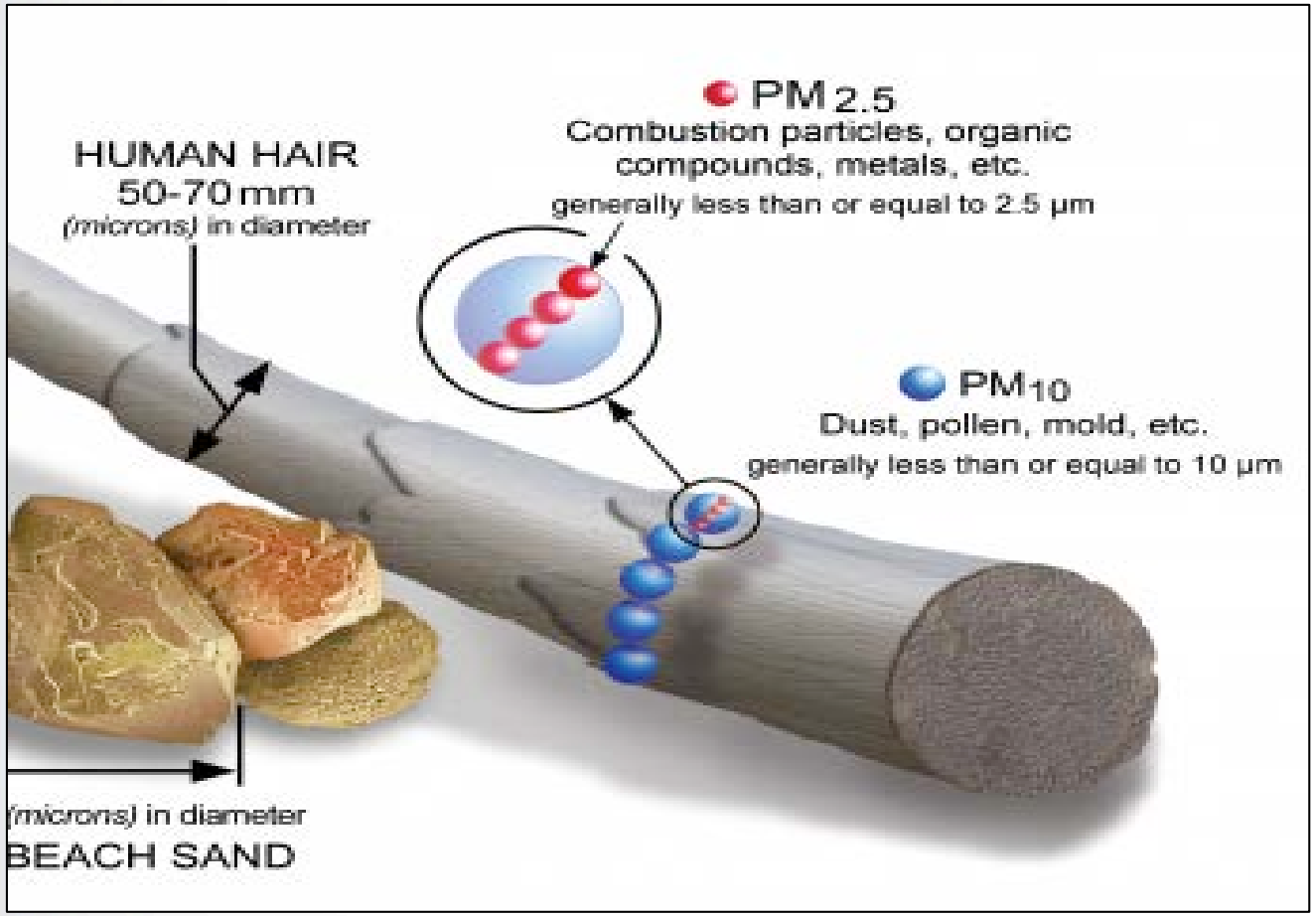
Causes of Deaths in U.S.

- ***~125,000 excess deaths attributed to outdoor air pollution in the U.S.***
- ***Comparable in numbers to: diabetes, Influenza and pneumonia***



National Vital Statistics Report 2016

What is Airborne Particulate Matter?

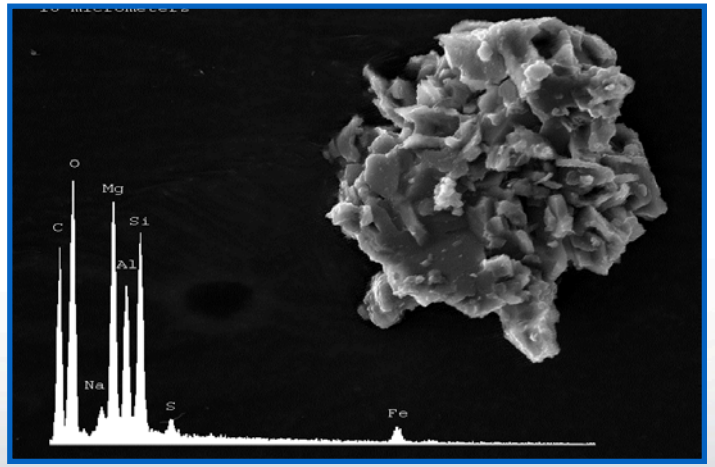


Particulate matter (PM) – "soot"

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

National Ambient Air Quality Standards (NAAQS)

- 35 ug/m^3 - 24 hours
- 12 ug/m^3 - annual average



Scanning Electron Micrograph of air particle

Foundation of PM's Health Effect

Exposure Linked to Morbidity and Mortality

AHA Scientific Statement

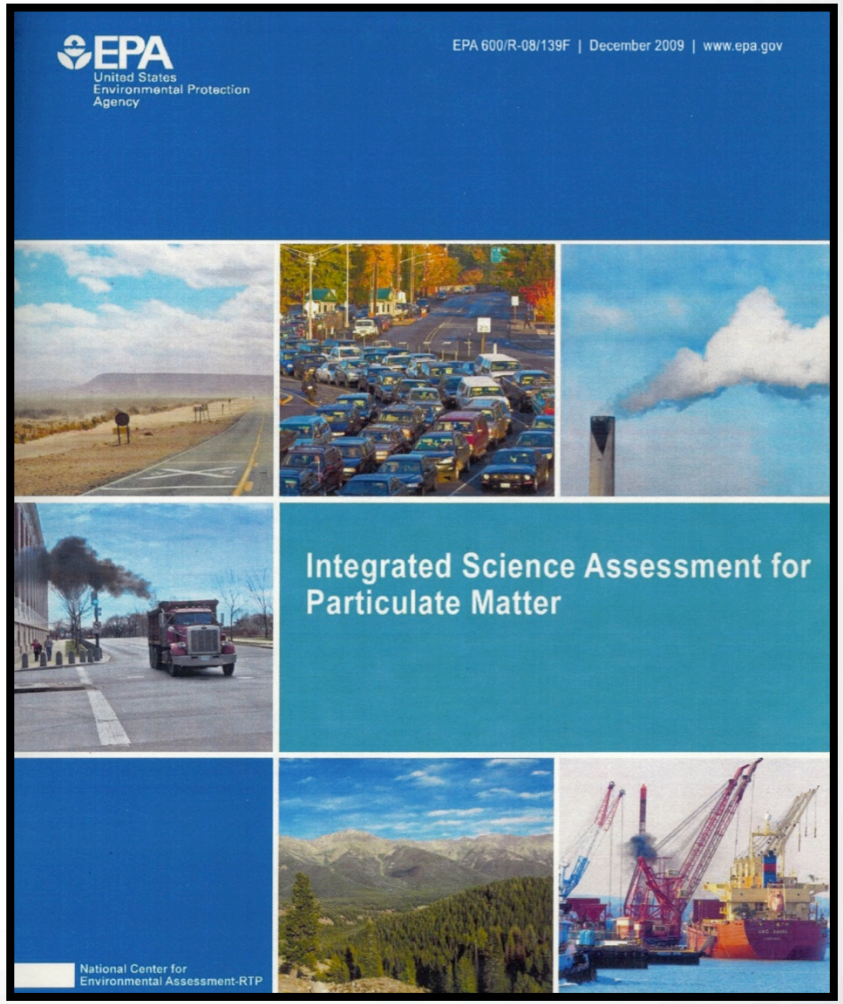
Air Pollution and Cardiovascular Disease

A Statement for Healthcare Professionals From the Expert Panel on Population and Prevention Science of the American Heart Association

Robert D. Brook, MD; Barry Franklin, PhD, Chair; Wayne Cascio, MD; Yuling Hong, MD, PhD; George Howard, PhD; Michael Lipsett, MD; Russell Luepker, MD; Murray Mittleman, MD, ScD; Jonathan Samet, MD; Sidney C. Smith, Jr, MD; Ira Tager, MD

Abstract—Air pollution is a heterogeneous, complex mixture of gases, liquids, and particulate matter. Epidemiological studies have demonstrated a consistent increased risk for cardiovascular events in relation to both short- and long-term exposure to present-day concentrations of ambient particulate matter. Several plausible mechanistic pathways have been described, including enhanced coagulation/thrombosis, a propensity for arrhythmias, acute arterial vasoconstriction, systemic inflammatory responses, and the chronic promotion of atherosclerosis. The purpose of this statement is to provide healthcare professionals and regulatory agencies with a comprehensive review of the literature on air pollution and cardiovascular disease. In addition, the implications of these findings in relation to public health and regulatory policies are addressed. Practical recommendations for healthcare providers and their patients are outlined. In the final section, suggestions for future research are made to address a number of remaining scientific questions. **(*Circulation*. 2004;109:2655-2671.)**

Brook RD et al. Circulation 2004



Short-term and long-term exposure to ambient air particulate matter is causally associated with cardiovascular morbidity and mortality (EPA ISA 2009)

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. Luepker, MD, MS, FAHA;

Fine particulate matter (PM) or particle pollution can:

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

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

Brook RD, et al. Circulation 2010

Call for Public Health & Healthcare Action

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

European Heart Journal (2015) **36**, 83–93
doi:10.1093/eurheartj/ehu458

CURRENT OPINION

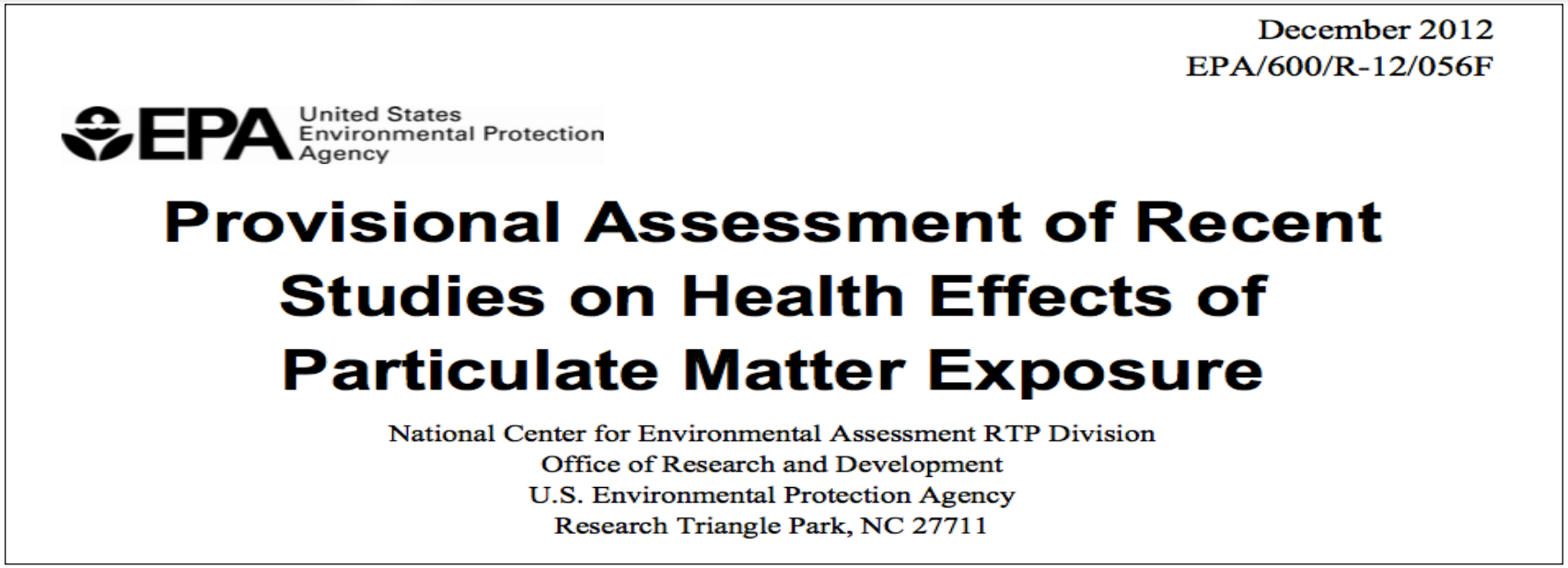
Expert position paper on air pollution and cardiovascular disease

David E. Newby[1], Pier M. Mannucci[2], Grethe S. Tell[3], Andrea A. Baccarelli[4], Robert D. Brook[5], Ken Donaldson[6], Francesco Forastiere[7], Massimo Franchini[8], Oscar H. Franco[9], Ian Graham[10], Gerard Hoek[11], Barbara Hoffmann[12],

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

Newby DE et al. Eur Heart J 2014

Long-term Air Pollutant Exposure
Contributes to Cardiovascular Morbidity & Mortality



December 2012
EPA/600/R-12/056F

United States Environmental Protection Agency

Provisional Assessment of Recent Studies on Health Effects of Particulate Matter Exposure

National Center for Environmental Assessment RTP Division
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

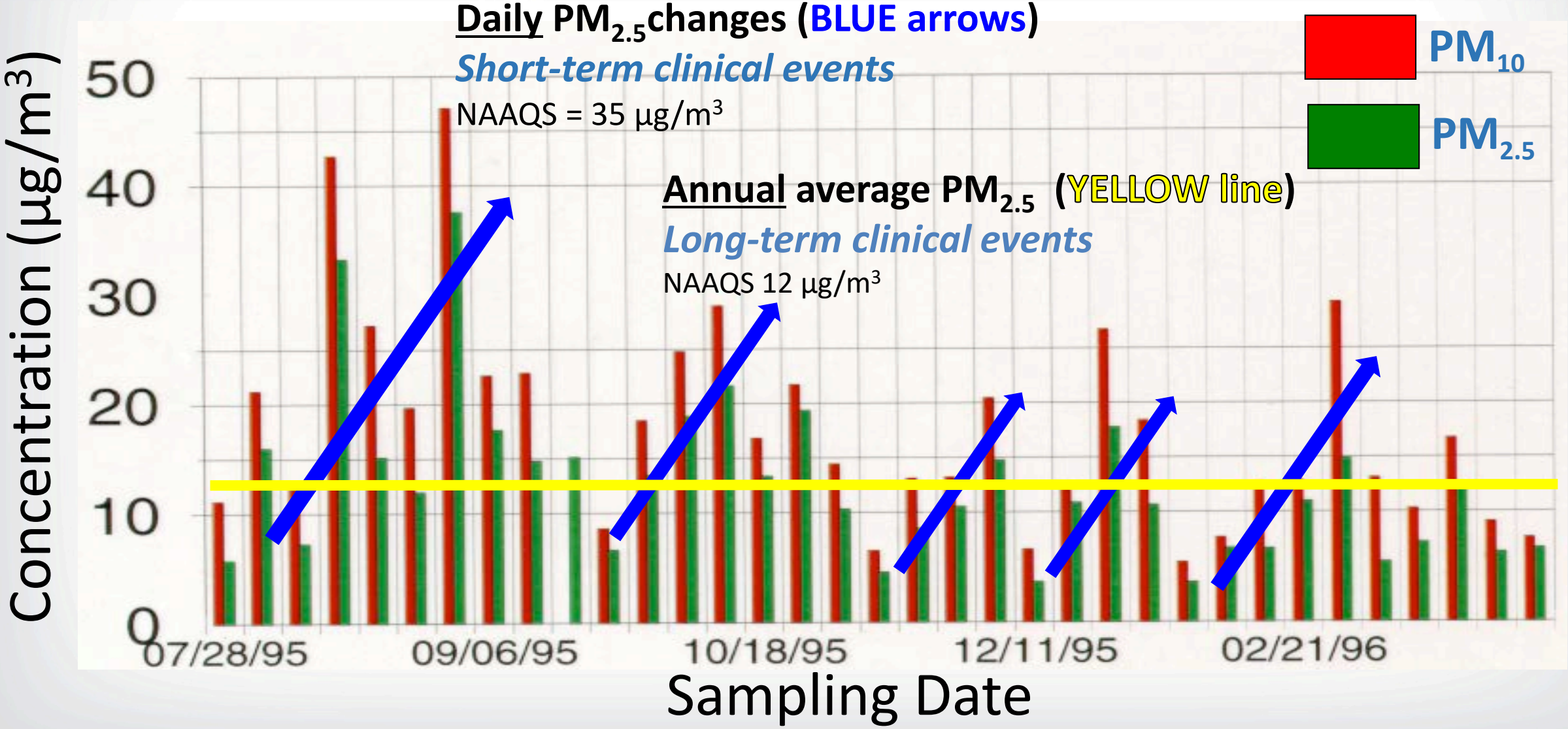
Ambient air particle pollution is associated with:

- *Hypertension*
- *Ischemic heart disease*
- *Stroke*
- *Cardiovascular Mortality*

Communities should be able to improve their cardiovascular health by complying with ambient air quality standards

Gold DR, et al. Circulation 2013

Daily Variability of PM_{10} & $PM_{2.5}$
Chapel Hill, NC 1995-96



Populations At-Risk from $PM_{2.5}$

Susceptible populations include –

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

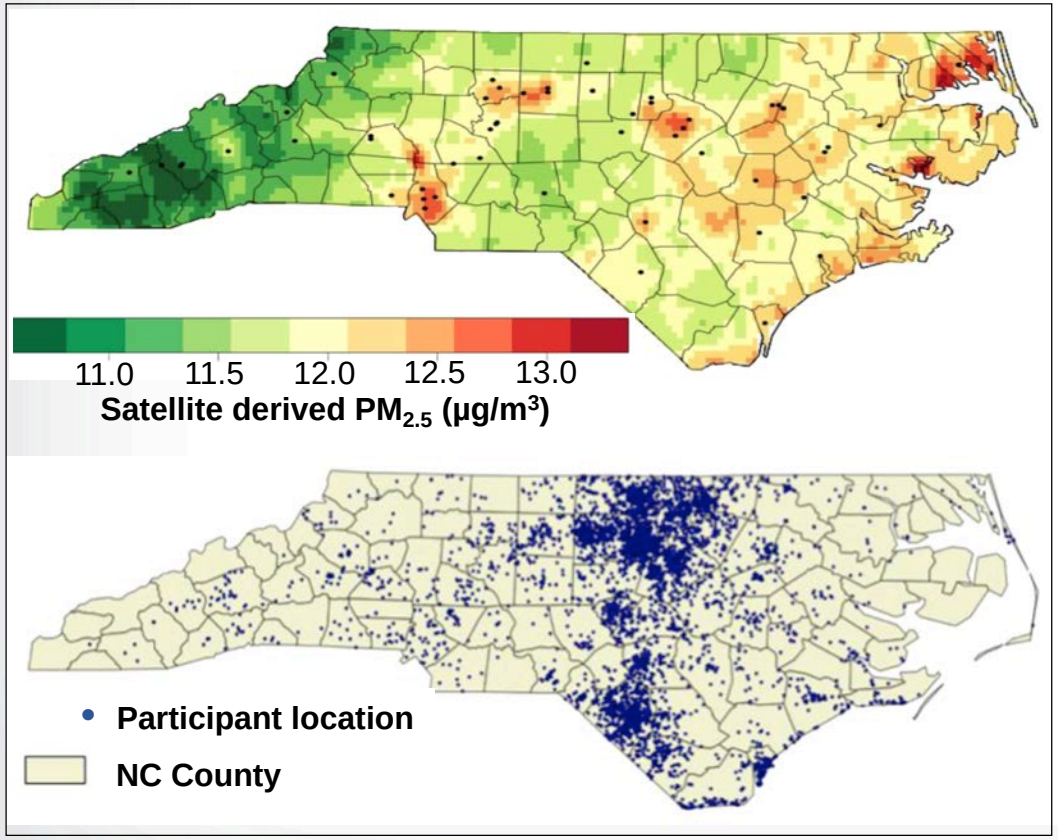
Populations suspected to be at greater risk –

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

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*



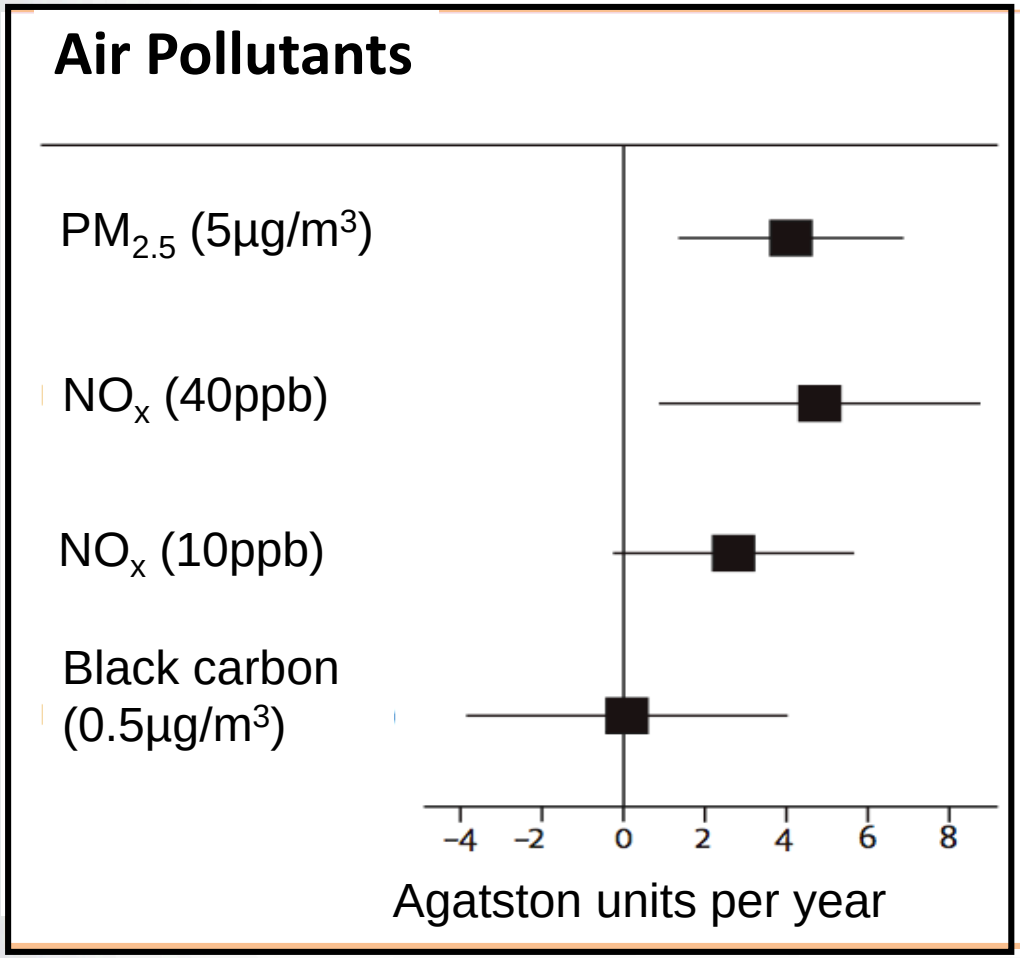
1 µg/m³ increase in annual average $PM_{2.5}$ was associated with an:

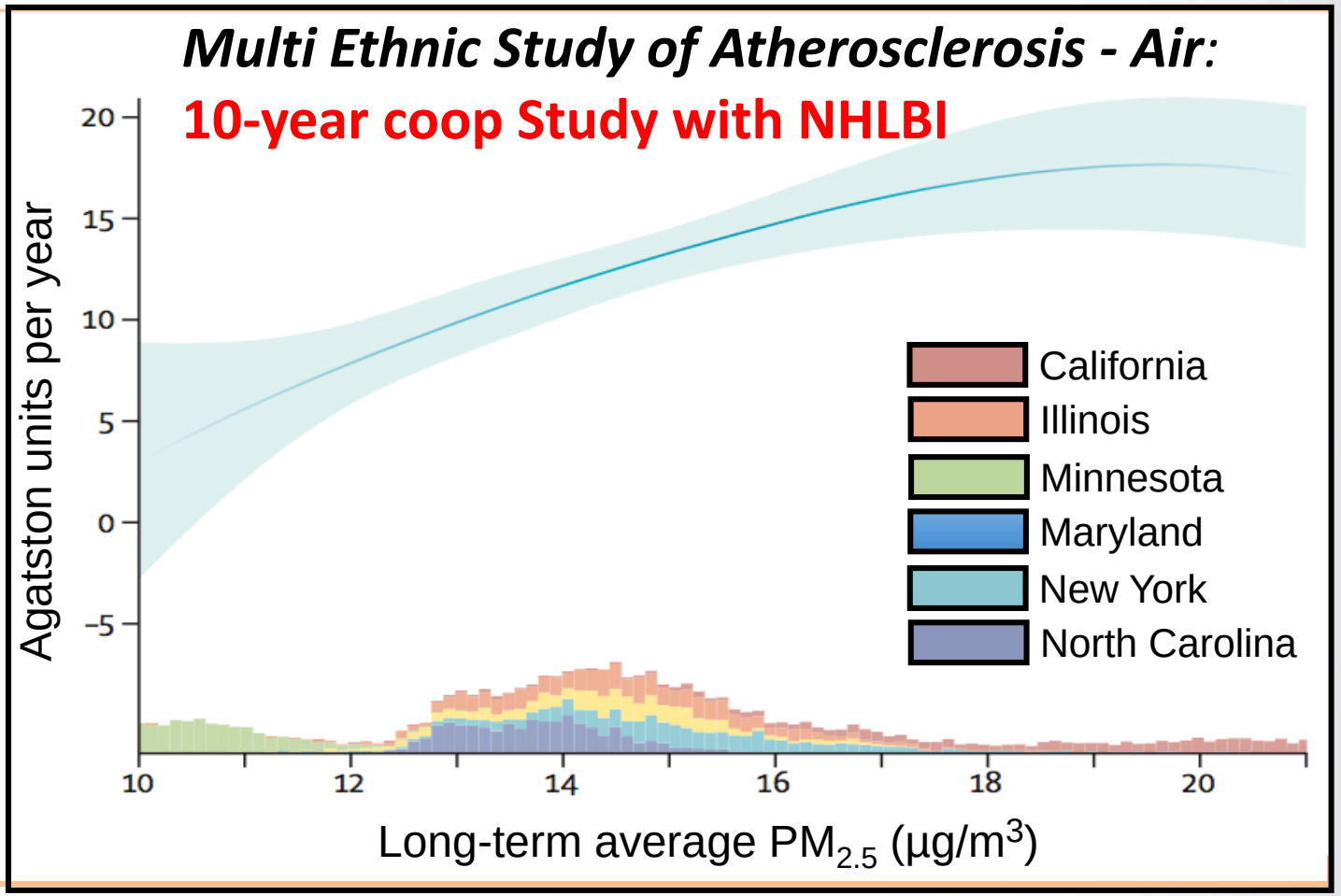
- **11.1% relative increase in odds of significant CAD**
- **14.2% increase in the odds of having had a heart attack during the previous year**

6,575 Ohio residents undergoing elective diagnostic coronary angiography found the same relationship*

*McGuinn LA, et al. *Environ Res* 2016 **Hartiala J, et al. J *Am Heart Assoc* 2016

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





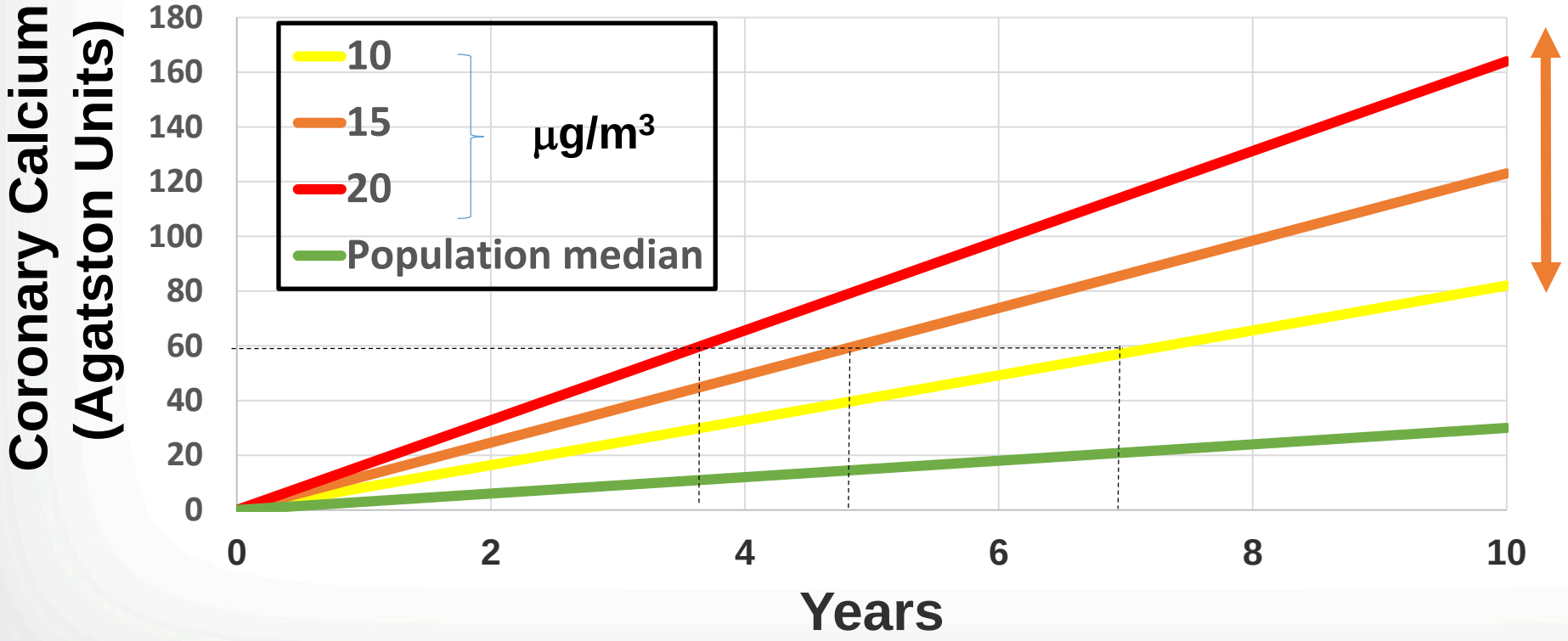
Long-term $PM_{2.5}$ and NO_2 increased coronary calcium, an indictor of atherosclerosis

Kaufman JD et al. Lancet 2016

Long-term $PM_{2.5}$ & Nox Exposure
Associated Atherosclerosis Progression

MESA Air Study – Led by University of Washington

$PM_{2.5}$ and Coronary Calcium

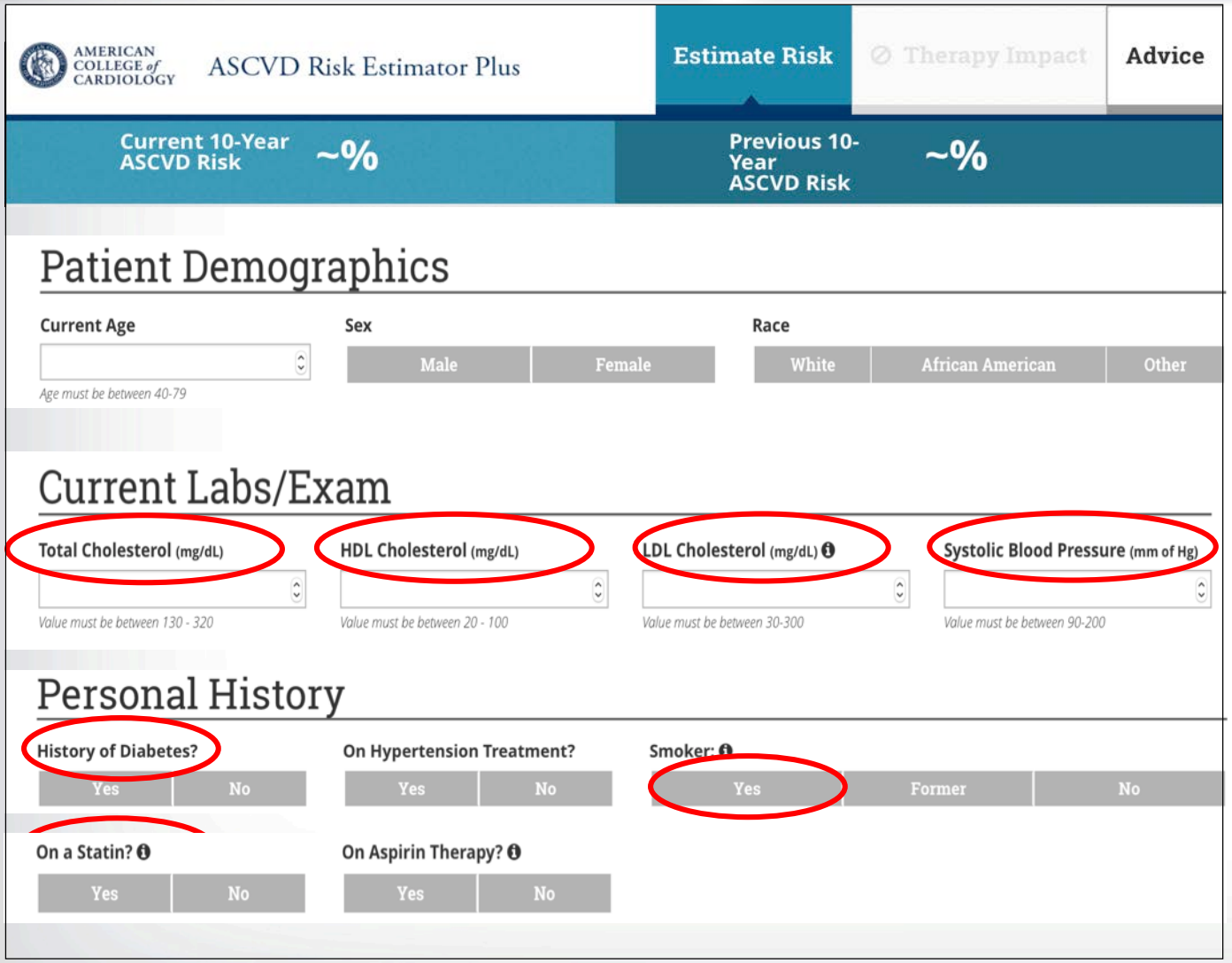


After 10 years 80 Agatston Unit difference between annual $PM_{2.5}$ of 10 and 20 µg/m³

Kaufman JD, et al. *Lancet* 2016

Air Pollution Worsens Vascular Risk Factors

Risk Factors for Atherosclerosis and Air Quality



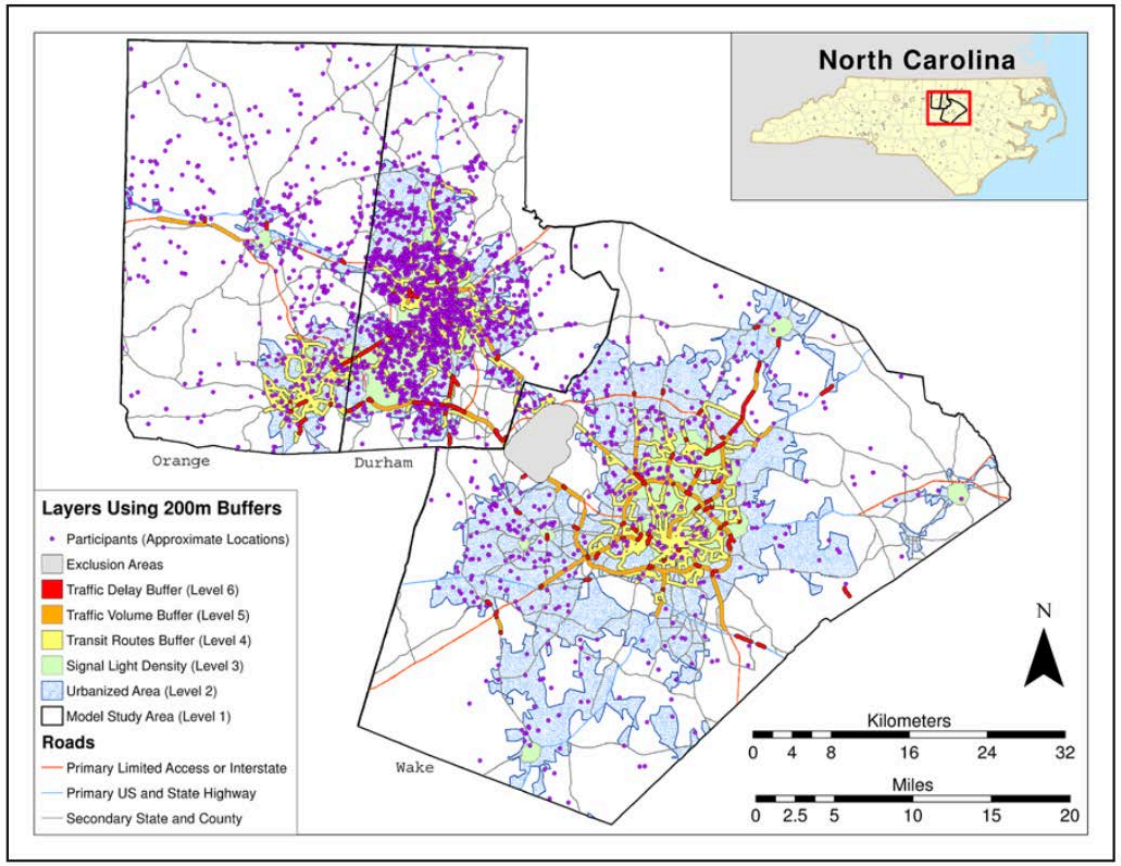
http://tools.acc.org/ASCVD-Risk-Estimator-Plus/#!/calculate/estimate/

Poor Air Quality:

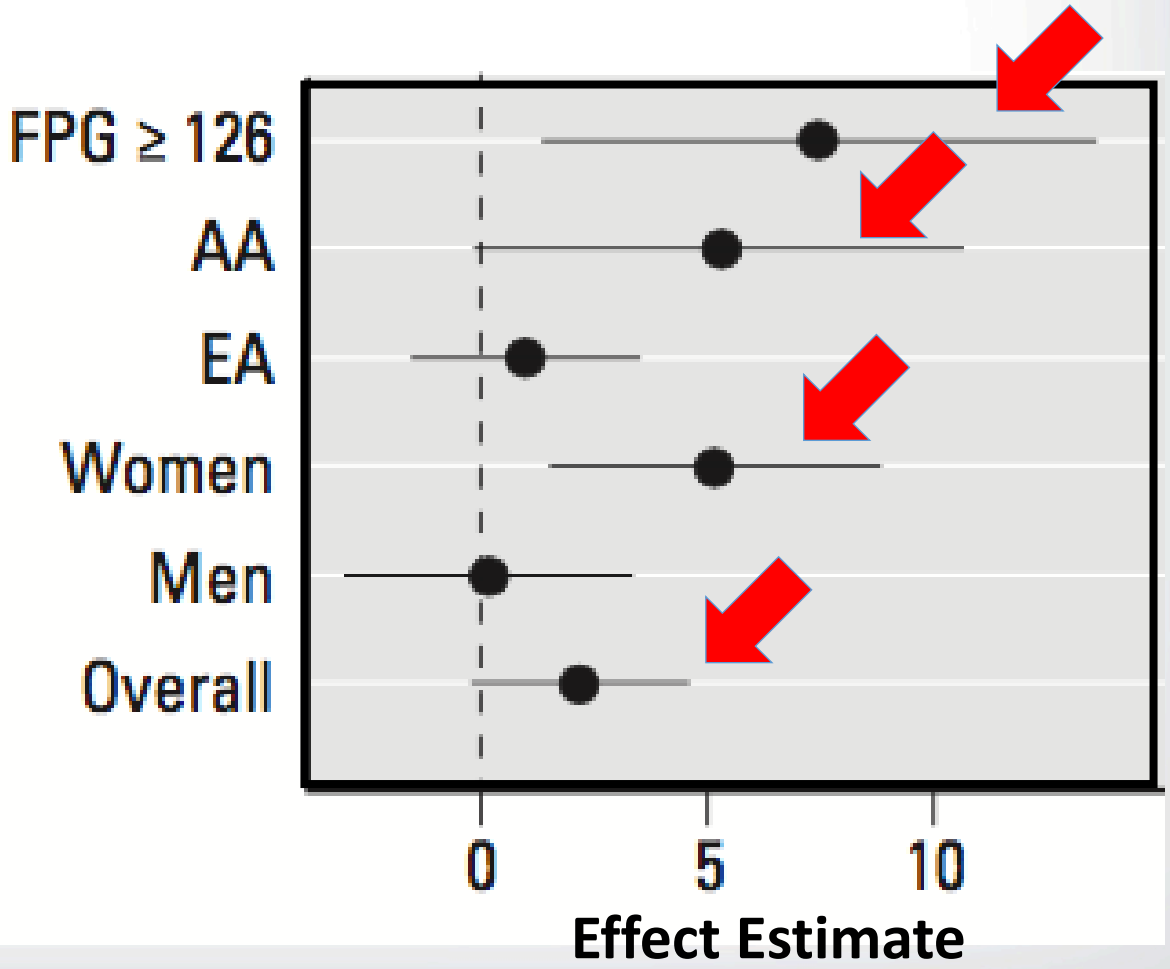
- ***Age*** – might accelerate aging
- ***Total Cholesterol*** – increases cholesterol
- ***HDL*** – decreases HDL particle number
- ***LDL*** – oxidizes LDL and ox-LDL receptor
- ***Systolic BP*** – increases blood pressure
- ***Diabetes*** – associated with type II diabetes
- ***Statin Therapy*** – might be protective

Roadway Proximity and Fasting Plasma Glucose

Distribution of CATHGEN participants within the study area of Durham, Wake, and Orange counties, NC



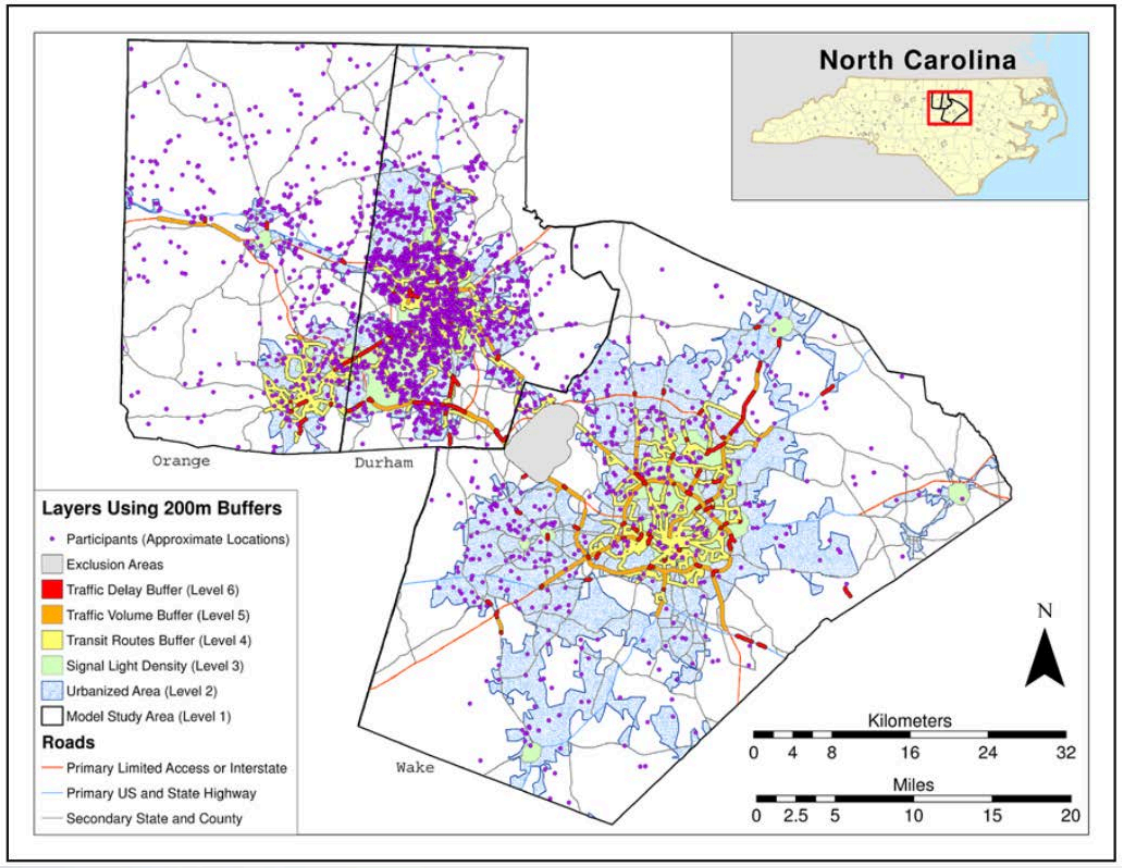
Fasting Plasma Glucose



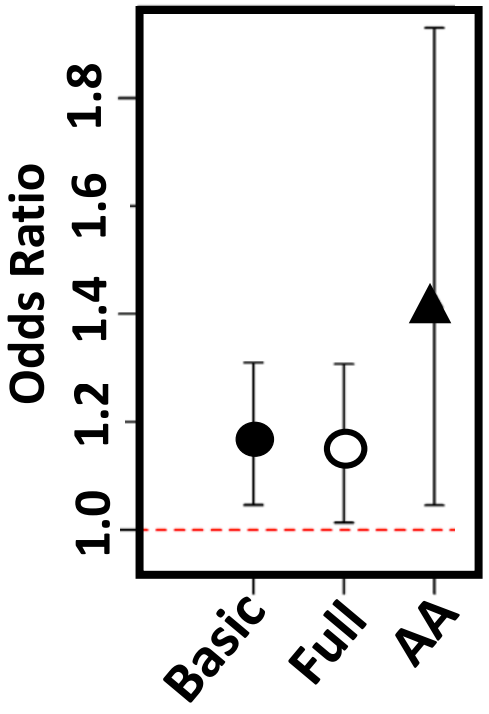
Ward-Caviness C et al. Environ Health Perspect 123:1007–1014

Residential Proximity to Traffic Hypertension, Vascular Disease and

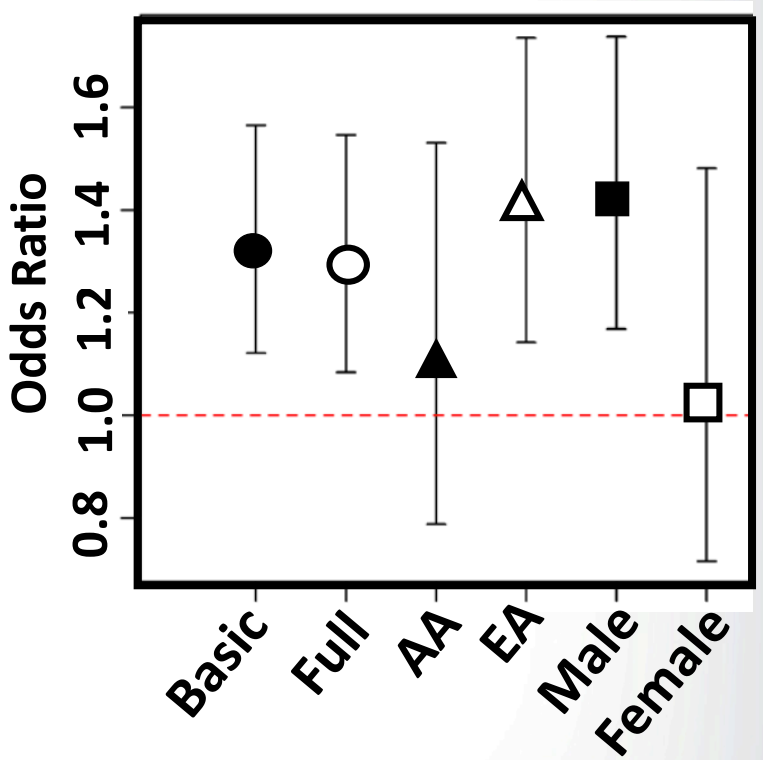
Distribution of CATHGEN participants within the study area of Durham, Wake, and Orange counties, NC



Hypertension



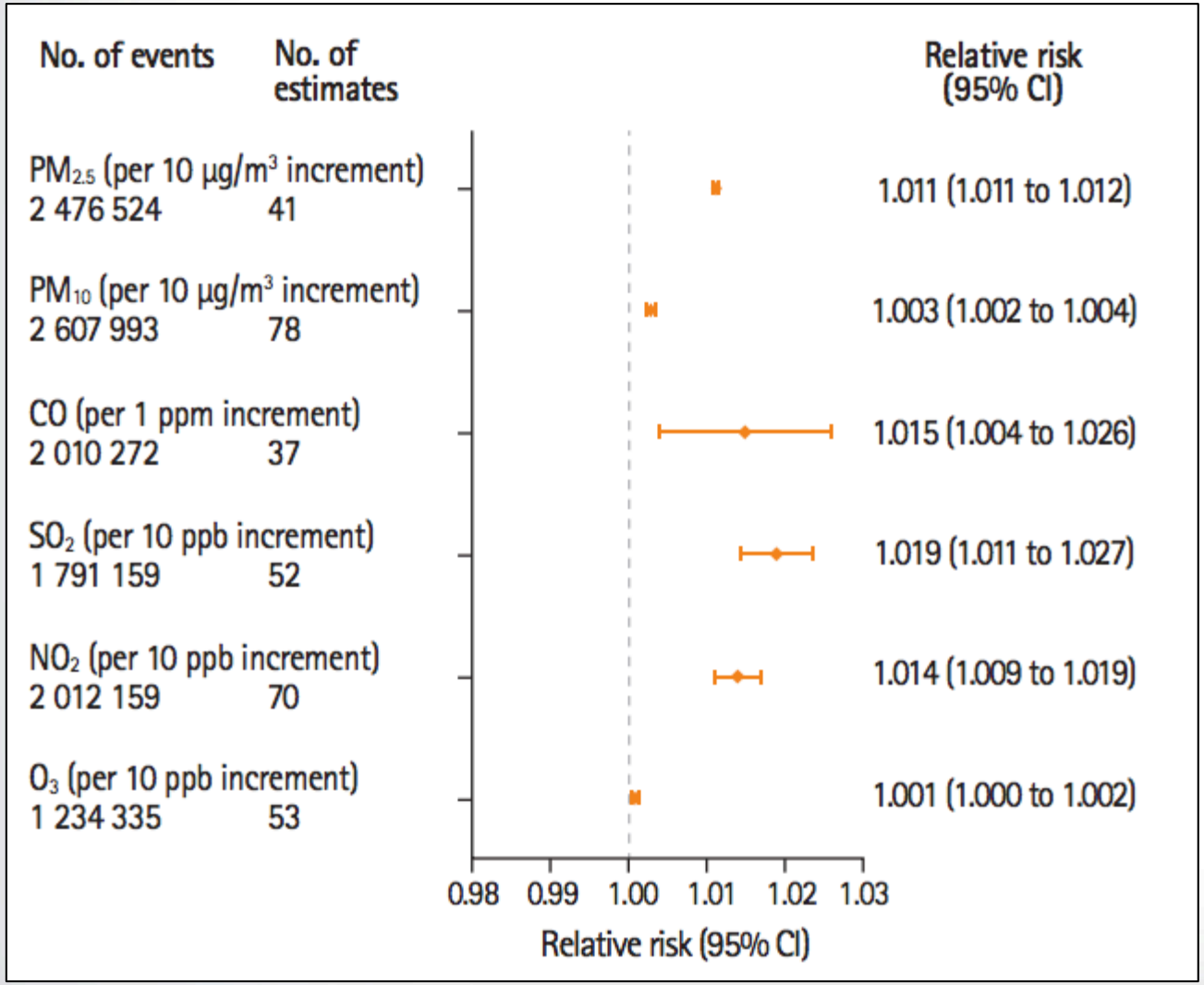
Peripheral Arterial Disease



Basic ▲ AA ■ Males
Full △ EA □ Females

Ward-Caviness W et al. Arterioscler Thromb Vasc Biol. 2018;38:275-282

Association Between Air Pollutants and Hospitalization or Mortality from Stroke



Systematic review and meta-analysis reported stroke to be associated with PM and air pollutants gases:

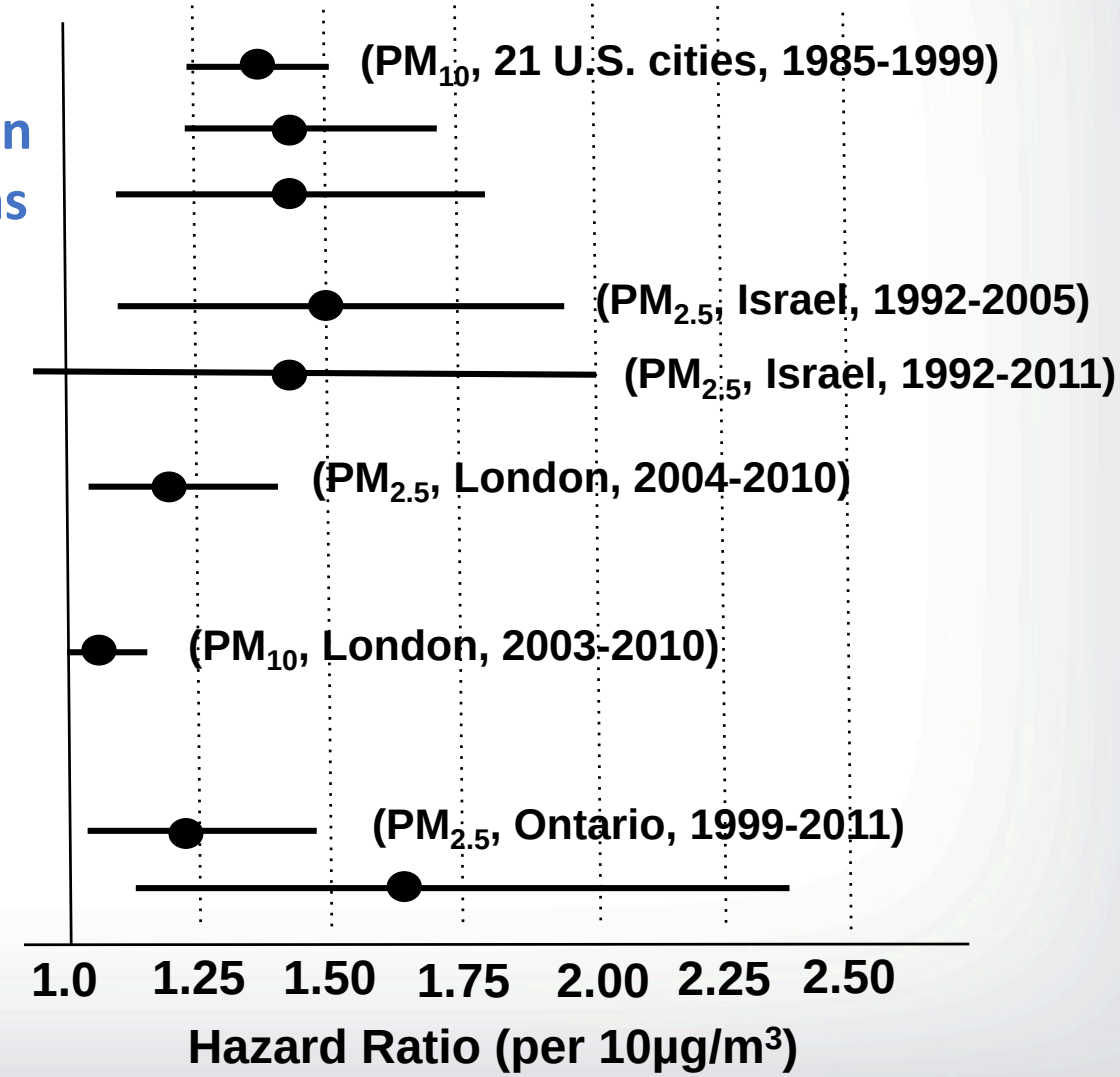
- **$PM_{2.5}$ and PM_{10} associated with admission to hospital for stroke and mortality**
- **NO_2 associated with hospital admission or mortality**
- **SO_2 and CO associated with admission or mortality**

Lee KK, et al. *Journal of Stroke* 2018;20(1):2-11

Air Pollution and Mortality

Effect of PM on Survival and Subsequent Clinical Events

Zanobetti A & Schwartz J. *Environ Health Perspect* 2007	Mortality	(PM_{10}, 21 U.S. cities, 1985-1999)
	CHF hospitalization	
	MI hospitalizations	
Koton *et al.* *Prev Med* 2013	MI, CHF, Stroke	($PM_{2.5}$, Israel, 1992-2005)
	Mortality	($PM_{2.5}$, Israel, 1992-2011)
Tonne et al. *Eur Heart J* 2013	Mortality	($PM_{2.5}$, London, 2004-2010)
Tonne et al. *Int J Hyg Envir Health* 2016	Mortality	(PM_{10}, London, 2003-2010)
Chen et al. *EHP* 2016 *Environ Health Perspect 2016*	Mortality	($PM_{2.5}$, Ontario, 1999-2011)
	MI Mortality	



Personal Health Care Spending in U.S. for Chronic Disease is High

COPD	$ 53.8 billion
Asthma	$ 32.5 billion
Pneumonia	$ 37.1 billion
Lung cancer	$ 13.1 billion
Ischemic heart disease	$ 88.1 billion
High blood pressure	$ 83.9 billion
Stroke	$ 43.8 billion
Heart failure	$ 28.5 billion
Atrial fibrillation	$ 27.7 billion
Peripheral vascular disease	$ 2.7 billion
Diabetes	$101.4 billion
Preterm birth	$ 4.9 billion

½ Trillion Dollars in 2013

Dieleman JL et al.
JAMA 2016

Air Pollutant Exposure is a Risk Factor

Air Pollution is Costly

- ***Air pollution adversely affects:***
  - Health, Longevity, Healthcare Resource Utilization and Public Welfare (e.g. effects on visibility, vegetation, and ecosystems)
- ***Most healthcare professionals & patients at-risk know of air pollution's adverse health effects***

Despite Knowledge of the Risks
the Healthcare System is Not Engaged

- ***Few healthcare professionals discuss the risks with their patients***
- ***At-risk patients don't take action to reduce exposure***

EPA's Healthy Heart Program

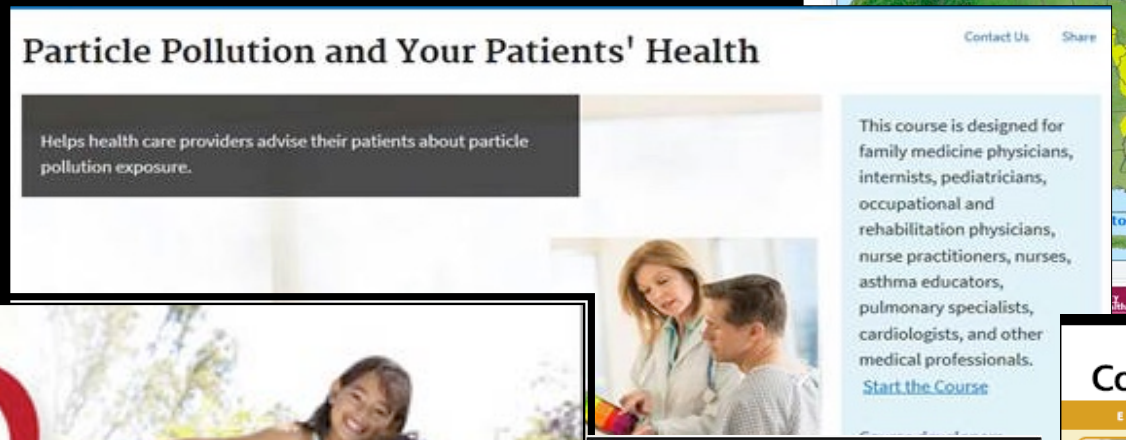
Increasing Environmental Health Literacy

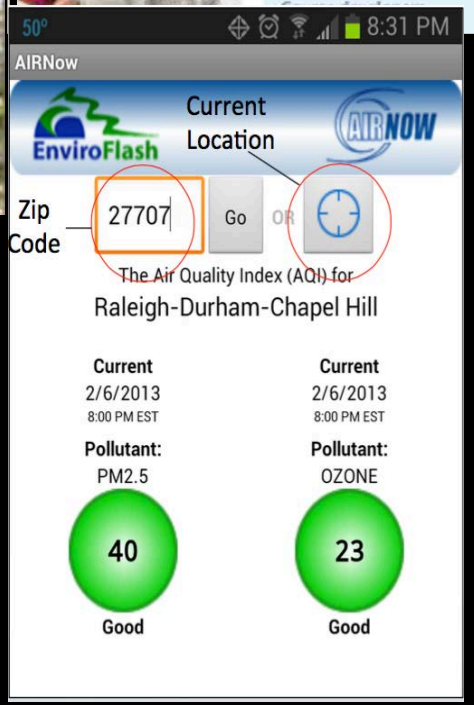
EPA's Healthy Heart program aims to prevent heart attacks and strokes by:

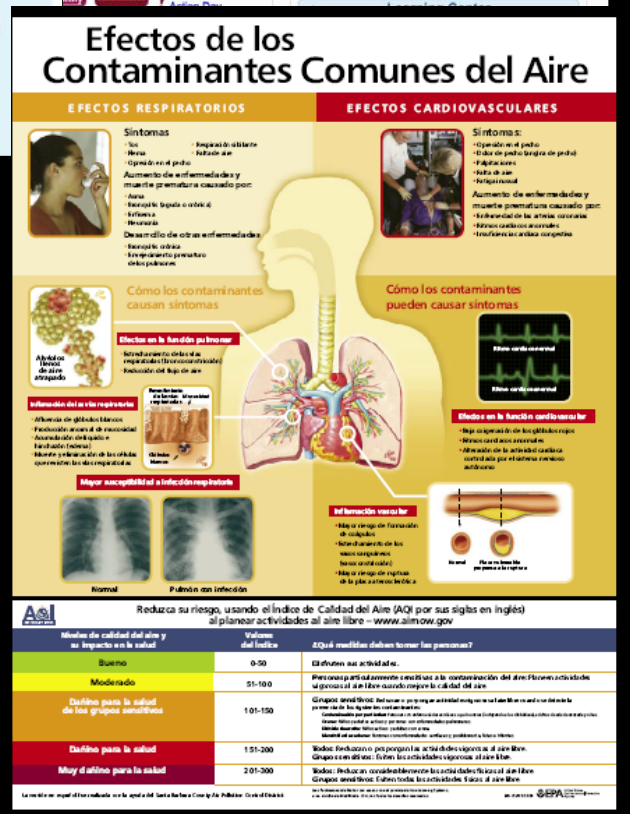
- Raising public awareness about the role outdoor air pollution plays in cardiovascular health, and
- Steps individuals can take to reduce their pollution exposure

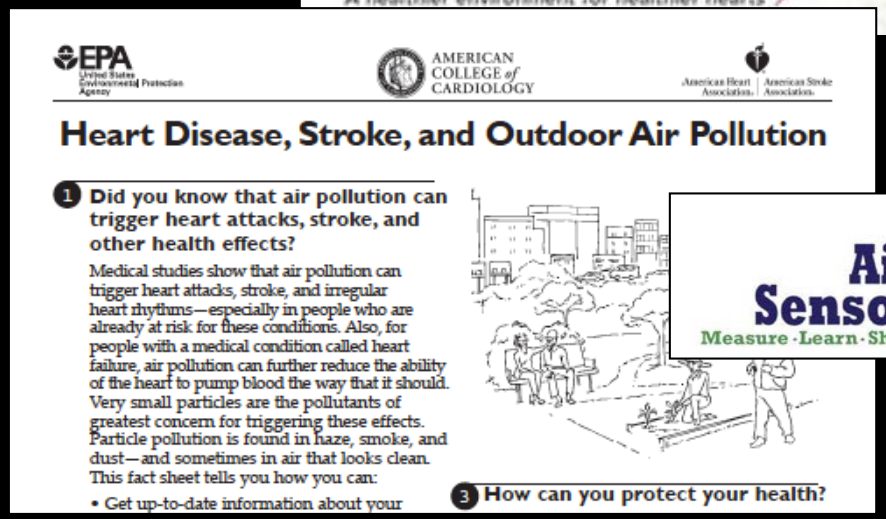
http://www.epa.gov/healthyheart/

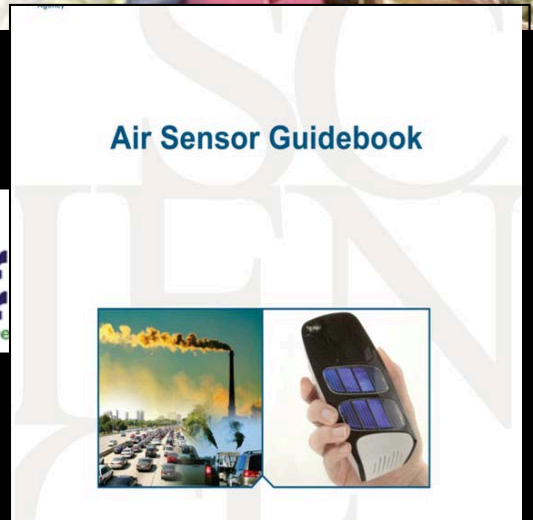
Examples of Products Engaging the Public











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

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

Informing the Public

www.airnow.gov via the Internet

AirNow National AQIs & forecast August 29, 2017

Fresno, CA AQI & forecast August 29, 2017

Current Conditions

Air Quality Index (AQI)
observed at 3:00 PDT

33 **Good**

Health Message: None

Note: Values above 500 are considered Beyond the AQI. Follow recommendations for the Hazardous category. Additional information on reducing exposure to extremely high levels of particle pollution is available here.

AQI - Pollutant Details

Ozone	33	Good

Air Quality Forecast

Today	Tomorrow
Air Quality Index (AQI)	**Air Quality Index (AQI)**
177 **Unhealthy**	**Unhealthy for Sensitive Groups**
Health Message: Active children and adults, and people with lung disease, such as asthma, should avoid prolonged or heavy exertion outdoors. Everyone else, especially children, should reduce prolonged or heavy exertion outdoors.	**Health Message:** People with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion.

AQI - Pollutant Details

Ozone	177	Unhealthy	Particles (PM2.5)	Unhealthy for Sensitive Groups

Healthy Heart Toolkit

www.epa.gov/air-research/healthy-heart-toolkit-and-research

EPA United States Environmental Protection Agency

Environmental Topics | Laws & Regulations | About EPA | Search EPA.gov

Related Topics: Air Research | CONTACT US | SHARE

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 heart attacks, strokes and worsen heart failure in people who are at risk for these conditions. If you have a heart condition, you could benefit by reducing your exposure to high levels of air pollution.

When are air pollution levels high?

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

Daily Air Quality

- Check Pollution Forecasts
- Get Free Email Alerts EXIT

Resources

- Be Smart, Protect Your Heart video EXIT
- Heart Disease, Stroke and Outdoor Air Pollution
- Million Hearts Initiative:

- *When are air pollution levels high?*
- *Are you at risk?*
- *Steps to Protect Your Heart*
- *How to Reduce your Risk?*
- *Warning Signs of a Heart Attack*
- *Warning Signs of a Stroke*

https://www.epa.gov/air-research/healthy-heart-toolkit-and-research-steps-you-can-take

CME for Health Care Professionals

Particle Pollution and Your Patients' Health

United States Environmental Protection Agency

www.epa.gov/particle-pollution-and-your-patients-health

Environmental Topics | Laws & Regulations | About EPA | Search EPA.gov

CONTACT US

SHARE

Particle Pollution and Your Patients' Health

An evidence-based training for healthcare professionals that:

- Describes the biological mechanisms responsible for the cardiovascular and respiratory health effects associated with particle pollution exposure.
- Provides educational tools to help patients understand how particle pollution exposure can affect their health and how they can use the Air Quality Index to protect their health.

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

Start the Course

Course developers

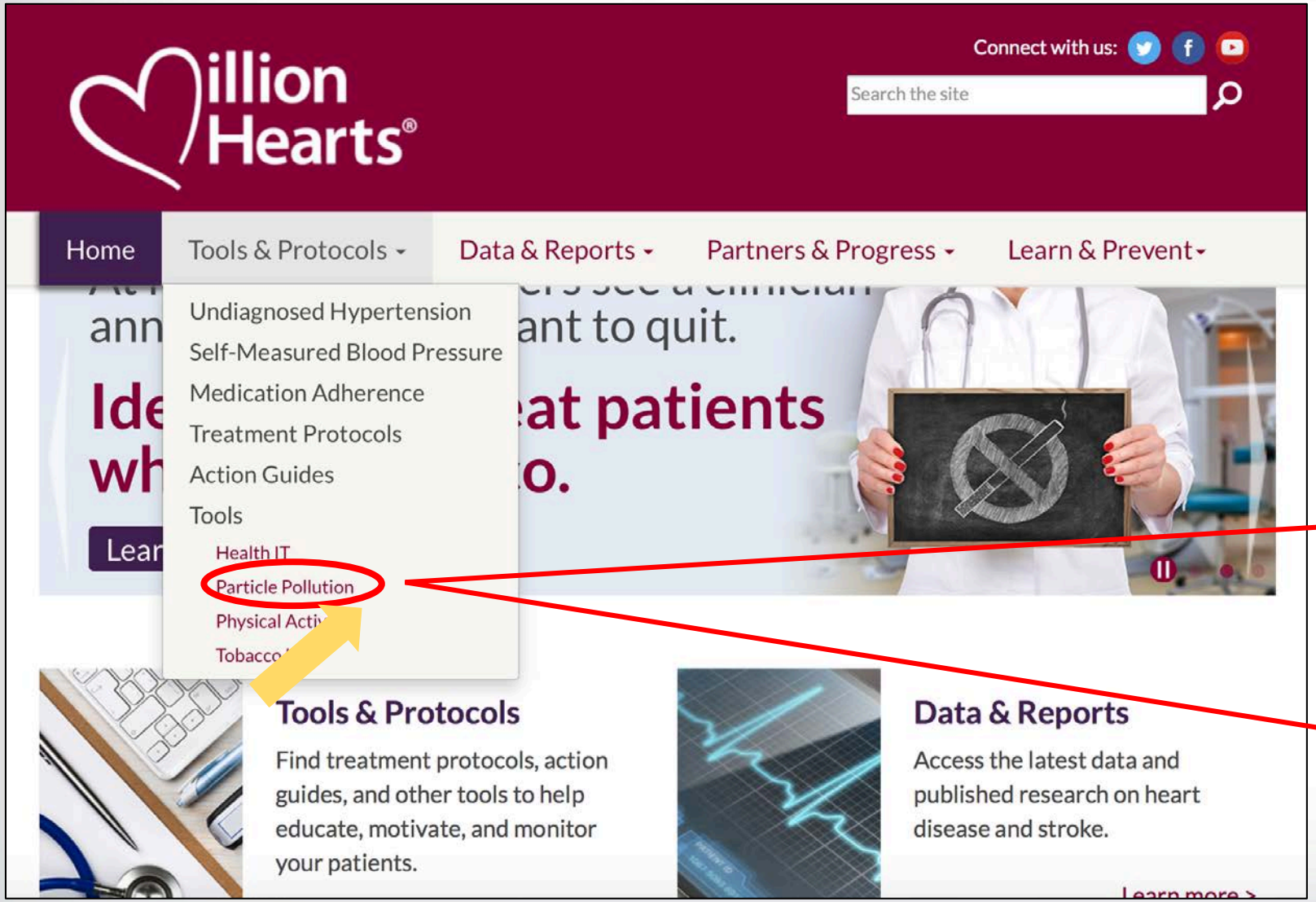
Partnering with HHS' Million Hearts®
Recommendations Supported by EPA Science

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*

http://millionhearts.hhs.gov/aboutmh/partners/epa.html

Million Hearts®
Provides Educational Tools on Particle Pollution



https://millionhearts.hhs.gov

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

Million Hearts®

Healthy Heart
A healthier environment for healthier hearts

- **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**

Modified from Auerbach J. *J Pub Health Manag Pract*, *22*: 215-218, 2016

High Resolution Air Pollution Mapping

Small Scale Variability due to Local Sources

Environmental Science & Technology

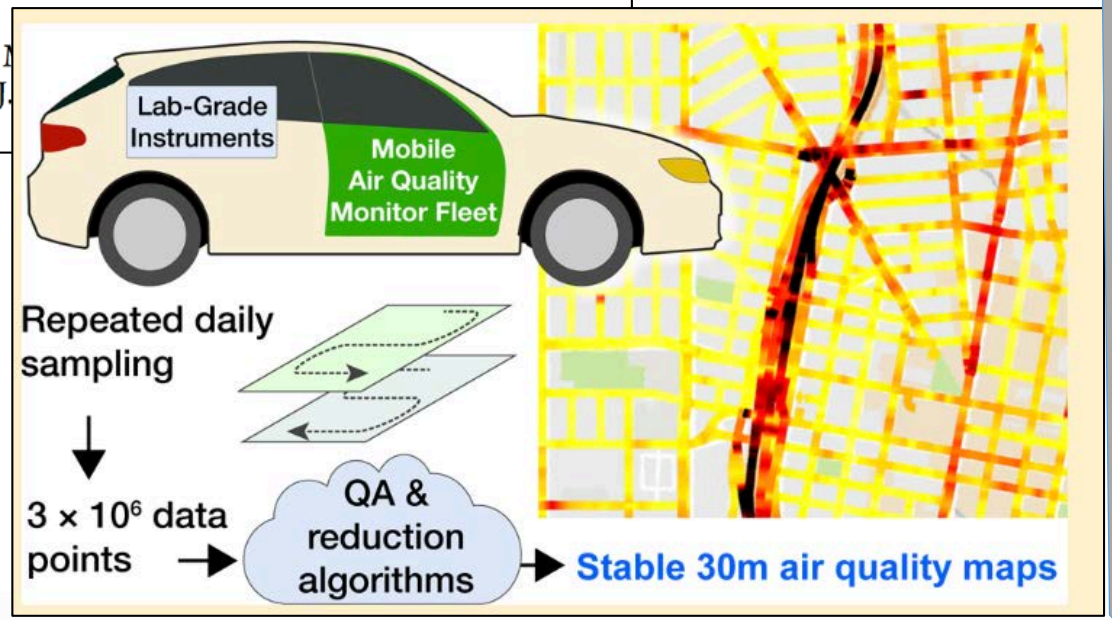
Article

pubs.acs.org/est

High-Resolution Air Pollution Mapping with Google Street View Cars: Exploiting Big Data

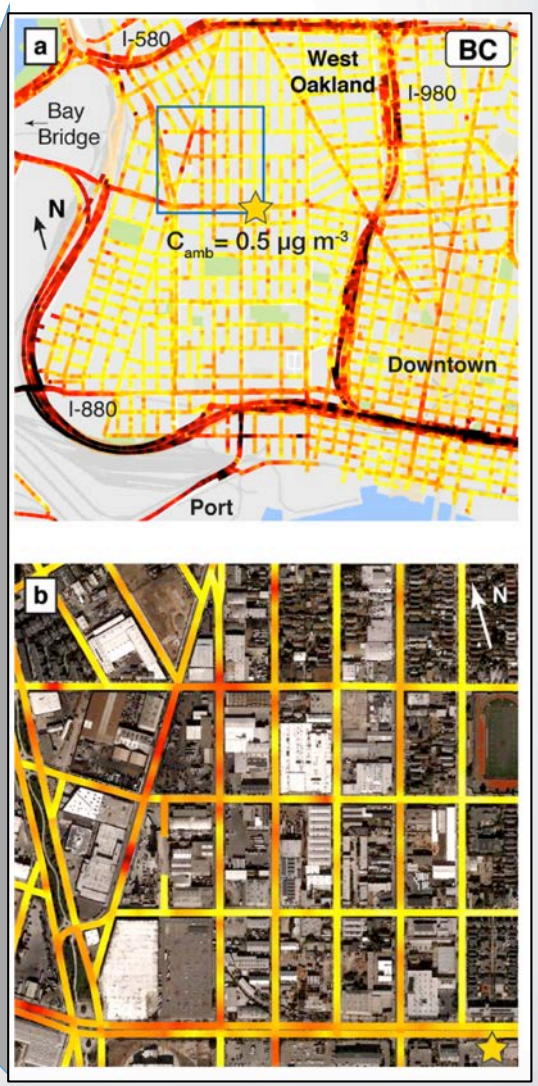
Joshua S. Apte,*,† Kyle P. Messier,†,‡ Shahzad Gani,† Melissa M. Lunden,⊥ Julian D. Marshall,# Christopher J. and Steven P. Hamburg‡

Apte JS et al. Environ Sci Technol 2017



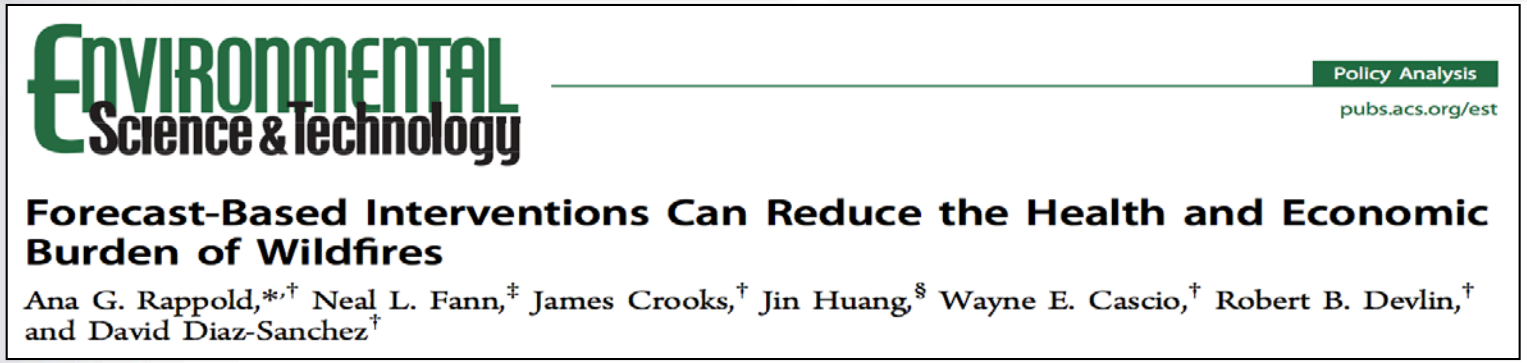
Oakland, CA

Spatial distribution of Black Carbon (BC)



Hankey S et al. Population-Level Exposure to Particulate Air Pollution during Active Travel: Planning for Low-Exposure, Health-Promoting Cities. *Environmental Health Perspectives* 125:527–534, *2017*

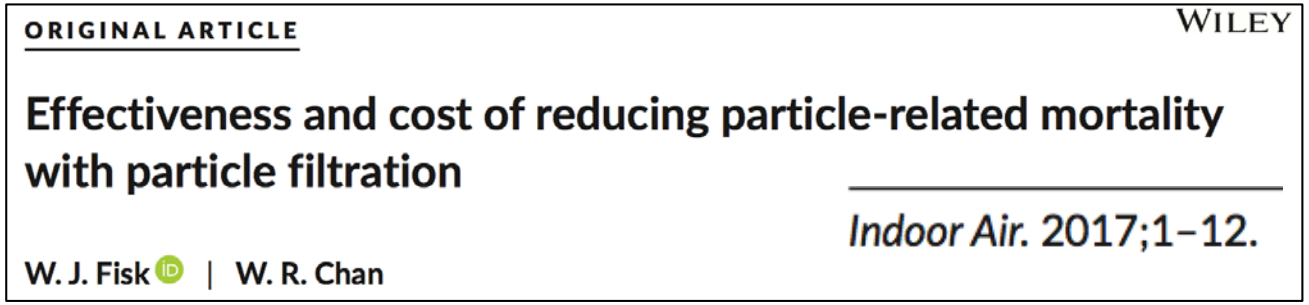
Moving to the Future



Forecast-based interventions predicted to reduce the health and economic burden of wildfires

Rappold AG, et al.
Environ Sci Technol 2014

Cost effectiveness is improved by intervening only in the homes of those at highest risk, e.g. older persons



Fisk WJ, Chan WR *Indoor Air* 2017

"… we believe that the time is ripe to definitively test the efficacy of personal-level interventions…"

Brook RD, et al.
JAMA Cardiol. 2017

Summary and Opportunities

- **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

Summary and Opportunities

- **High-risk patients should be educated about risks of air pollution and educated about measures to reduce exposure**
- **Decreased short-term exposure in high patients is predicted to mitigate adverse health effects in high-risk individuals**
- **Randomized controlled trials are needed to proved effectiveness of interventions to reduce exposure**
- **Health risks need to be addressed through integrated efforts of public health and health care at the community and individual level**
- **More effective health communication strategies are needed to encourage health protective behaviors**

Thank you

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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

Fall in Air Pollution Related Deaths Over Time

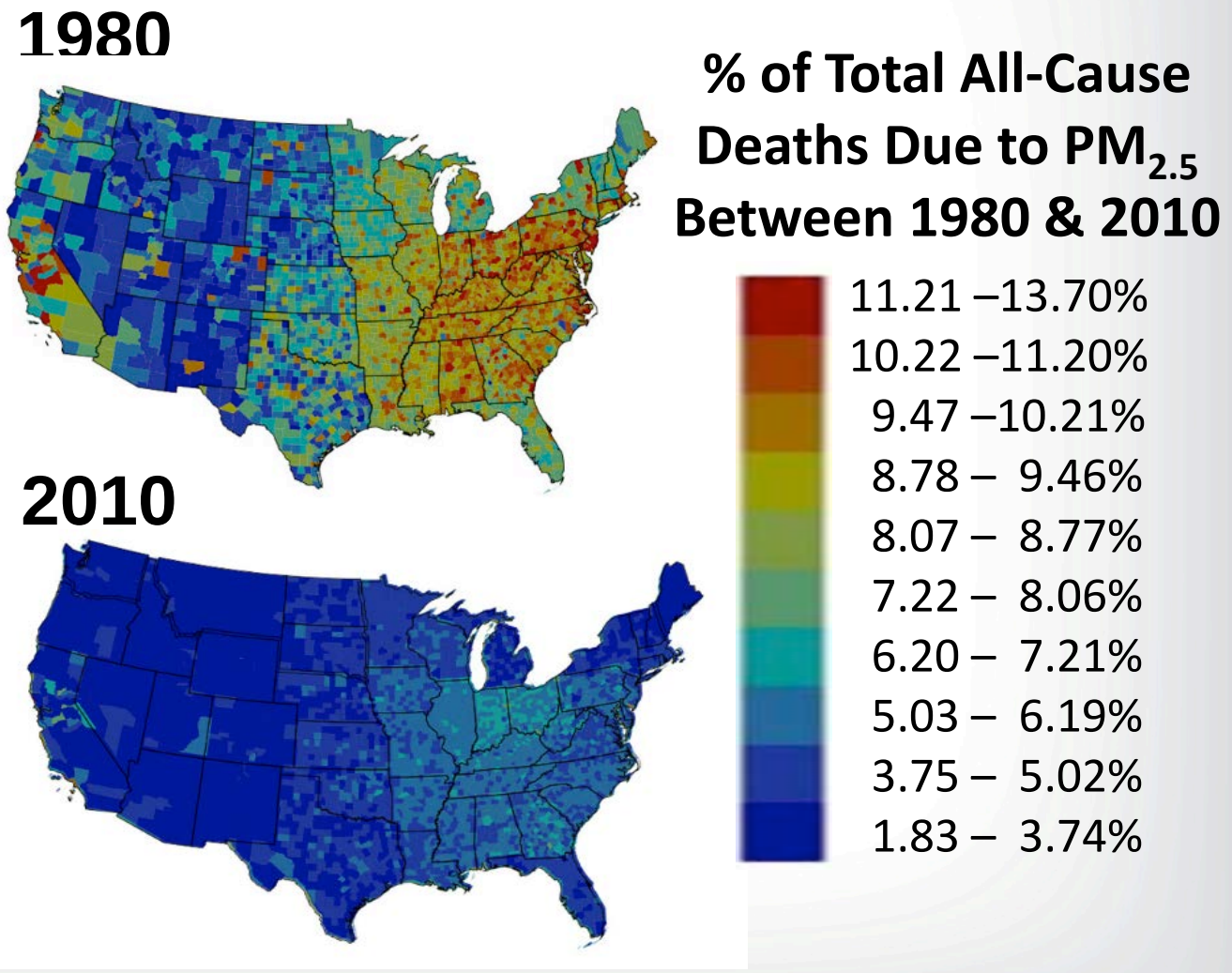
Fraction of Total All-Cause Deaths Attributed to $PM_{2.5}$

After the implementation of local, state, and federal air quality policies

- $PM_{2.5}$ precursor emissions declined over the course of several decades

Between 1980 - 2010, $PM_{2:5}$ exposures fell by about half, and estimated excess deaths decreased by about a third

- California, Virginia, New Jersey, and Georgia had some of the largest estimated reductions in $PM_{2.5}$-attributable deaths



Fann N, et al. Environmental Health Perspectives 2017

Long-term Health Effects of Air Pollution

$PM_{2.5}$ Exposure and Post-MI Survival in Ontario, Canada

Post-Myocardial Infarction Survival Ontario, Canada 1999-2011

- 8,873 patients with 4,016 non-accidental deaths
- Mortality follow-up through 2011
- Cumulative time-weighted exposures to $PM_{2.5}$ were derived from satellite observations
- **For each 10-µg/m^3 increase in $PM_{2.5}$ non-accidental mortality increased by 22%**

Conclusions:

- Long-term air pollution exposure adversely affects the survival of Heart Attack patients

Post-Stroke Survival London, England 1995-2006

- 3,320 patients with 1,856 deaths
- Stroke follow-up to mid-2006
- Outdoor NO_2 and PM_{10} modeled for 2002
- HRs were adjusted for relevant factors
- **10-µg/m^3 increase in NO_2 and PM_{10} was associated with a 28% and 52% increase in risk of death, respectively**

Conclusions:

- Improvements in outdoor air quality might contribute to better survival after stroke
- A 10 µg/m^3 reduction in NO_2 exposure is expected to reduce mortality comparable to that for stroke units

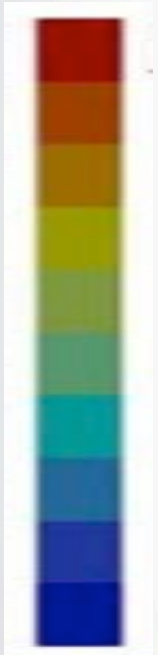
Chen H, et al. *Environ Health Perspect*, 2016

Maheswaran et al. *Stroke* 2010

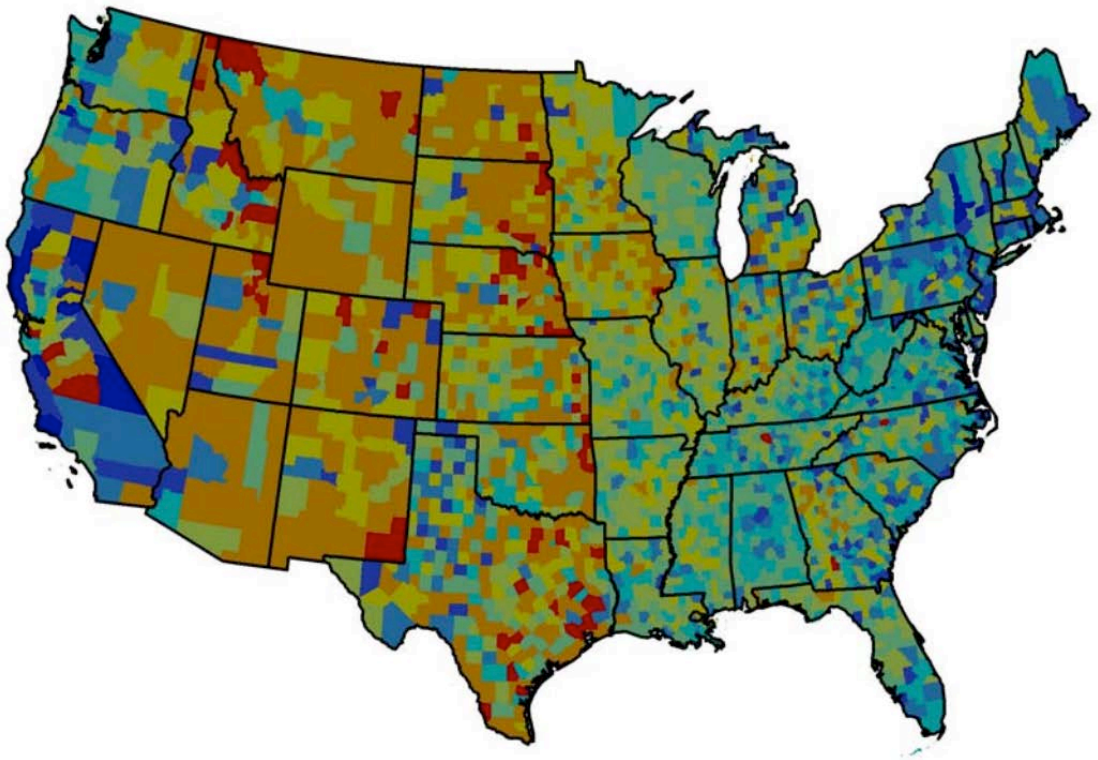
Air Pollution

Public Health Benefits of Decreasing $PM_{2.5}$ 1980-2010

Change in the % of Death Due to $PM_{2.5}$ Between 1980 - 2010



-2.85 – -0.04%
-0.03 – -0.01%
0.02 – 2.18%
2.19 – 3.01%
3.02 – 3.71%
3.72 – 4.37%
4.38 – 5.09%
5.10 – 6.07%
6.08 – 8.11%
8.12 – 11.7%



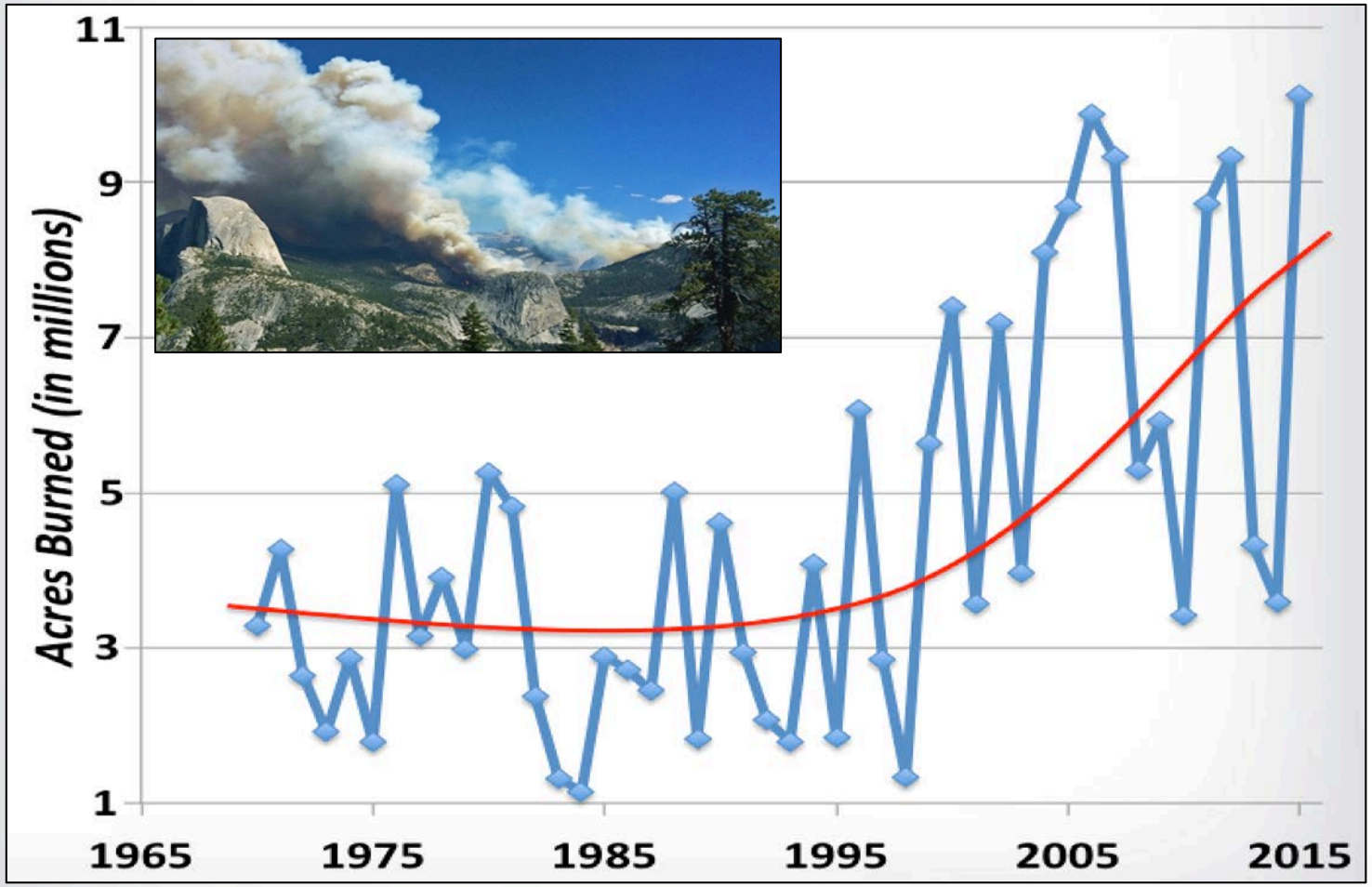
Relative to a hypothetical population with exposures held constant at 1980 levels

- people born in 2050 would live about 1 year longer
- there would be a cumulative gain of 4.4 million life years among adults ≥30 years of age

Fann N, et al. Environmental Health Perspectives 2017

Wildfire: An Issue of Concern for the States

Impacts of Local and National Importance



Adapted from https://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html

- ***Wildland fires accounted for 38% of $PM_{2.5}$ emissions in 2014***
- ***2017 was substantially worse than the average of the last 10 years***
- ***Between 2001 - 2010 over 40% of the country's large wildfires occurred in the Southeast***
- ***U.S. spends more than $2 billion each year to fight wildfires***

Wildfire-$PM_{2.5}$ Increases Heart Attack & Stroke

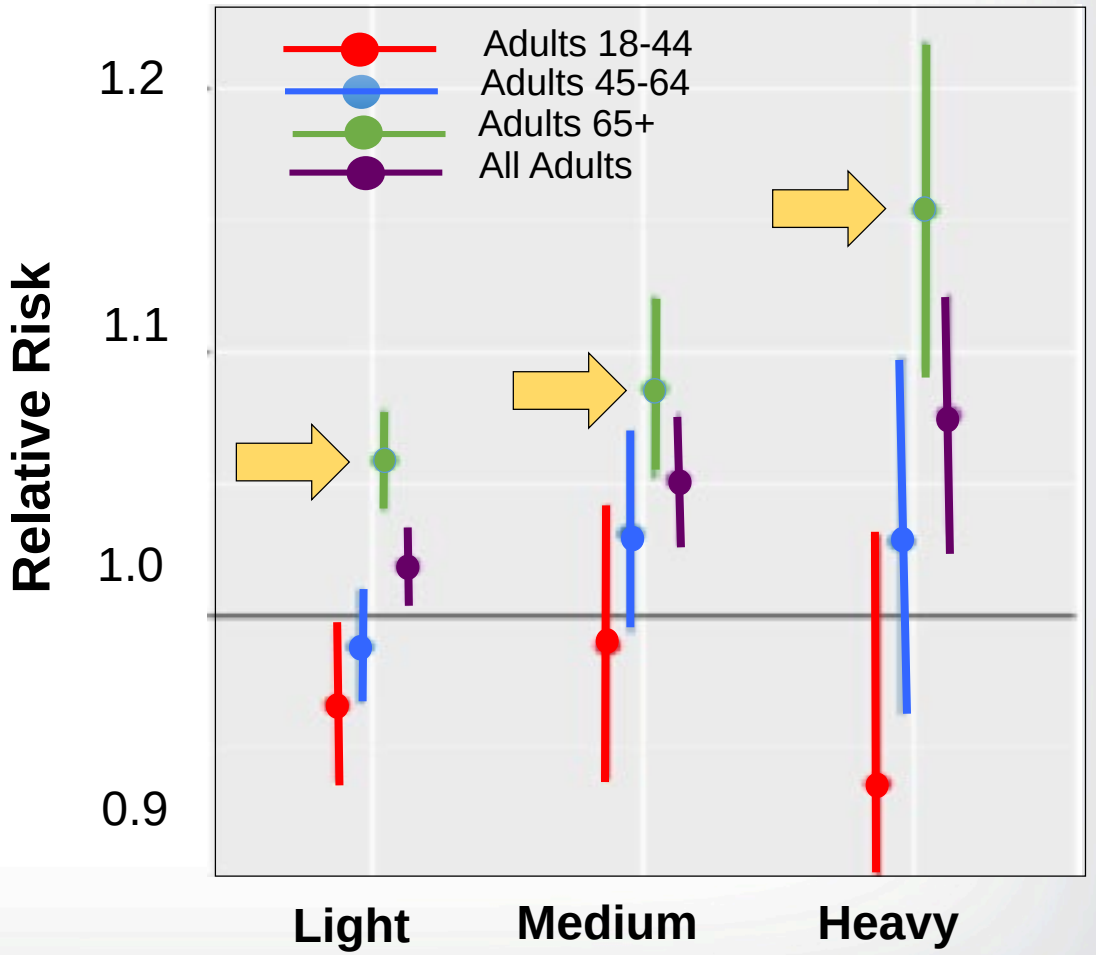
California 2015 Wildfire Study

Results: Wildfire-$PM_{2.5}$ associated with heart attacks and strokes for all adults, particularly for those over 65 years old

- Increase in risk the day after exposure:
  - All cardiovascular, 12%
  - Heart attack, 42%
  - Abnormal heart rhythm, 24% (same day)
  - Heart failure 16%
  - Stroke 22%
  - All respiratory causes 18%

Impact: Highlights the importance of decreasing exposure in at-risk populations

All Cardiovascular Causes



Wettstein Z, Hoshiko S, Cascio WE, Rappold AG et al. (in review, 2018)