Health Effects of Air Pollution in Your Patients: The Relevance to Cardiac and Pulmonary Rehabilitation

Wayne Cascio, MD, FACC

Director

Center for Public Health and Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency

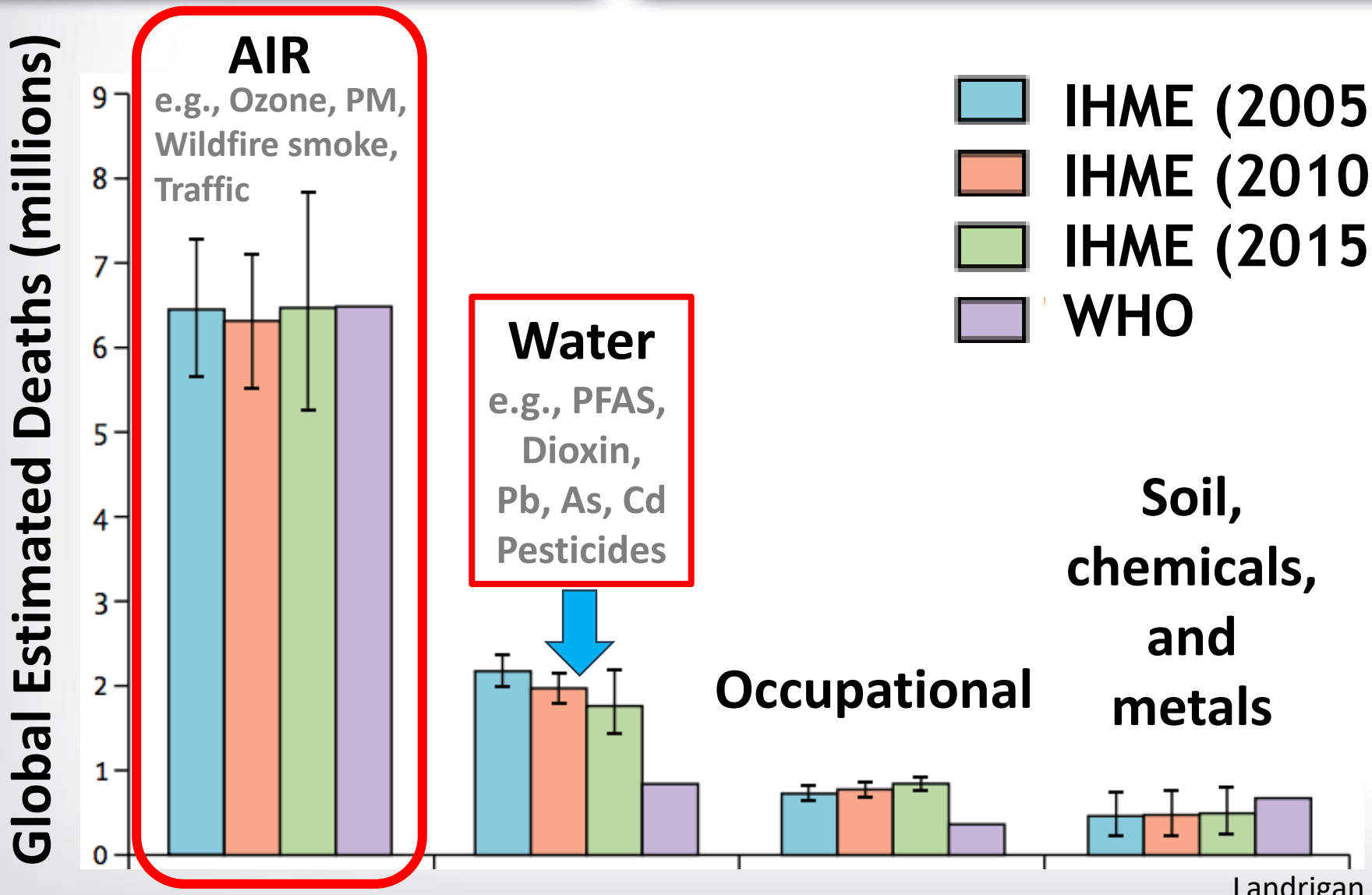
45th Annual Symposium of the North Carolina Cardiopulmonary Rehabilitation Association

Chapel Hill, NC
April 4, 2025

What is the Global Mortality Burden of Exposure to Environmental Pollution?

Global Estimated Deaths by Pollution, 2015

Putting Different Pollutant Sources into Perspective



On a global scale air pollution is the dominant driver of mortality

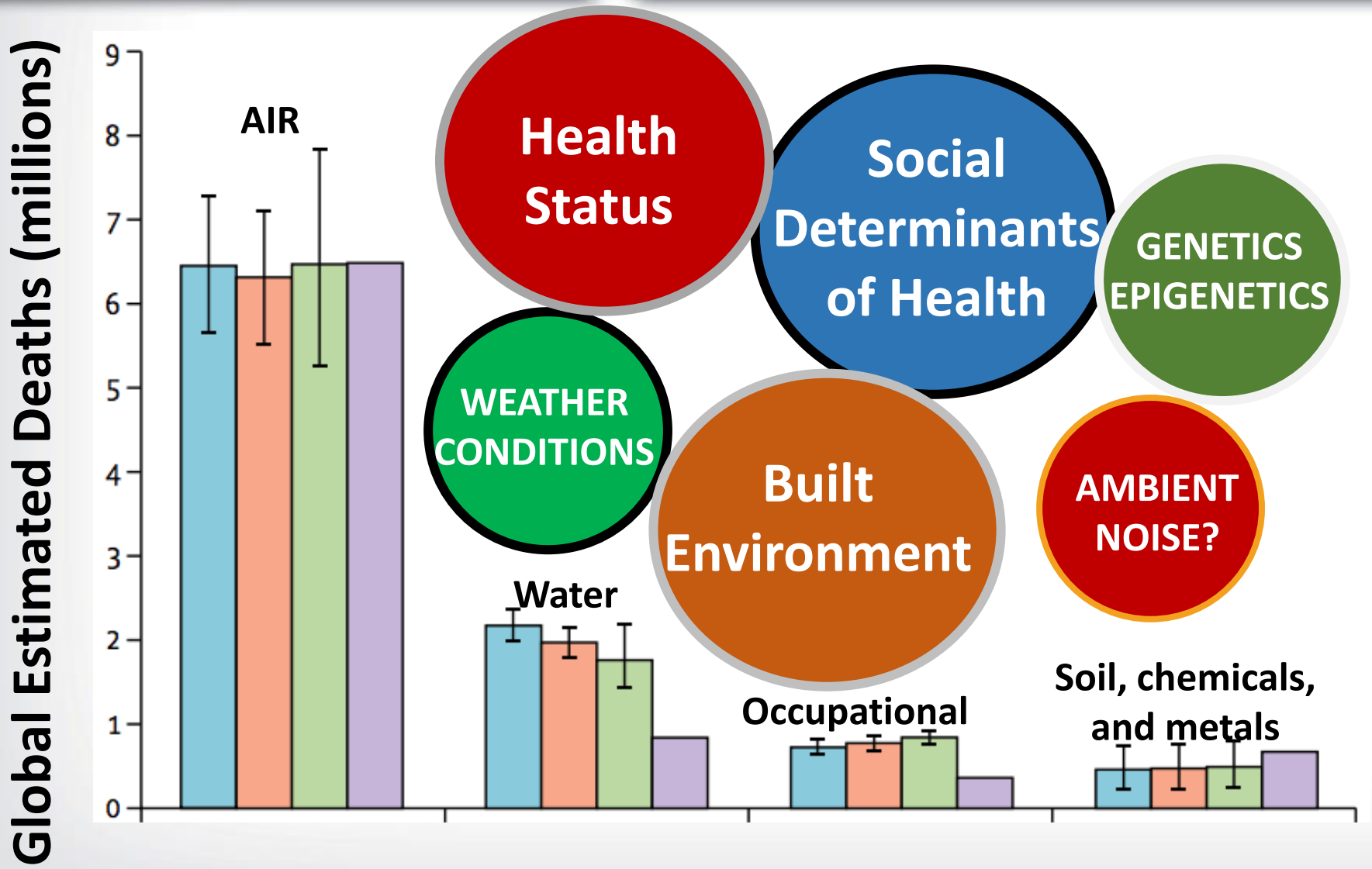
Data from the Global Burden of Disease study and WHO

IHME = Institute for Health Metrics and Evaluation

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

Global Estimated Deaths by Pollution, 2015

Environmental Pollutants Don't Act Alone



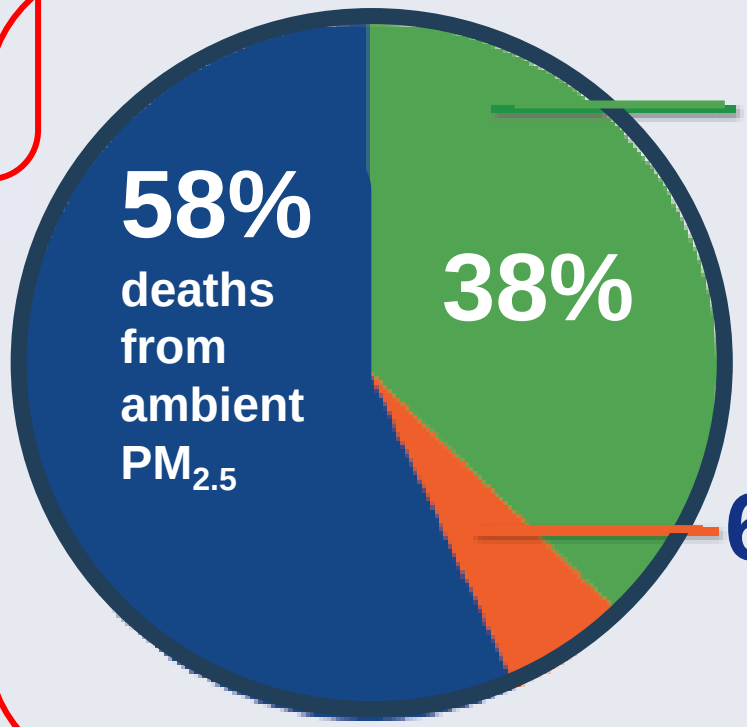
Health outcomes associated with environmental pollutants are influenced by other environmental factors, individual factors and socioeconomic factors

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

EPA

STATE OF GLOBAL AIR /2024

8.1 million total deaths due to air pollution in 2021



2nd

largest risk factor of deaths in 2021

Countries in South Asia and Africa face the highest burden of disease.

Global Risk Factors for Death

1. High blood pressure
2. Air pollution
3. Tobacco
4. Diet
5. High fasting plasma glucose

Since 2000

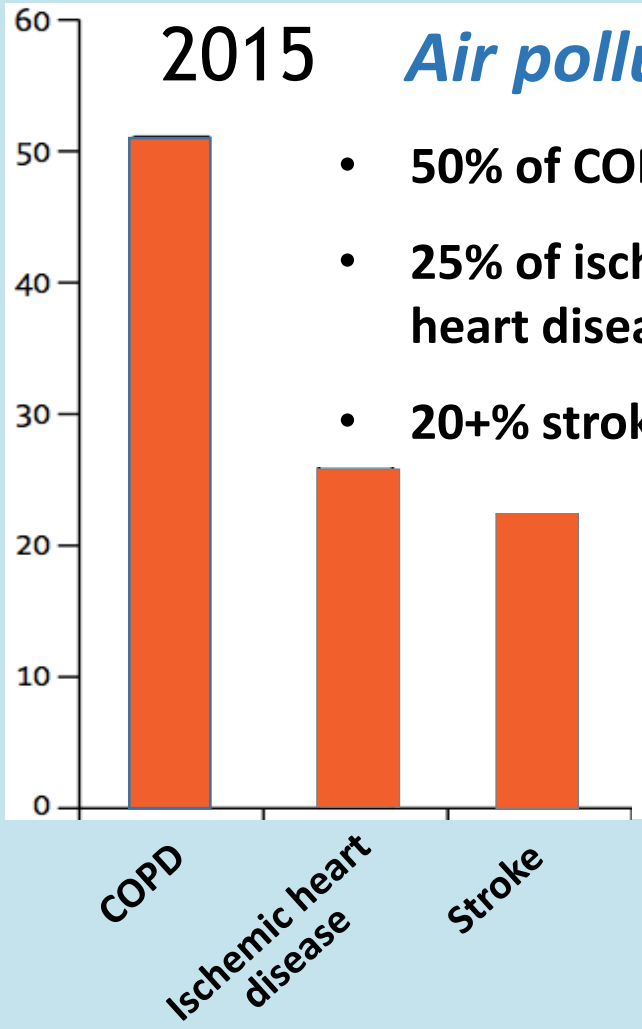
The disease burden for household air pollution (HAP) has decreased largely due to reductions in exposure in China and South Asia.

There has been a **36%** decline in deaths from HAP.

Lower respiratory infection deaths are decreasing across most regions.

Health Effects Institute. 2024. State of Global Air 2024. Special Report. Boston, MA: Health Effects Institute

Contribution of Pollution as Cause of Cardiac Pulmonary & Stoke Deaths, 2015 vs 2021

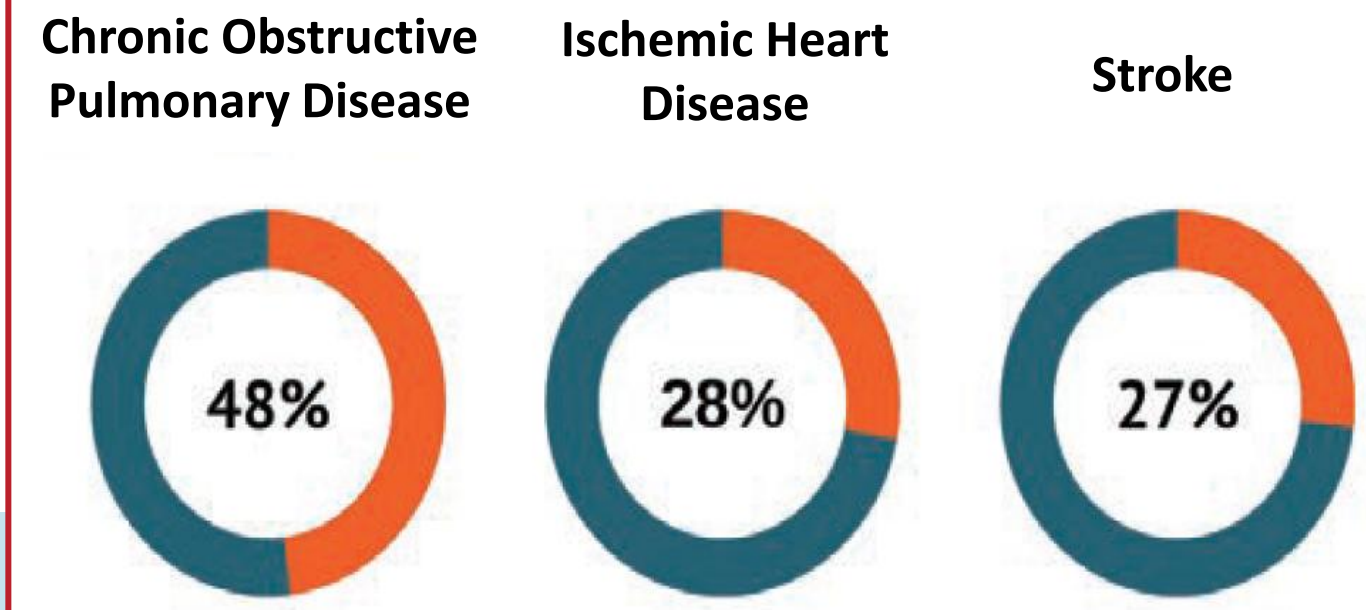


2015 *Air pollution contributes to:*

- **50% of COPD**
- **25% of ischemic heart disease**
- **20+% stroke**

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

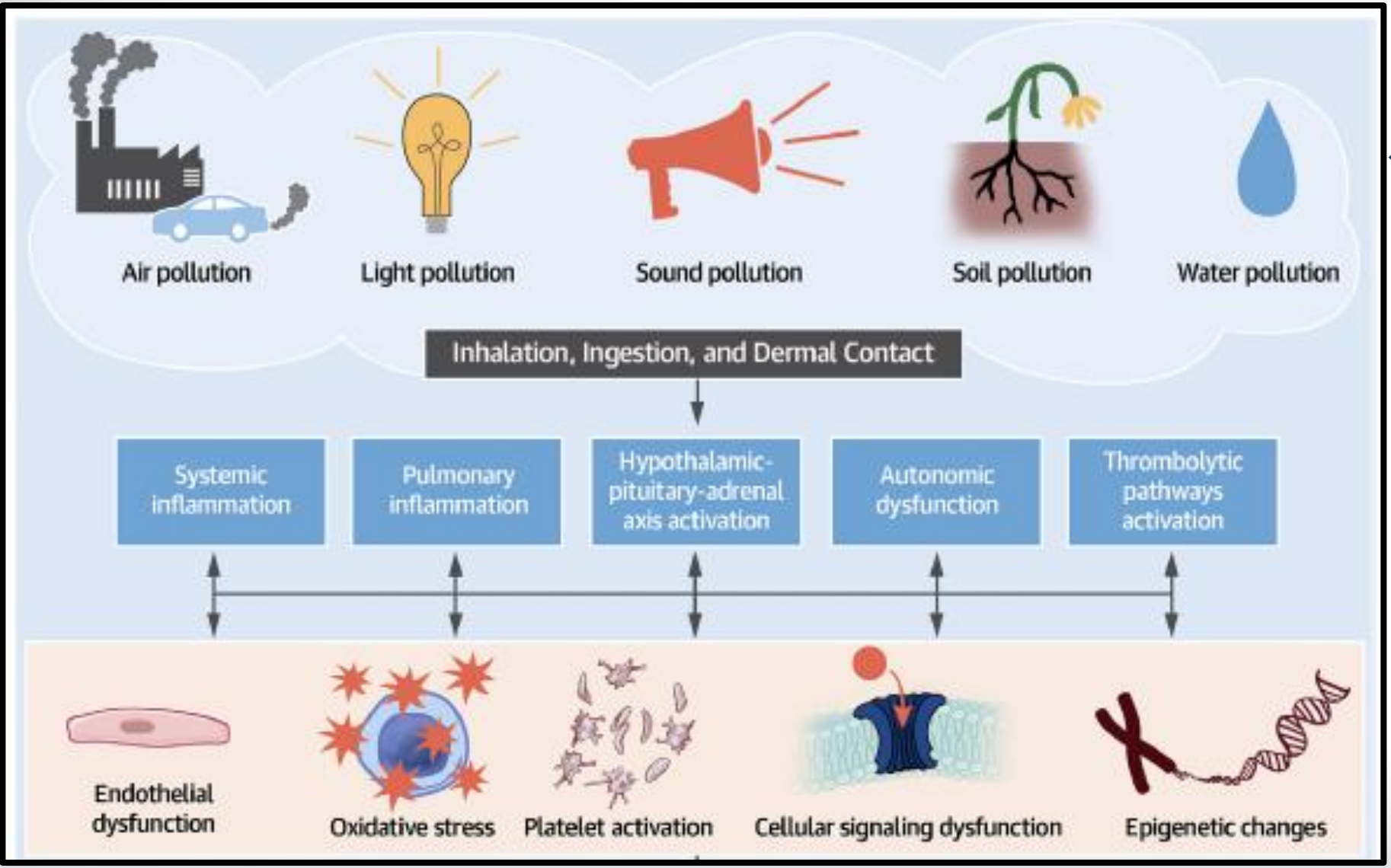
2021 *Air pollution contributes to:*



Health Effects Institute. 2024. State of Global Air 2024. Special Report.

Pollution and Cardiovascular Disease

Usman Sagheer et al. *JACC: Advances* 3(2): 100805, 2024



Pollutants

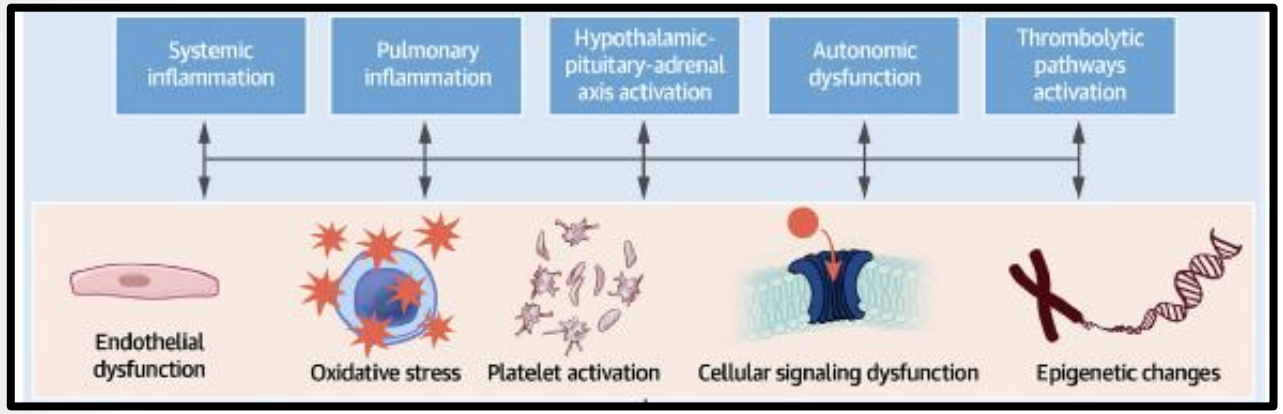
Exposure Pathways

Primary Initiating Mechanisms

Secondary Effector Pathways

Pollution and Cardiovascular Disease

Usman Sagheer et al. *JACC: Advances* 3(2): 100805, 2024

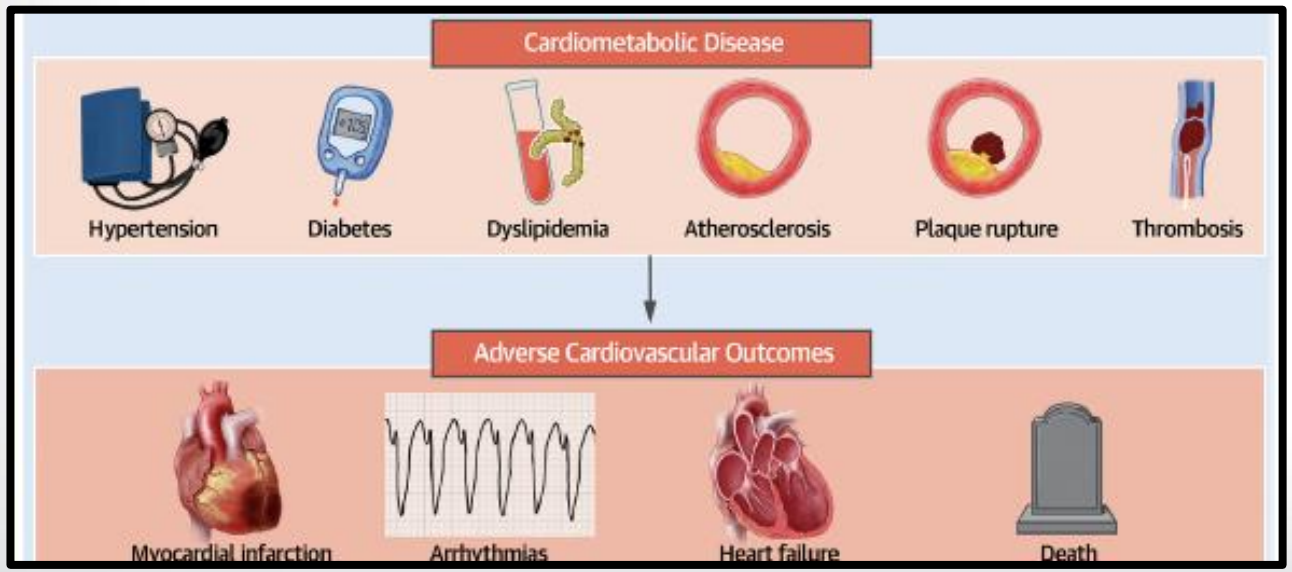


Primary Initiating Mechanisms

Systemic inflammation, Pulmonary inflammation Hypothalamic-Pituitary-Adrenal Axis activation, Autonomic Dysfunction, Thrombolytic pathways activation

Secondary Effector Pathways

Endothelial dysfunction, Oxidative stress, Platelet activation, Epigenetic changes, Cellular signaling dysfunction



End-Organ Effector Mechanisms

Hypertension, Diabetes, Dyslipidemia, Atherosclerosis, Plaque rupture, Thrombosis

End-organ Effector Pathways

MI, Arrhythmia, Heart failure, Death

Environmental Stressors

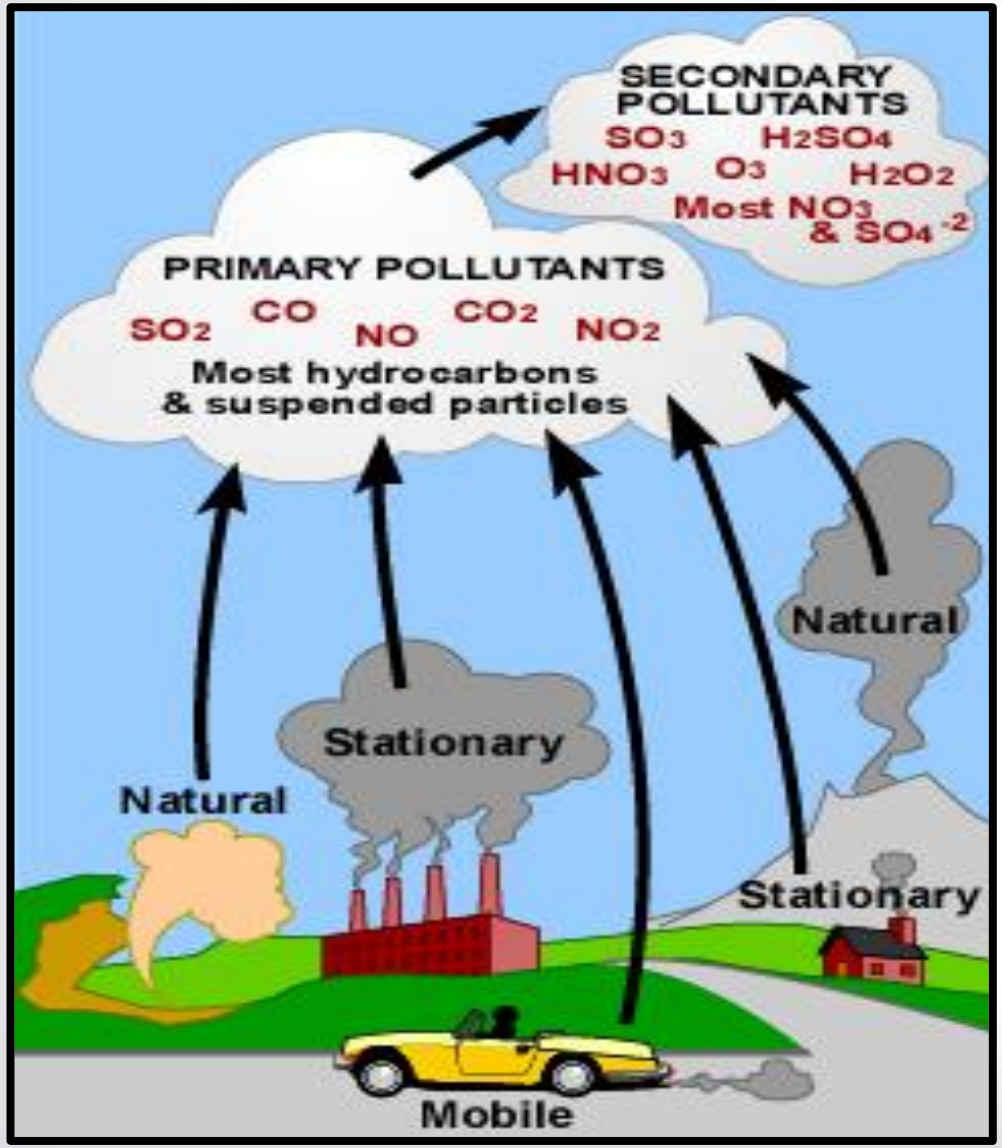
- **Climate/Weather Stressors**
  - Extreme heat (heat waves)
  - Extreme cold
  - Extreme humidity
  - Drought & Dust storms
  - Winter storms
- **Disasters**
  - Wildland fires and smoke
  - Flooding
  - Hurricanes & Cyclones
  - Tornados
  - Earthquakes/Tsunamis
  - Landslides
  - Volcanic eruptions

[Effects of Extreme Humidity and Heat on Ventricular Arrhythmia Risk in Patients With Cardiac Devices.](#)
Keeler C, Cleland SE, Hill KL, Mazzella AJ, Cascio WE, Rappold AG, Rosman LA. *JACC Adv*. 2024 Dec 13;4(1):101463. doi: 10.1016/j.jacadv.2024.101463

What is Ambient Air Pollution?

Common Air Pollutants

Sources and Distribution



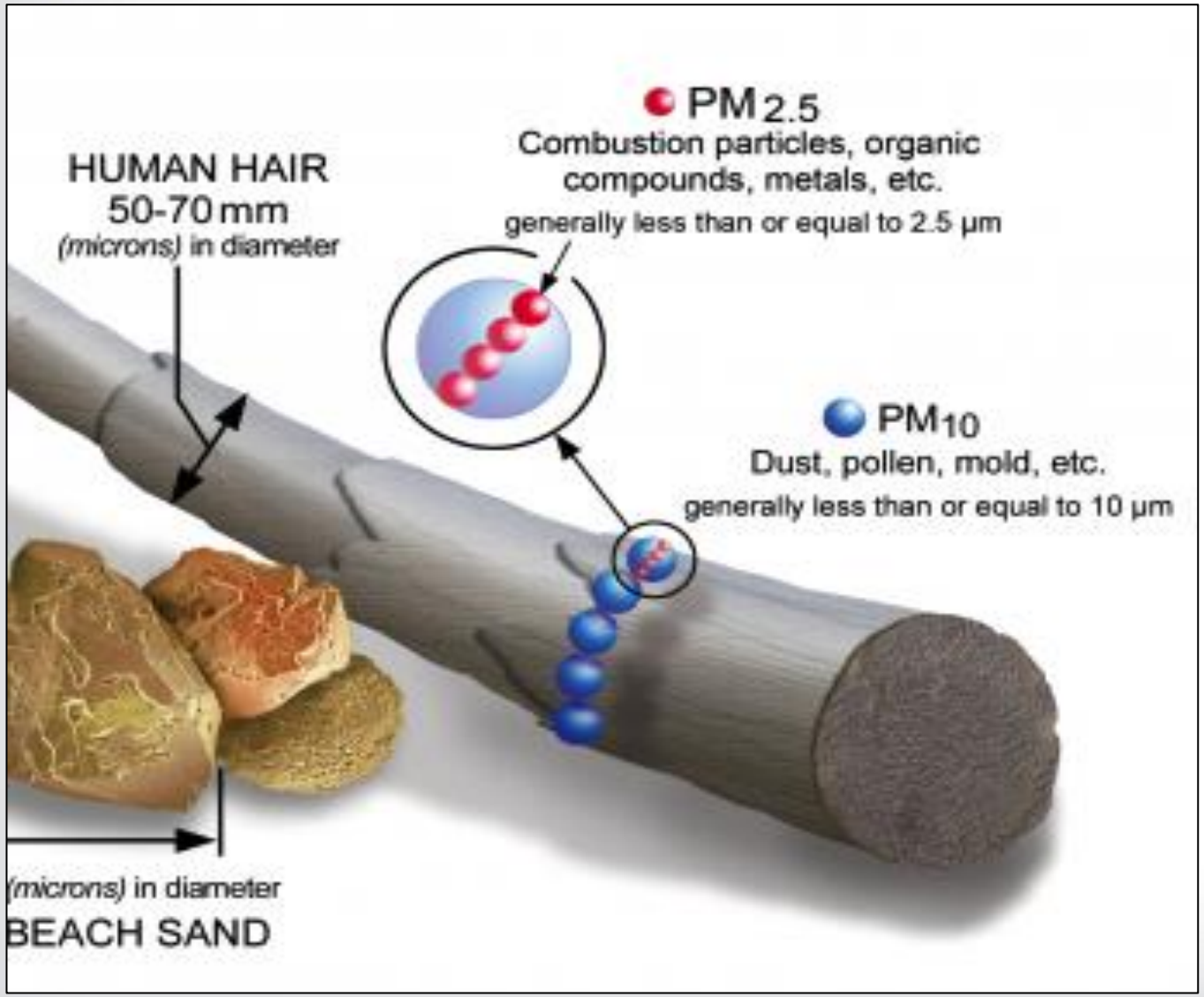
- **Primary air pollutants**
  - **CO**
  - CO_2
  - **SO_2**
  - **Suspended particles**
  - **Pb**
  - **NO_x**
  - VOCs
- **Secondary air pollutants**
  - **O_3**
  - SO_3
  - HNO_3
  - H_2SO_4
  - H_2O_2
  - SO_4 salts
  - PAH
  - Secondary organic aerosols

Air Pollution and Cardiovascular Disease

Usman Sagheer et al. JACC: Advances 3(2): 100805, 2024

Air Pollutant	Major Source	Putative Mechanism of CVD Effects
Particulate Matter (PM)	**Natural sources:** wildfires and sand dust storms; **Anthropogenic sources:** combustion of fossil fuel, transportation, and industrial processes	Localized pulmonary and **systemic inflammation**; **Endothelial dysfunction**; **Autonomic dysfunction**; Activation of prothrombic pathways; Hypothalamic-pituitary-adrenal axis activation
Ozone (O_3)	**Natural sources:** lightening **Anthropogenic sources:** photochemical reactions involving sunlight, NOx, VOCs - transportation & industrial processes	**Activation of inflammatory pathways**; **Endothelial dysfunction**; **Autonomic dysfunction**; **Oxidative stress**
Carbon Monoxide (CO)	**Natural sources:** wildfires and volcanic activity **Anthropogenic sources:** incomplete combustion of fossil fuel, industrial processes, and motor vehicles	**Systemic inflammation**; **Platelet activation;** Hypoxic injury; Free radical generation; Mitochondrial inhibition
Nitrogen dioxide (NO_2)	**Natural sources:** wildfires; **Anthropogenic sources:** motorized road traffic and fossil fuel-fired; power generation	**Activation of inflammatory pathways**; **Endothelial dysfunction** **Autonomic dysfunction**; **Oxidative stress**
Sulfur dioxide (SO_2)	**Natural sources:** volcanic activity **Anthropogenic sources:** coal-fired power plants, burning of heavy fuel oil in shipping, and petroleum processing	**Activation of inflammatory pathways**; **Endothelial dysfunction** **Autonomic dysfunction**; **Oxidative stress**; Impaired respiratory function
Lead (Pb)	**Natural sources:** geochemical weathering & volcanic activity; **Anthropogenic sources:** lead-based paint, lead-acid battery manufacturing, combustion of leaded gasoline	**Activation of inflammatory pathways**; **Endothelial dysfunction** **Oxidative stress**; Disruption of calcium signaling; Interference with heme synthesis

What is Airborne Particulate Matter?

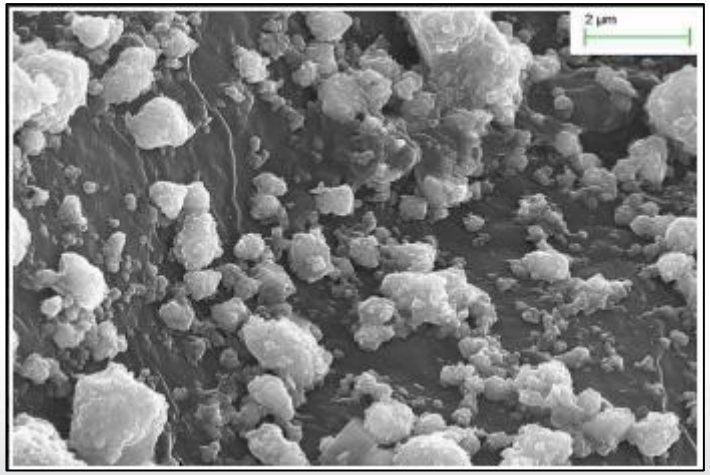


Particulate Matter (PM) – "soot"

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

National Ambient Air Quality Standards (NAAQS)

- 35 µg/m^3 24-hour average
- 9 µg/m^3 Annual average

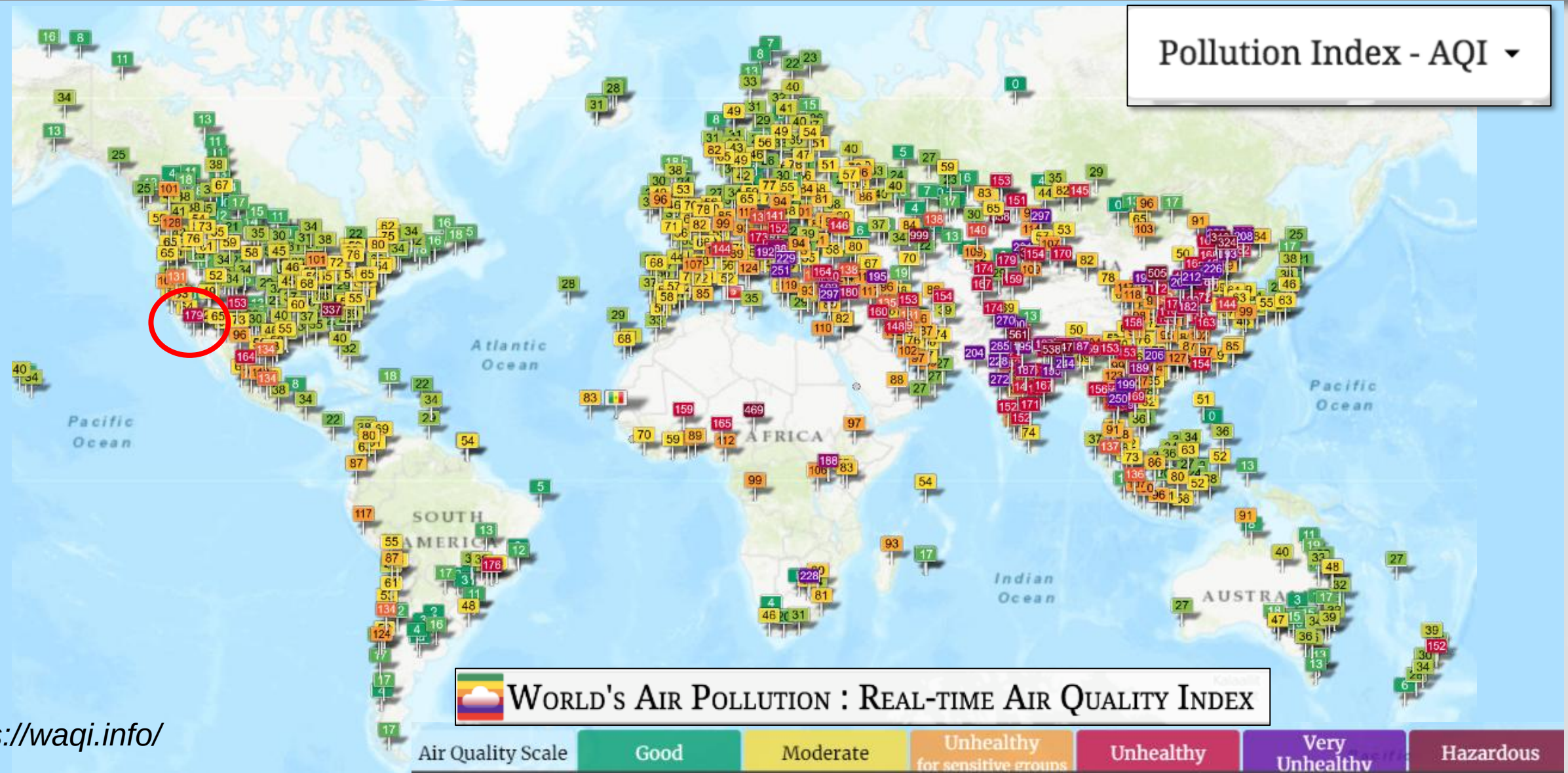


MacKenzie AR. Environ. Sci. Technol. 2012

What is the Spatiotemporal Distribution and Scale of Exposure to Ambient Air Pollution?

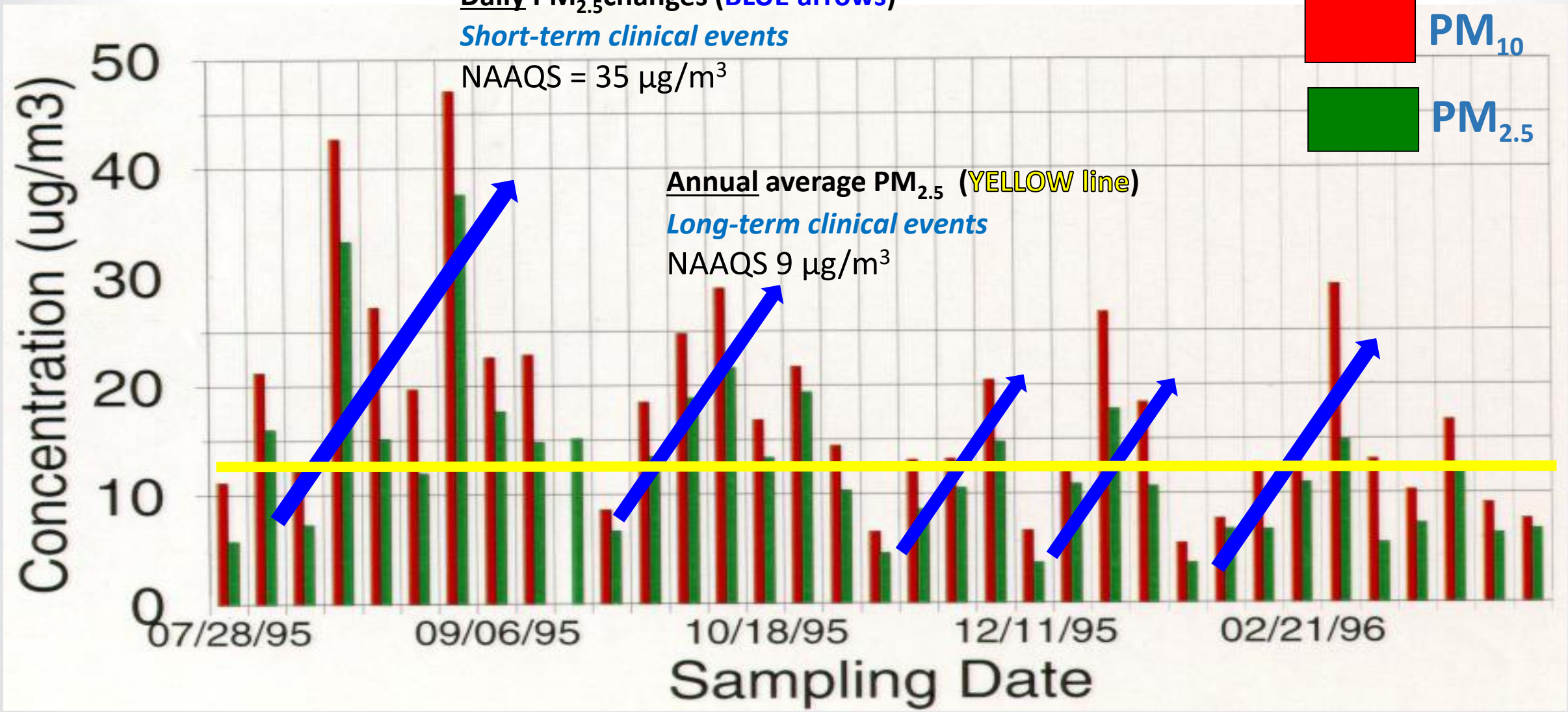
International Air Quality Measures

January 25, 2025



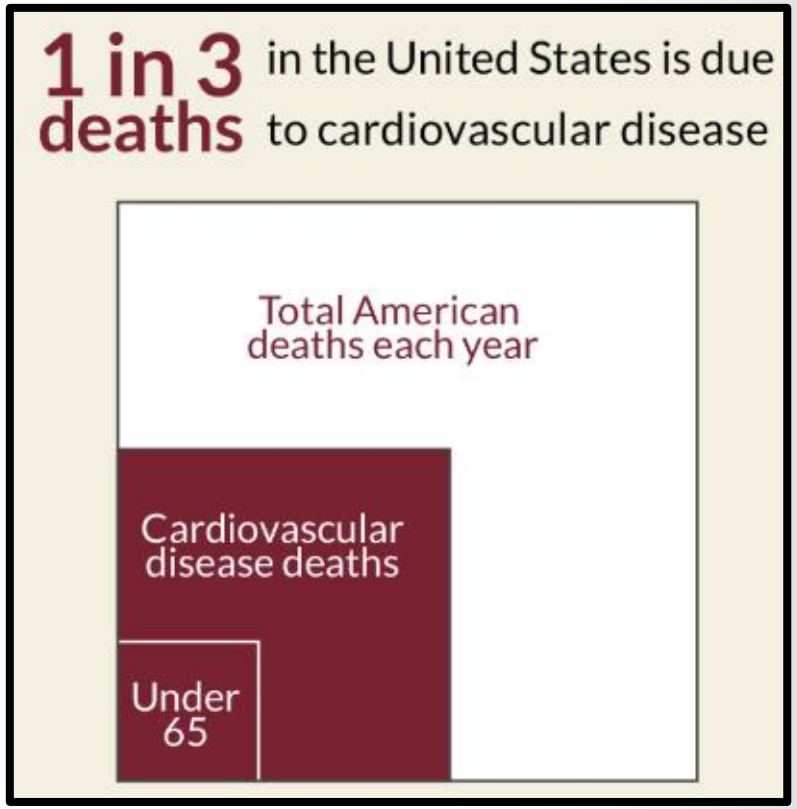
https://waqi.info/

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



Air Pollution & Cardiopulmonary Outcomes

- **Myocardial infarction, ischemic heart disease, heart failure and COPD increase the risk of hospitalization and mortality.**
- Short-term and long-term exposures to ambient PM are are associated with hospitalization and mortality in patients with ischemic heart disease, heart failure and COPD.
- Cardiopulmonary Rehabilitation reduces hospitalization and mortality rates and improves quality of life.
- *Should Cardiac and Pulmonary Rehabilitation Programs incorporate into their curriculum guidance instructing patients to reduce exposure to poor air quality – namely PM and ozone? And, what about other environmental stressors?*



https://millionhearts.hhs.gov/learn-prevent/cost-consequences.html

Air Pollution Cardiopulmonary Outcomes

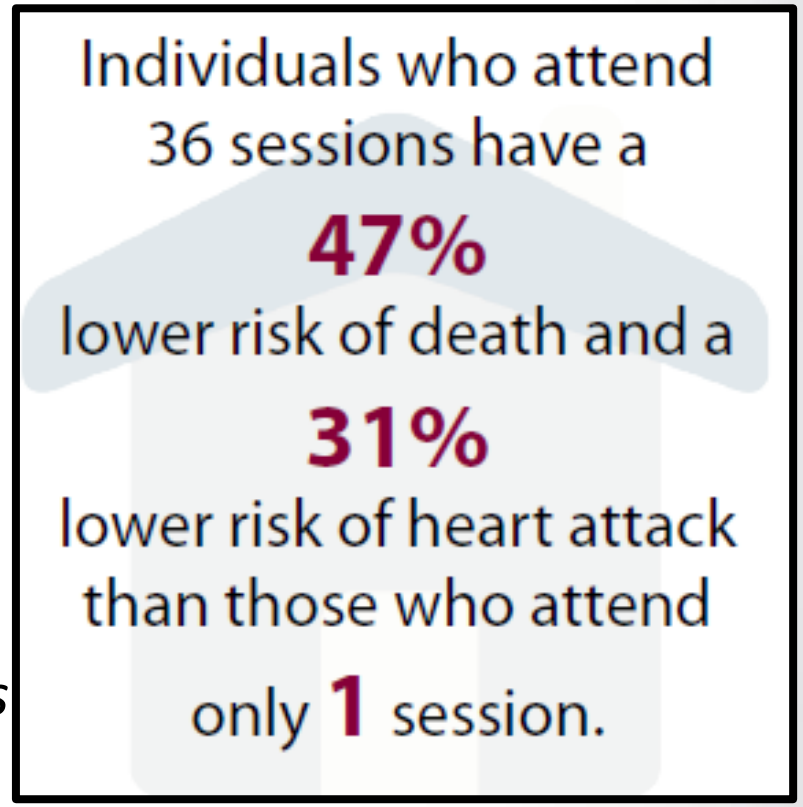
- Myocardial infarction, ischemic heart disease, heart failure and COPD increase the risk of hospitalization and mortality.
- **Short-term and long-term exposures to ambient PM are associated with hospitalization and mortality in patients with ischemic heart disease, heart failure & COPD.**
- Cardiopulmonary Rehabilitation reduces hospitalization and mortality rates and improves quality of life.
- *Should Cardiac and Pulmonary Rehabilitation Programs incorporate into their curriculum guidance instructing patients to reduce exposure to poor air quality – namely particulate matter and ozone? And, what about other environmental stressors?*

Weinhold B. *EHP* 112:15, 2004

Cardiac and Pulmonary Rehabilitation

Restoring Health and Preventing Disease Progression

- Myocardial infarction, ischemic heart disease, heart failure and COPD increase the risk of hospitalization and mortality.
- Short-term and long-term exposures to ambient PM are associated with hospitalization and mortality in patients with ischemic heart disease, heart failure and COPD.
- **Cardiopulmonary Rehabilitation reduces hospitalization and mortality rates and improves quality of life.**
- *Should Cardiac and Pulmonary Rehabilitation Programs incorporate into their curriculum guidance instructing patients to reduce exposure to poor air quality – namely particulate matter and ozone? And, what about other environmental stressors?*



millionhearts.hhs.gov

Cardiac and Pulmonary Rehabilitation

Restoring Health and Preventing Disease Progression

- Myocardial infarction, ischemic heart disease, heart failure and COPD increase the risk of hospitalization and mortality.
- Short-term and long-term exposures to ambient PM are associated with hospitalization and mortality in patients with ischemic heart disease, heart failure and COPD.
- Cardiopulmonary Rehabilitation reduces hospitalization and mortality rates and improves quality of life.
- ***Should Cardiac and Pulmonary Rehabilitation Programs incorporate into their curriculum guidance instructing patients to reduce exposure to poor air quality – namely particulate matter and ozone? And, what about other environmental stressors?***

Air Quality Health Risk Communication and Cardiac Rehabilitation

Group	Summary of Findings
Patient	Patients reported a high volume of learning during cardiac rehabilitation and with virtually no emphasis or integration of air quality content. Patients who participated in this study were open to the idea of using a device like a portable air purifier to reduce their exposure to air pollution.
Non-Physician Provider	Non-physician healthcare providers assume other roles in addition to healthcare provider ranging from educator, counselor, friend and coach. Individuals in this group indicated air pollution was a topic currently not commonly discussed with cardiac rehabilitation patients.
Physician	Physicians who participated in this study indicated a relatively limited awareness of recent research describing the connection between air pollution and adverse cardiovascular health outcomes. Integration of air pollution related health risk messaging into cardiac care routines. Additional education for providers on the physiological mechanisms underlying the risk, as well as health benefits of reducing exposure my facilitate integrating that information into patient interactions.

Hano MC, et al. ***Illuminating Stakeholder Perspectives at the Intersection of Air Quality Health Risk Communication and Cardiac Rehabilitation*** *Int. J. Environ. Res. Public Health* **2019**, *16*(19), 3603; https://doi.org/10.3390/ijerph16193603

What are the Health Effects of Particulate Matter Exposure?

Foundational Science 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 Particle 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; Murray A. Mittleman, MD, DrPH, FAHA; Annette Peters, PhD; David Siscovick, MD, MPH, FAHA;

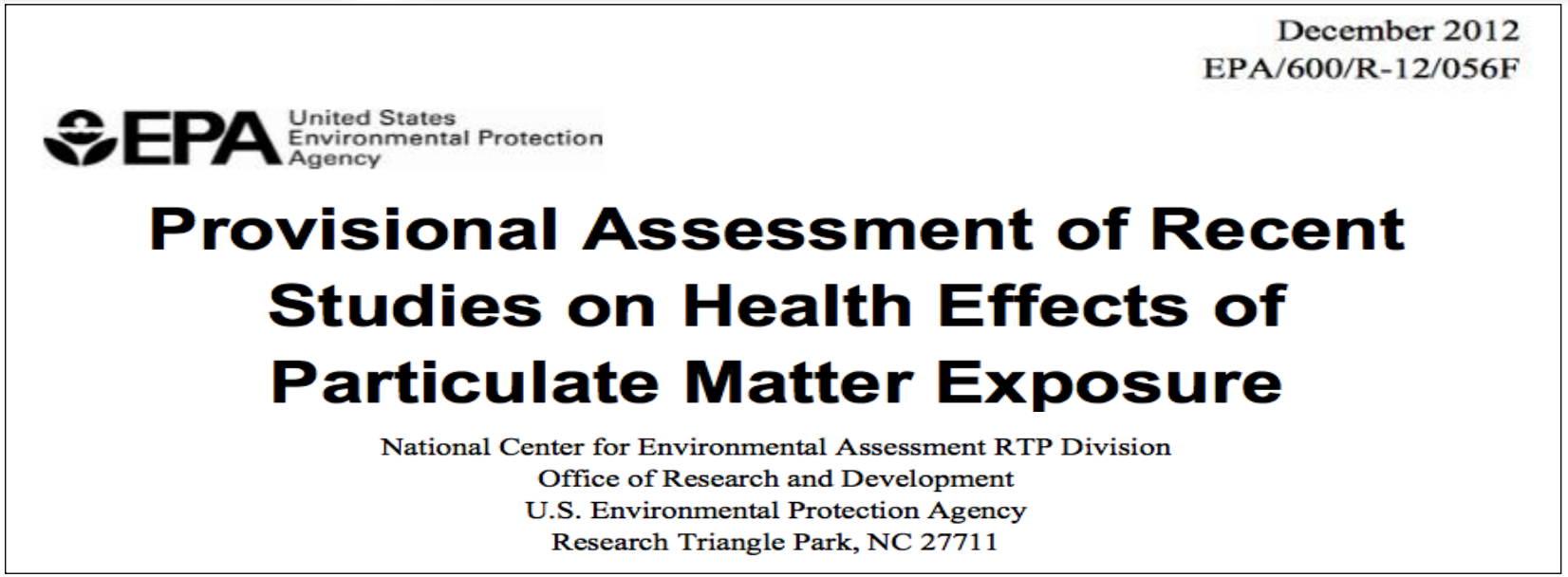
Fine particulate matter (PM) or particle pollution can:

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

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

Brook RD, et al. Circulation 2010

Long-term Air Particle 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 the cardiovascular health by complying with ambient air quality standards

Call for Public Health & Healthcare Action

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

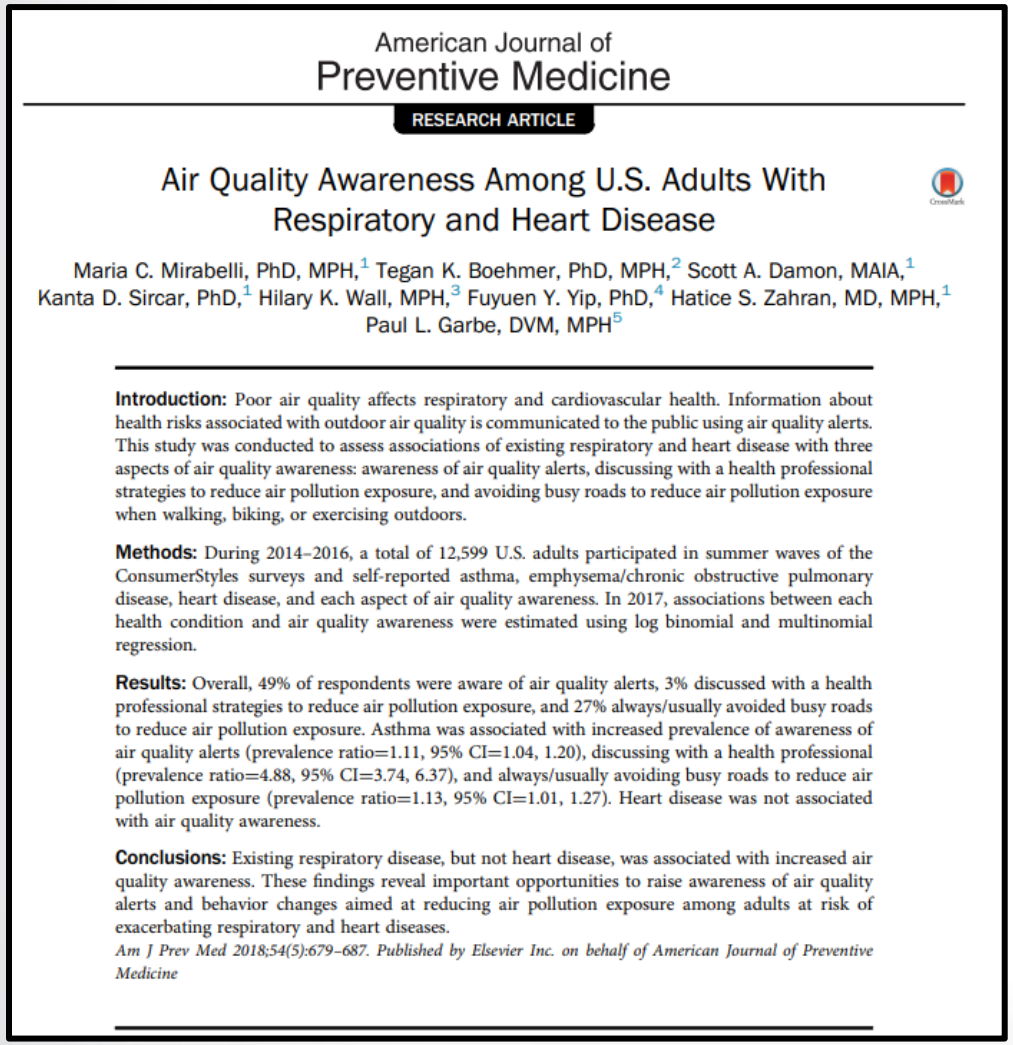
David E. Newby[1], Pier M. Mannucci[2], Grethe S. Tell[3], Andrea A. Baccarelli[4], Robert D. Brook[5], Ken Donaldson[6], Francesco Forastiere[7], Massimo Franchini[8], Oscar H. Franco[9], Ian Graham[10], Gerard Hoek[11], Barbara Hoffmann[12], Marc F. Hoylaerts[13], Nino Künzli[14,15], Nicholas Mills[1], Juha Pekkanen[16,17], Annette Peters[18,19], Massimo F. Piepoli[20], Sanjay Rajagopalan[21], and Robert F. Storey[22]*, 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."*

Newby DE et al. *Eur Heart J 2014*

Public Awareness of Air Quality's Health Effects



American Journal of
Preventive Medicine

RESEARCH ARTICLE

Air Quality Awareness Among U.S. Adults With Respiratory and Heart Disease

Maria C. Mirabelli, PhD, MPH,[1] Tegan K. Boehmer, PhD, MPH,[2] Scott A. Damon, MAIA,[1] Kanta D. Sircar, PhD,[1] Hilary K. Wall, MPH,[3] Fuyuen Y. Yip, PhD,[4] Hatice S. Zahran, MD, MPH,[1] Paul L. Garbe, DVM, MPH[5]

Introduction: Poor air quality affects respiratory and cardiovascular health. Information about health risks associated with outdoor air quality is communicated to the public using air quality alerts. This study was conducted to assess associations of existing respiratory and heart disease with three aspects of air quality awareness: awareness of air quality alerts, discussing with a health professional strategies to reduce air pollution exposure, and avoiding busy roads to reduce air pollution exposure when walking, biking, or exercising outdoors.

Methods: During 2014–2016, a total of 12,599 U.S. adults participated in summer waves of the ConsumerStyles surveys and self-reported asthma, emphysema/chronic obstructive pulmonary disease, heart disease, and each aspect of air quality awareness. In 2017, associations between each health condition and air quality awareness were estimated using log binomial and multinomial regression.

Results: Overall, 49% of respondents were aware of air quality alerts, 3% discussed with a health professional strategies to reduce air pollution exposure, and 27% always/usually avoided busy roads to reduce air pollution exposure. Asthma was associated with increased prevalence of awareness of air quality alerts (prevalence ratio=1.11, 95% CI=1.04, 1.20), discussing with a health professional (prevalence ratio=4.88, 95% CI=3.74, 6.37), and always/usually avoiding busy roads to reduce air pollution exposure (prevalence ratio=1.13, 95% CI=1.01, 1.27). Heart disease was not associated with air quality awareness.

Conclusions: Existing respiratory disease, but not heart disease, was associated with increased air quality awareness. These findings reveal important opportunities to raise awareness of air quality alerts and behavior changes aimed at reducing air pollution exposure among adults at risk of exacerbating respiratory and heart diseases.

Am J Prev Med 2018;54(5):679–687. Published by Elsevier Inc. on behalf of American Journal of Preventive Medicine

During 2014-2016, U.S. adults participated in the ConsumerStyles surveys & self-reported:
asthma, emphysema/COPD, heart disease, and each aspect of air quality awareness

- 49% were aware of air quality alerts, 3% discussed with a health professional air pollution exposure reduction strategies, and 27% always/usually avoided busy roads to reduce air pollution exposure.
- Asthma was associated with increased prevalence of awareness of air quality alerts, discussing with a health professional, and always/usually avoiding busy roads to reduce air pollution exposure.
- Heart disease was not associated with air quality awareness.

Mirabelli MC, et al. *Am J Prev Med.* 2018;54:679-687

Public Awareness of Air Quality's Health Effects is Increasing

Environmental Research 183 (2020) 109185

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Air Quality Index and air quality awareness among adults in the United States

Maria C. Mirabelli[a,*], Stefanie Ebelt[b], Scott A. Damon[a]

[a] Asthma and Community Health Branch, Division of Environmental Health Science and Practice, National Center for Environmental Health, Centers for Disease Control and Prevention, 4770 Buford Hwy NE, Mailstop S106-6, Atlanta, GA, 30341, USA

[b] Department of Environmental Health, Rollins School of Public Health, Emory University, 1518 Clifton Rd NE, Atlanta, GA, 30322, USA

ARTICLE INFO

Keywords:
Adults
Air quality
Behavior
Environmental health
Epidemiology

ABSTRACT

Background: Information about local air quality is reported across the United States using air quality alerts such as the Environmental Protection Agency's Air Quality Index. However, the role of such alerts in raising awareness of air quality is unknown. We conducted this study to evaluate associations between days with Air Quality Index ≥101, corresponding to a categorization of air quality as *unhealthy for sensitive groups, unhealthy, very unhealthy, or hazardous*, and air quality awareness among adults in the United States.

Methods: Data from 12,396 respondents to the 2016–2018 ConsumerStyles surveys were linked by geographic location and survey year to daily Air Quality Index data. We evaluated associations between the number of days in the past year with Air Quality Index ≥101 and responses to survey questions about awareness of air quality alerts, perception of air quality, and changes in behavior to reduce air pollution exposure using logistic regression.

Results: Awareness of air quality alerts (prevalence ratio [PR] = 1.23; 95% confidence interval [CI] = 1.15, 1.31), thinking/being informed air quality was bad (PR = 2.02; 95% CI = 1.81, 2.24), and changing behavior (PR = 2.27; 95% CI = 1.94, 2.67) were higher among respondents living in counties with ≥15 days with Air Quality Index ≥101 than those in counties with zero days in the past year with Air Quality Index ≥101. Each aspect of air quality awareness was higher among adults with than without asthma, but no differences were observed by heart disease status. Across quintiles of the number of days with Air Quality Index ≥101, air quality awareness increased among those with and without selected respiratory and cardiovascular diseases.

Conclusions: Among U.S. adults, air quality awareness increases with increasing days with alerts of unhealthy air. These findings improve our understanding of the extent to which air quality alerts prompt people to take actions to protect their health amidst poor air quality.

2016-2018 ConsumerStyles survey

- Air quality awareness was higher among adults with than without asthma.
- No differences were observed by heart disease status.
- Across quintiles of the number of days with Air Quality Index ≥101, air quality awareness increased among those with and without selected respiratory and cardiovascular diseases.

Mirabelli MC, et al. *Environ Res*. 2020;183:109185

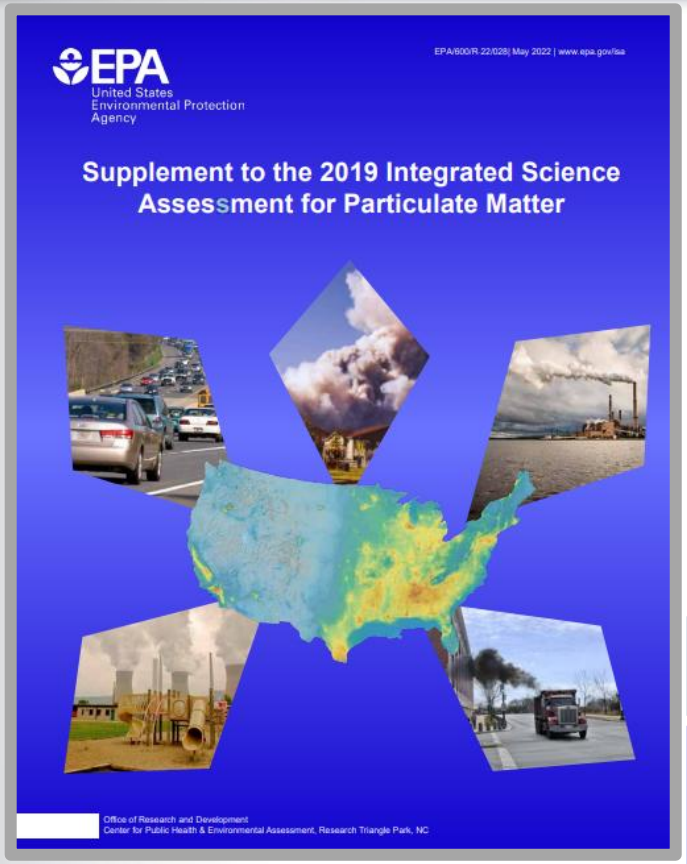
May-July 2022 ConsumerStyles survey and self-reported their heart disease status and perceptions, awareness, and behaviors about ambient air pollution and health

- 90% of U.S. adults reported that air pollution can impact a person's health.
- 44% reported that pollution can cause or worsen heart disease.
- Awareness that air pollution can cause or worsen heart disease was higher among adults with than without heart disease.

Dowling TC, et al. *AJPM Focus*. 2024;3(4):100249

Health Effects of $PM_{2.5}$ Exposure

US EPA PM Integrated Science Assessment 2019



U.S. EPA. Supplement to the 2019 Integrated Science Assessment for Particulate Matter (Final Report, 2022). EPA/635/R-22/028, 2022

Short-Term Exposure Effects

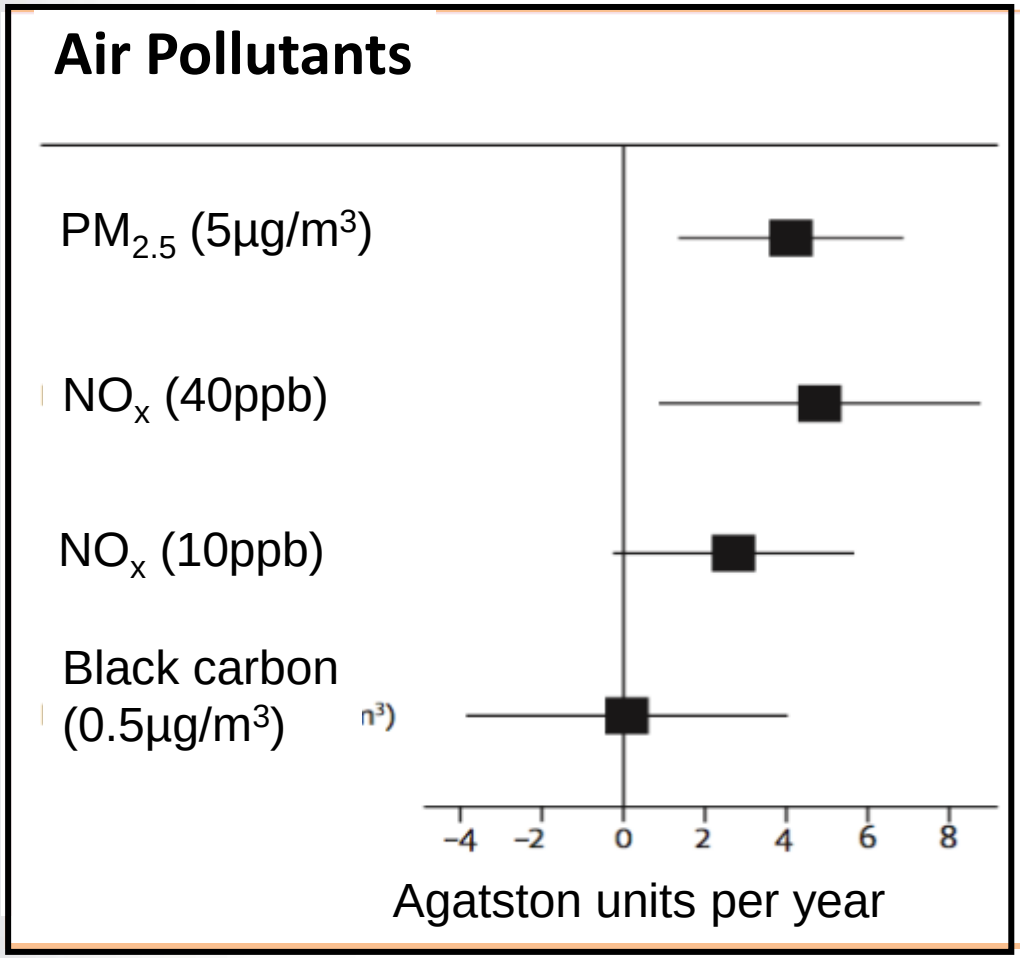
	Level of Certainty for Causality
• Respiratory	Likely Causal
• Cardiovascular	Causal
• Metabolic	Suggestive
• Mortality	Causal
• Reproductive & Developmental	
- Pregnancy/Birth Outcomes	Suggestive
- Reproduction/Fertility	Suggestive

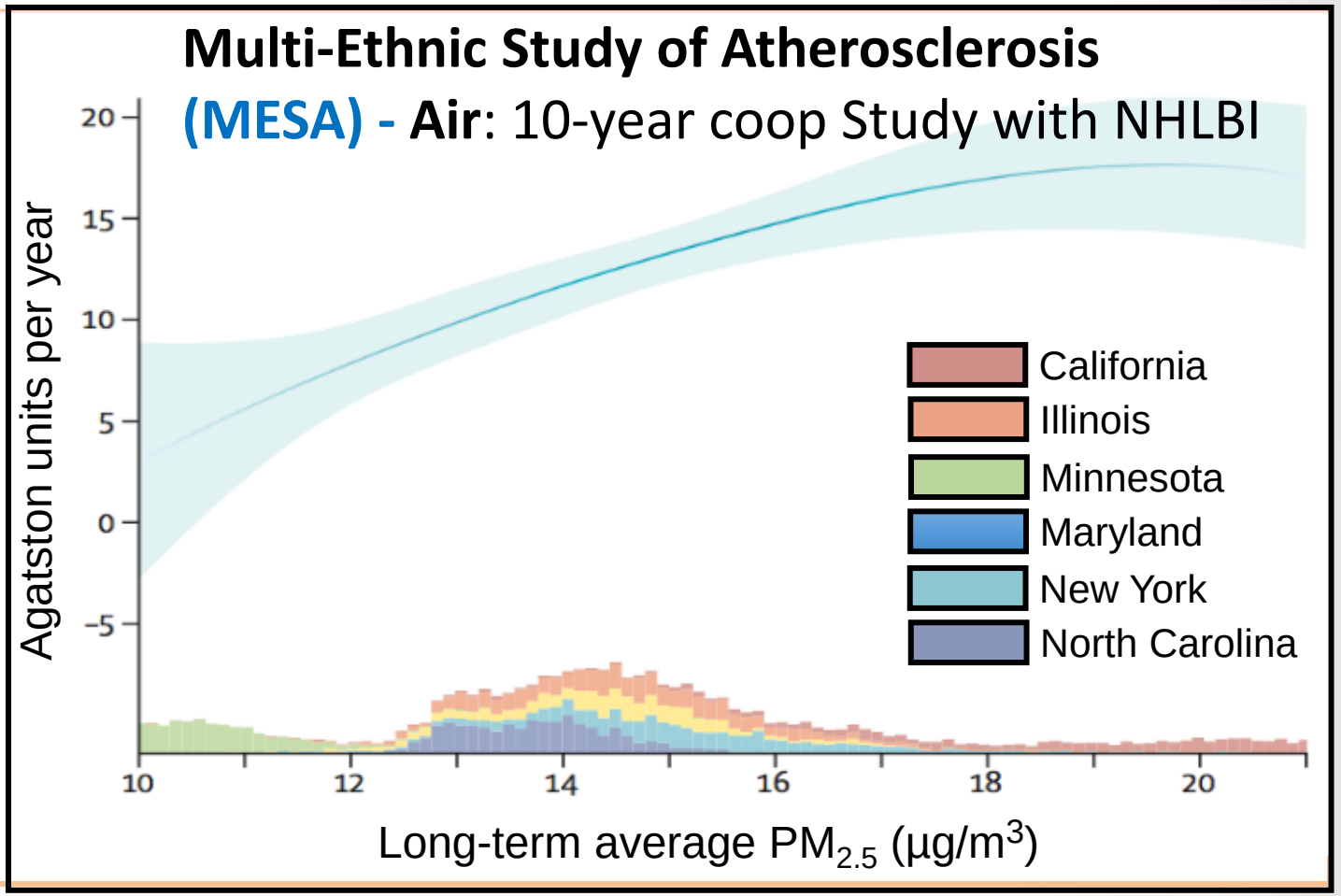
Long-Term Exposure Effects

• Respiratory	Likely Causal
• Cardiovascular	Causal
• Metabolic	Suggestive
• Neurological	Likely Causal
• Mortality	Causal
• Cancer	Likely Causal

Particulate Air Pollution Contributes to the Development of Chronic Cardiovascular Disease

Long-Term $PM_{2.5}$, NO_x & Black Carbon Exposure Increases Coronary Artery Calcium





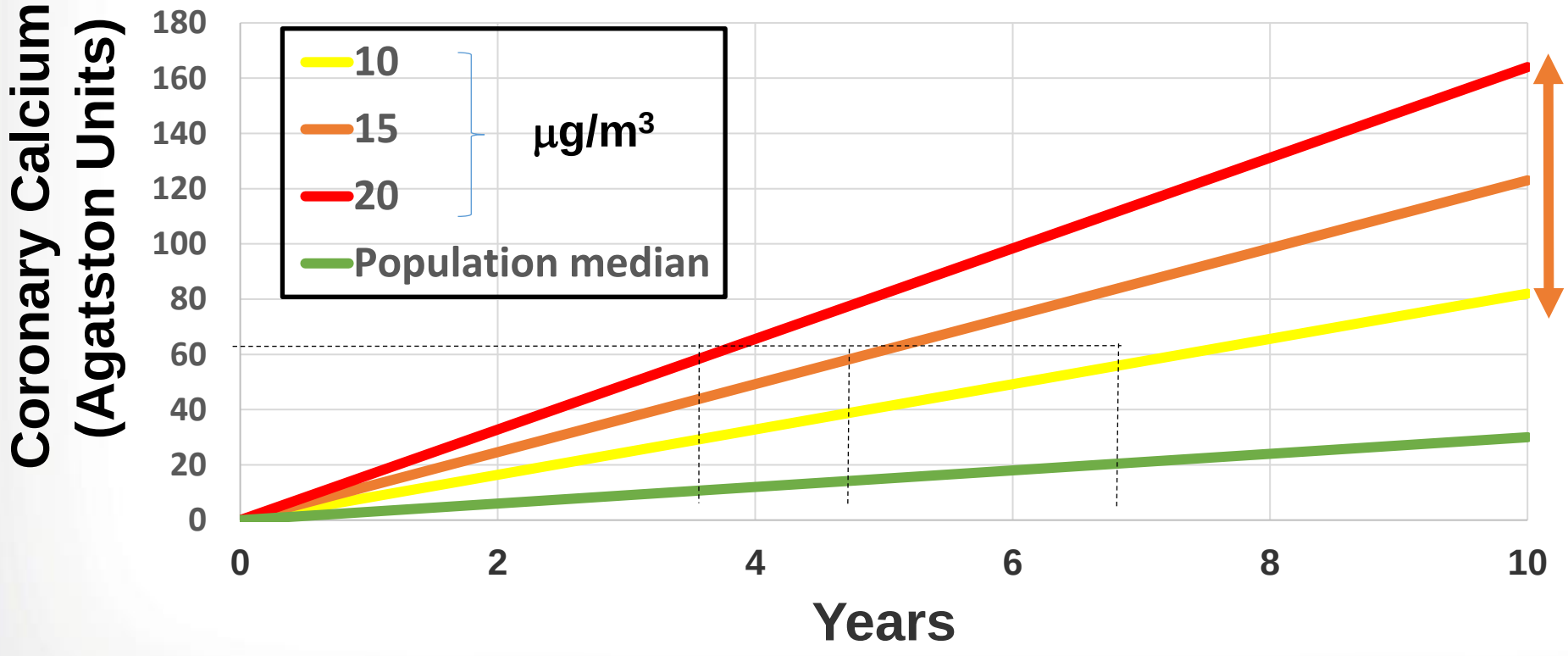
Long-term $PM_{2.5}$ and NO_x increased coronary calcium, an indictor of atherosclerosis

Kaufman JD et al. Lancet 2016

Long-Term $PM_{2.5}$ & NO_x Exposure
Associated with Atherosclerosis Progression

MESA Air Study

$PM_{2.5}$ 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

Poor Air Quality:

Age – accelerates epigenetic aging

Wang SN, et al. Ecotoxicol Environ Saf. 2024; Koenigsberg SH et al. Environ Int. 2023; Ward-Caviness et al. Octotarget 2016

Total Cholesterol – increases cholesterol

Shanley et al. Epidemiology 2016

HDL – decreases HDL particle number

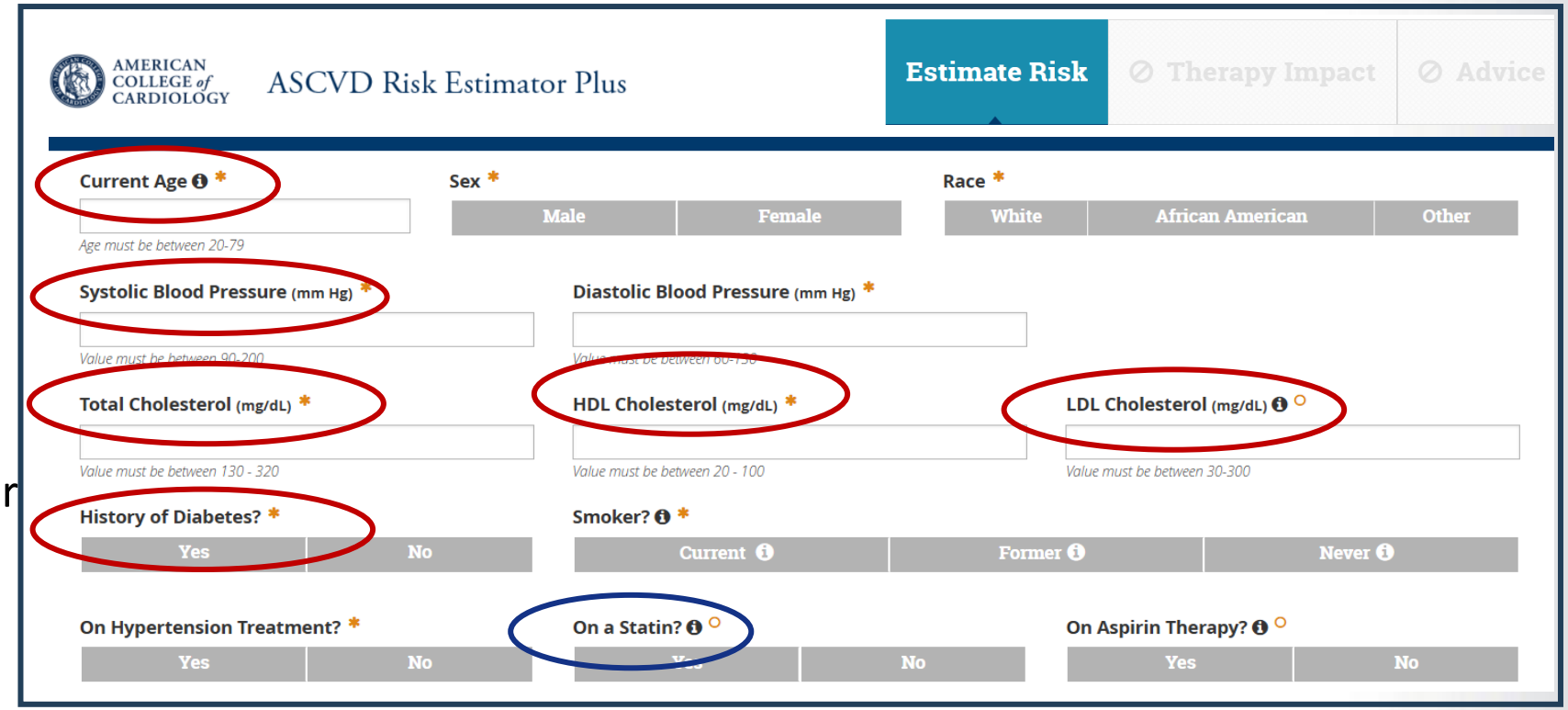
Bell et al. Arterioscler Thromb Vasc Biol 2017

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 and Beta-blocker Therapy – might be protective

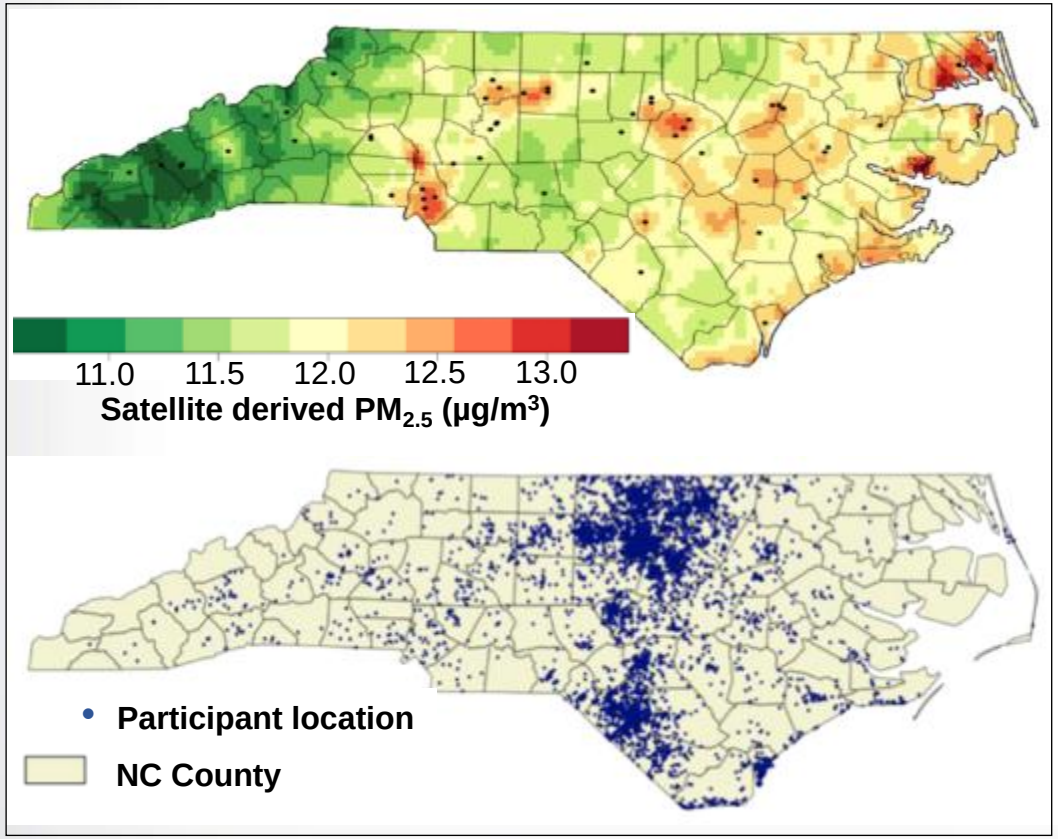
O'Neill et al. Occup Environ Med 2007; Alexeeff et al. Environ Health Perspect 2011

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

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

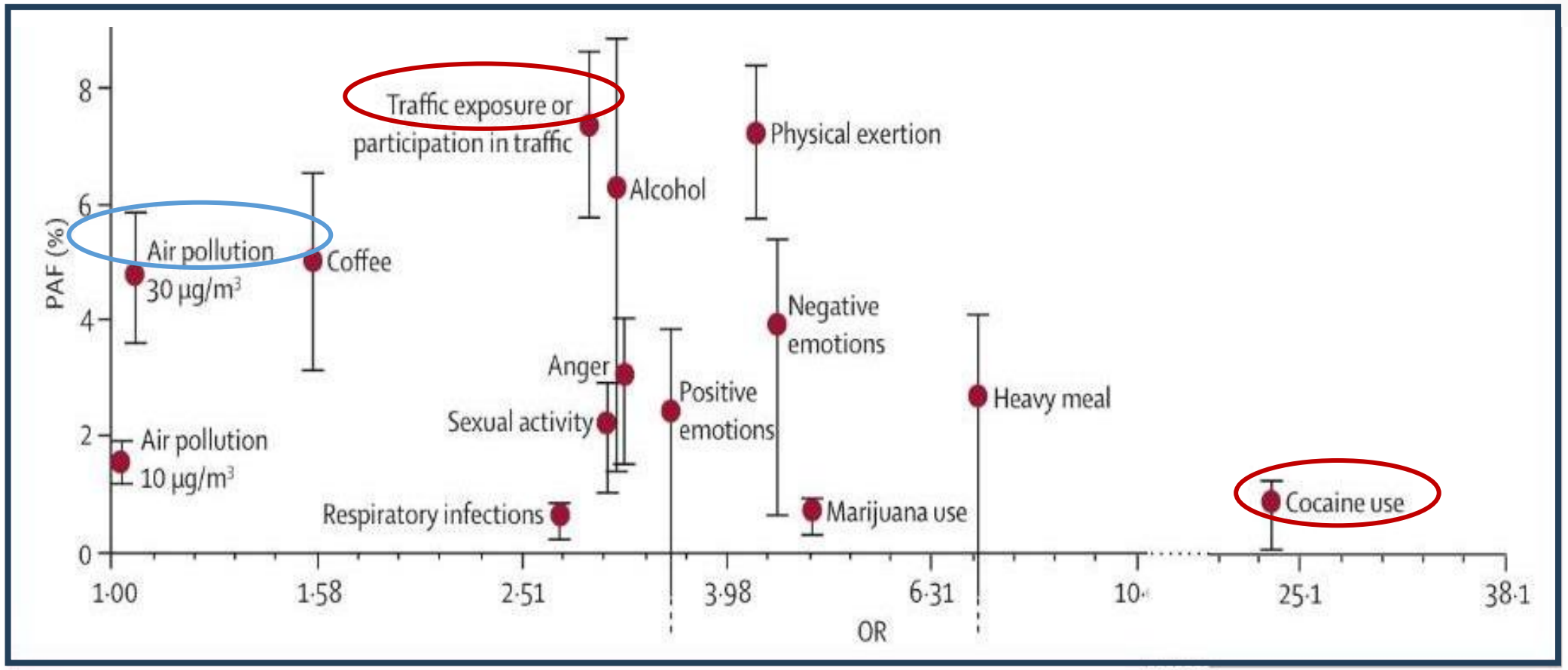
**Hartiala J, et al. J *Am Heart Assoc* 2016

$PM_{2.5}$ Pollution Triggers Heart Attacks

Lower exposure associated with lower risk

Population Attributable Fractions (PAF)

The strength of the association between exposure to a risk factor and the prevalence of this risk factor within the population



Modified from Nawrot et al. *Lancet* 2011

Who's at risk from exposure to particle pollution?

Populations at Greater Risk of $PM_{2.5}$-related Health Effects and Exposures

- **People having pre-existing heart or lung disease:** Compromised health status; triggering/exacerbation of effects leading to emergency department visits, hospital admissions, and even death

- **Older adults:** Higher prevalence of pre-existing lung and cardiovascular disease and decline of physiologic processes, such as defense mechanisms; increased risk of ED visits, hospital admissions, and mortality

- **People having low socioeconomic status (SES):** Includes income, education, or occupation, plays a role in access to healthy environments as well as access to healthcare; less access to measures to reduce exposures, higher likelihood of untreated/insufficiently treated conditions; increased risk ED visits, hospital admissions, and even death

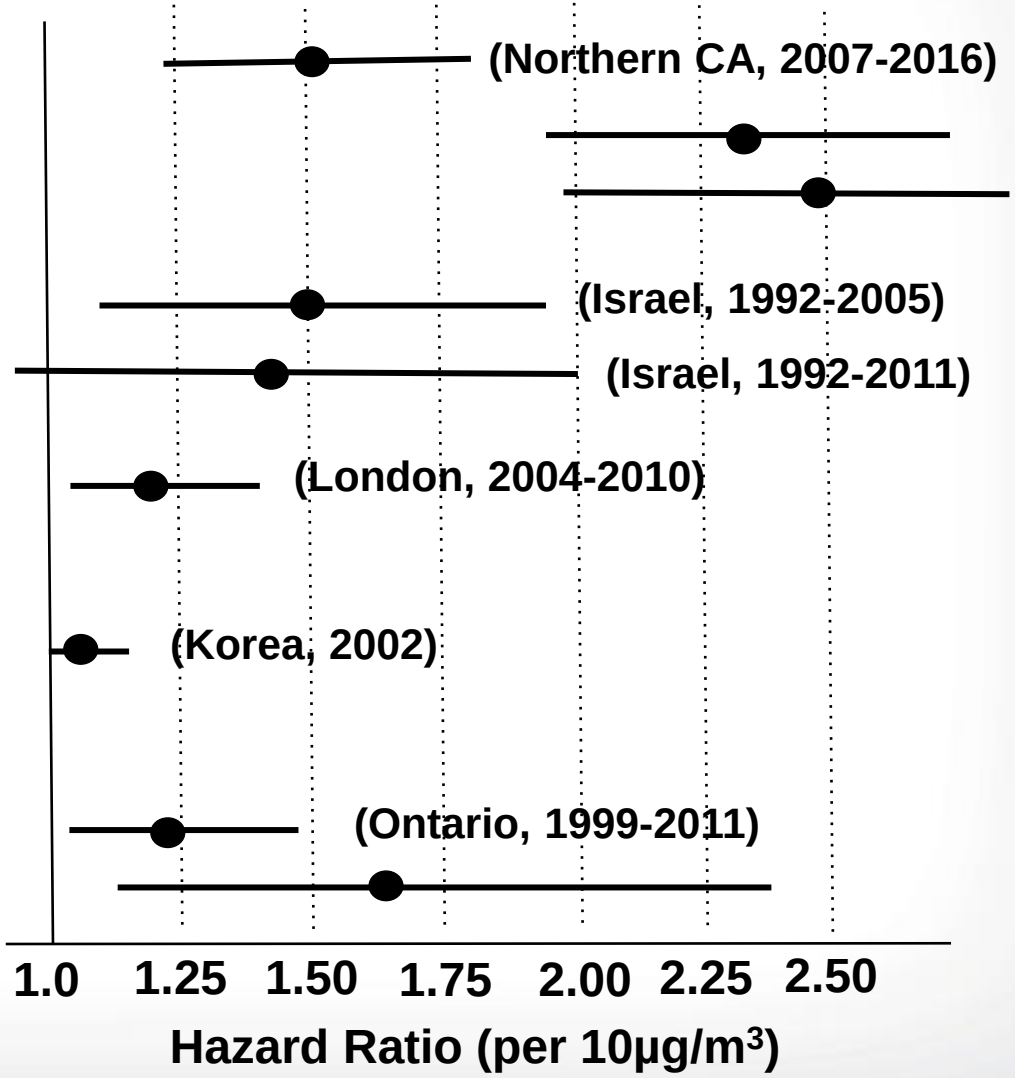
- **Children:** More time spent outdoors, vigorous activity, and inhalation of more air per pound of body weight compared to adults; increased risk of respiratory-related effects due to short-term exposures and impairments in lung function growth and asthma development due to long-term exposures

Source: U.S. EPA (2019). PM ISA.

Air Pollution and Morbidity & Mortality

Effect of Annual $PM_{2.5}$ on Post-MI Survival & Clinical Events

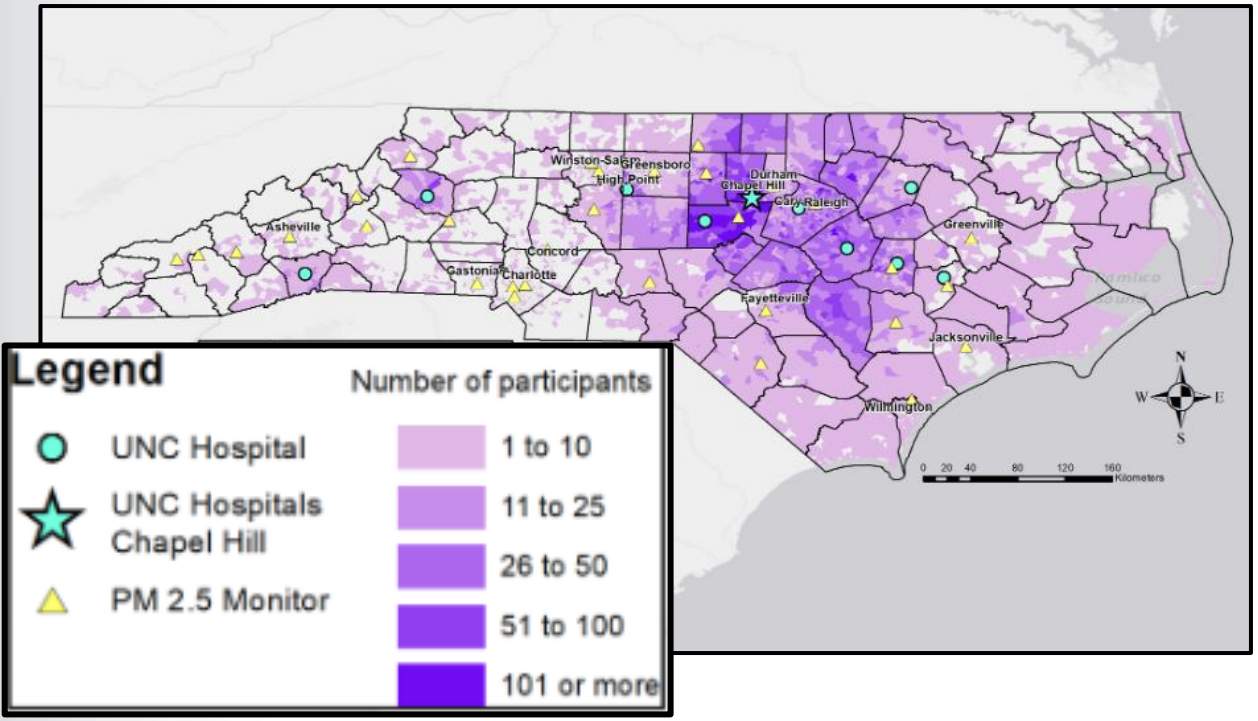
Liao et al. *J Am Heart Assoc 2021*	Acute MI CVD Mortality IHD Mortality	(Northern CA, 2007-2016)
Koton *et al.* *Prev Med* 2013	MI, CHF, Stroke, Mortality	(Israel, 1992-2005) (Israel, 1992-2011)
Tonne et al. *Eur Heart J* 2013	Mortality	(London, 2004-2010)
Kim et al. *J Cardiol* 2020	Mortality	(Korea, 2002)
Chen et al. *EHP* 2016 *Environ Health Perspect 2016*	Mortality MI Mortality	(Ontario, 1999-2011)



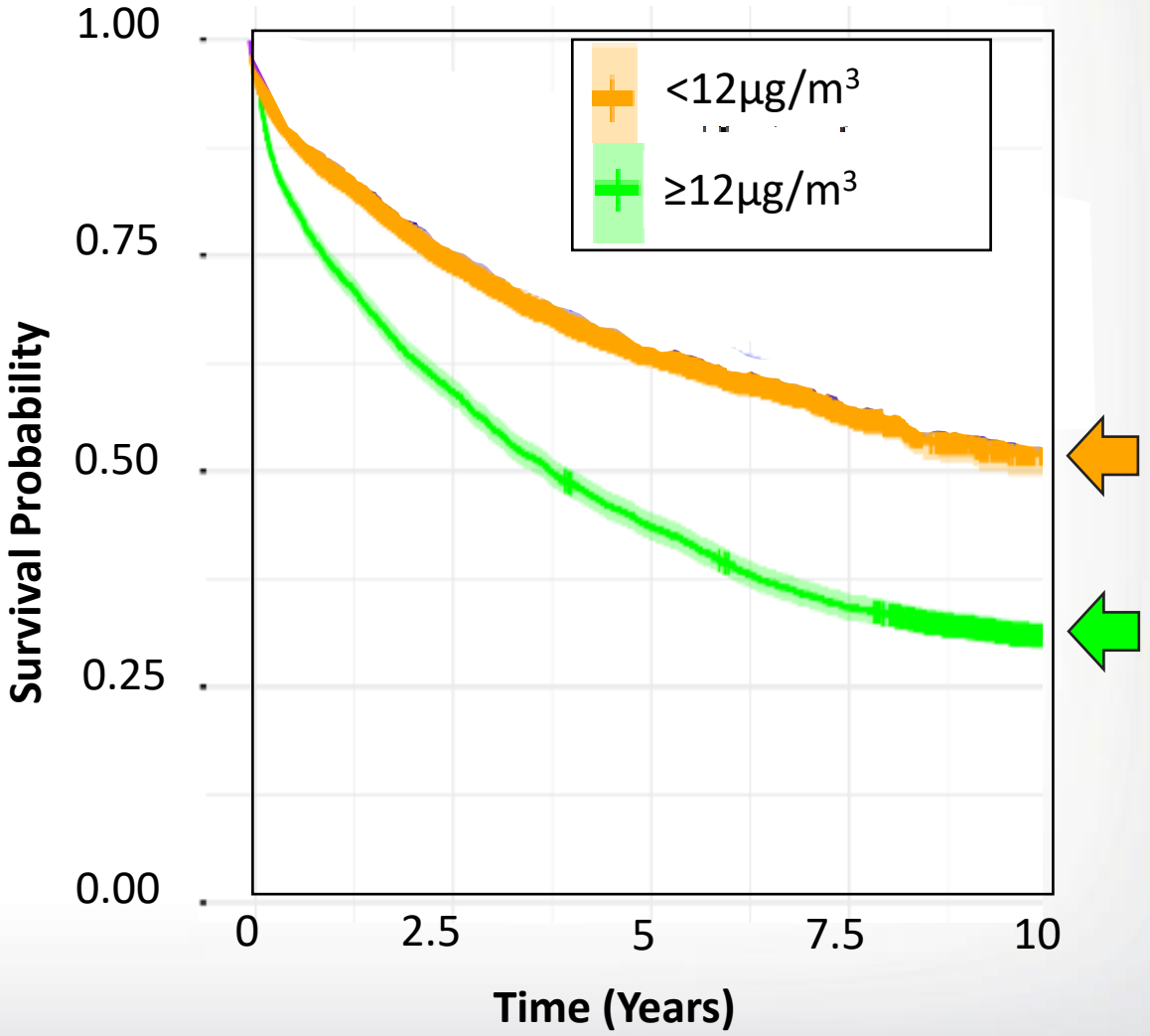
Conclusion: Long-term PM exposure worsens Post-MI outcomes

Air Pollution and Heart Failure Mortality
Association with Age & Annual $PM_{2.5}$

Heart Failure Patient in CARES Cohort



$PM_{2.5}$ by HF Diagnosis Age ≥ 65 years

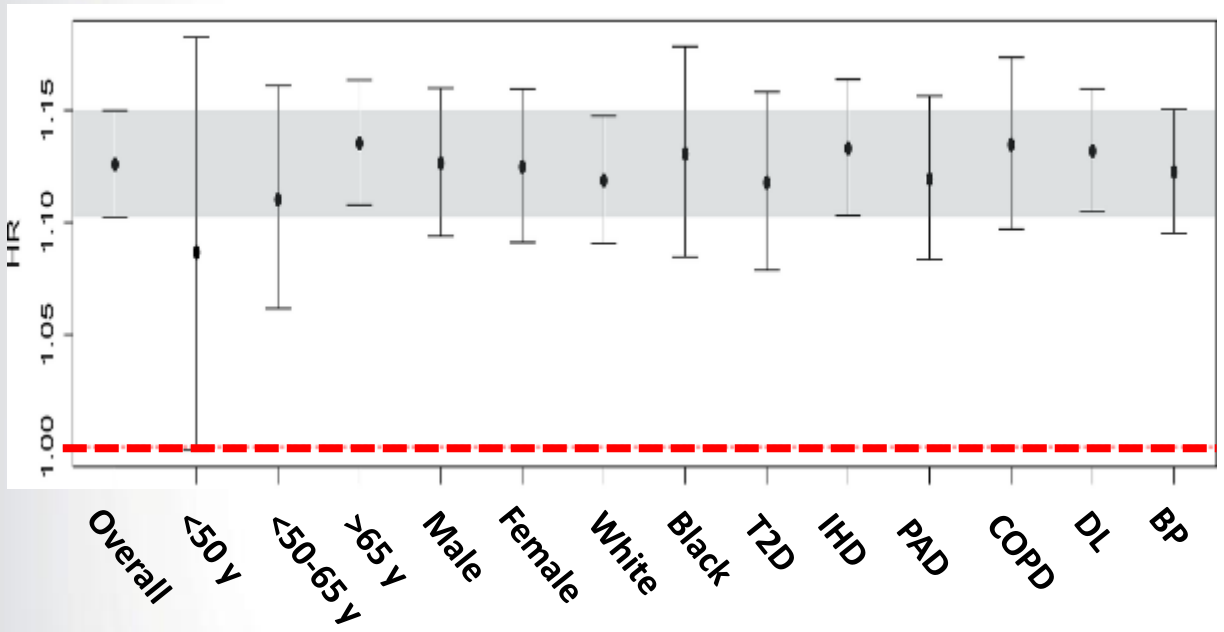


UNC-affiliated hospitals (blue circles) with the flagship hospital, located in Chapel Hill, NC, given as a blue star. EPA $PM_{2.5}$ monitors are represented as yellow triangles

Mortality and Rehospitalization with HF
Association with Long-term Exposure to $PM_{2.5}$

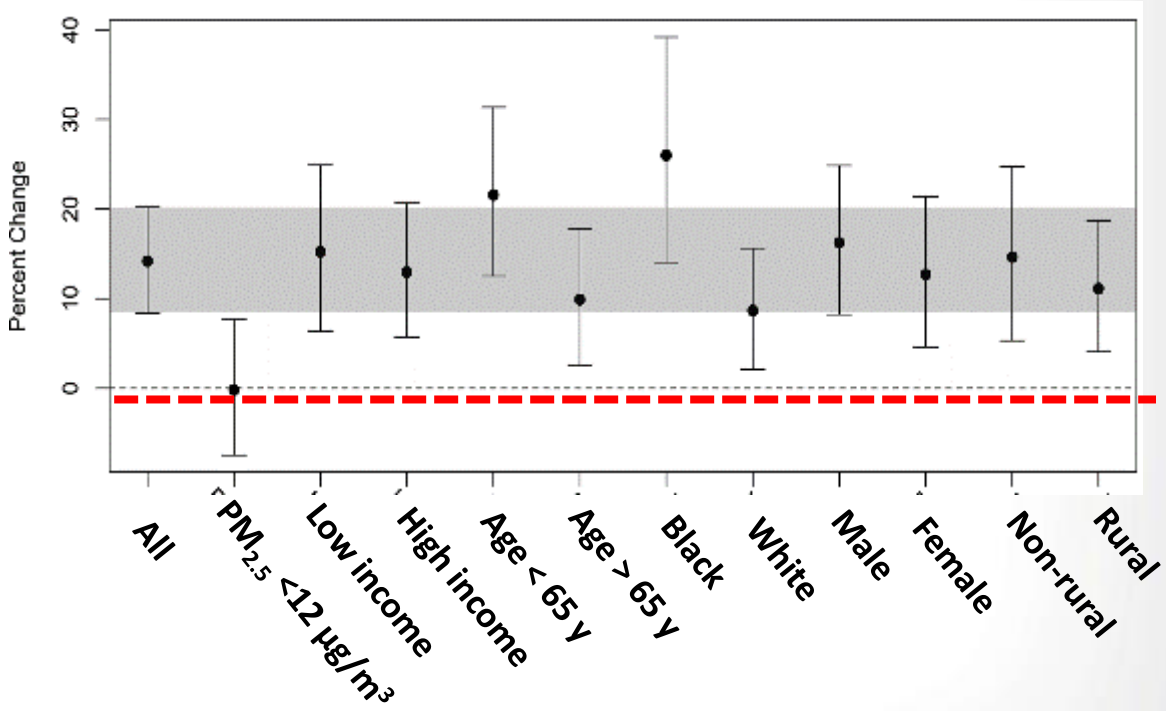
Associations Between Long-term $PM_{2.5}$ Exposure, Mortality and Readmissions in Heart Failure Patients

$PM_{2.5}$ Exposure and Mortality



Ward-Caviness CK, et al. *J Am Heart Assoc.* 2020 Mar 17;9(6):e012517.

$PM_{2.5}$ Exposure and 30-day Readmission



Ward-Caviness CK, et al. *J Am Heart Assoc.* 2021 May 18;10(10):e019430.

Healthy Heart & Million Hearts®

Total Population Community-Wide Prevention

PM NAAQS
24-hour Std:
35 µg/m³

Annual Standard
12 µg/m³

Innovative Clinical Prevention

Healthy Heart
A healthier environment for healthier hearts

Million Hearts®

Traditional Clinical Prevention

RCT supported "evidence-based" clinical prevention management strategies

Public Health ⟷ **Health Care**

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

EPA

Million Hearts®

Search the site

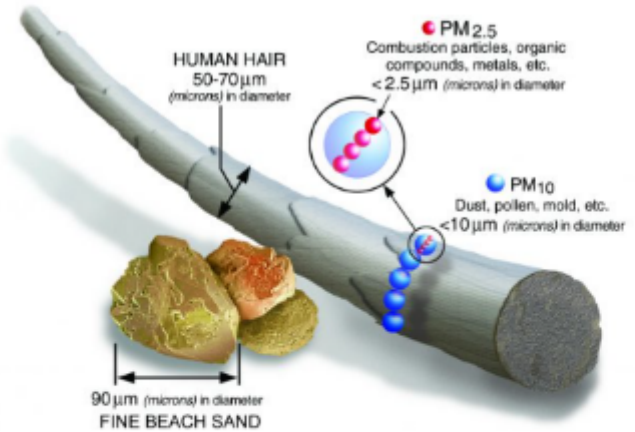
Home | About | Tools & Protocols | Data & Reports | Partners & Progress | Learn & Prevent

Home > About Million Hearts® 2027 > Building Healthy Communities

- 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.[1] 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.[2]



About Particle Pollution

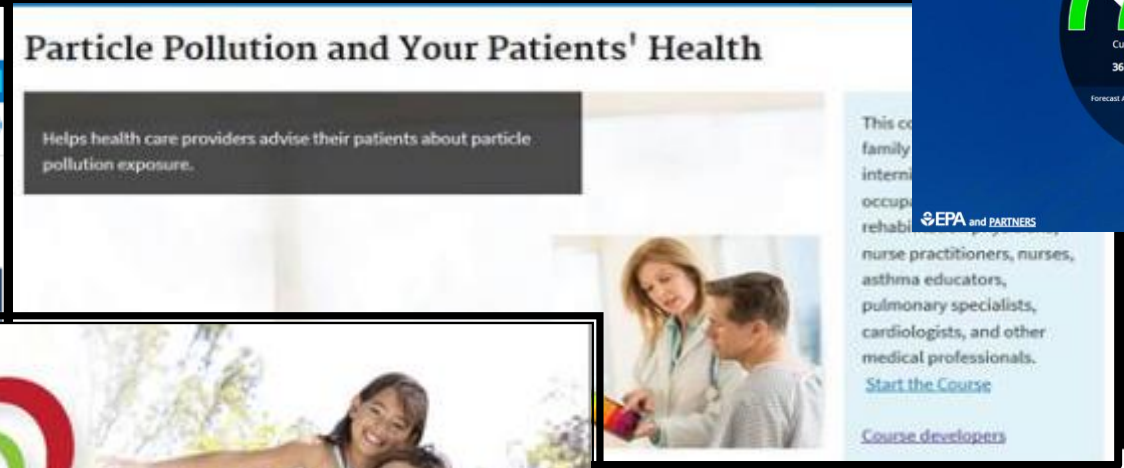
Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are

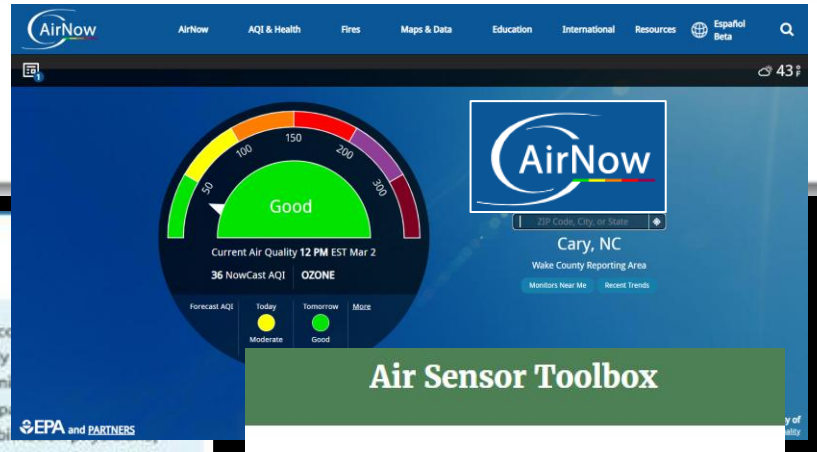
PM10 is inhalable particles with

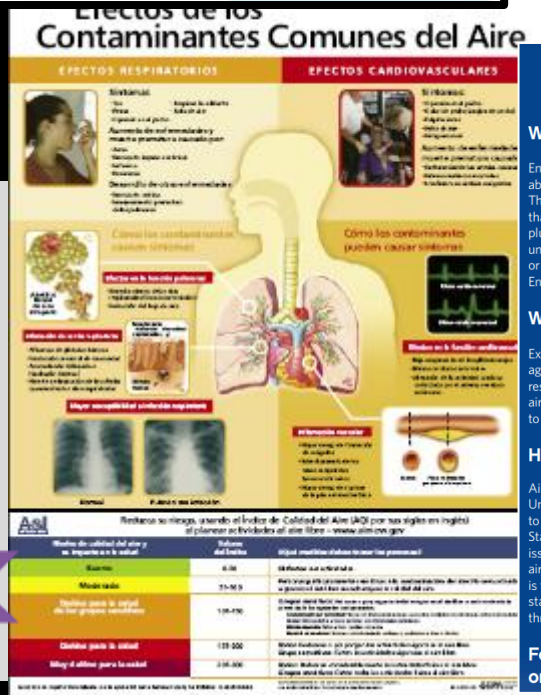
https://millionhearts.hhs.gov/about-million-hearts/building-communities/particle-pollution.html

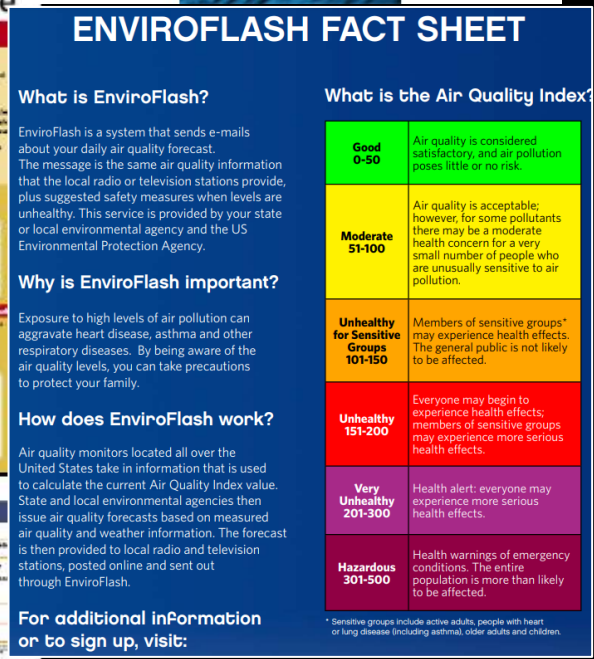
Engaging the Public

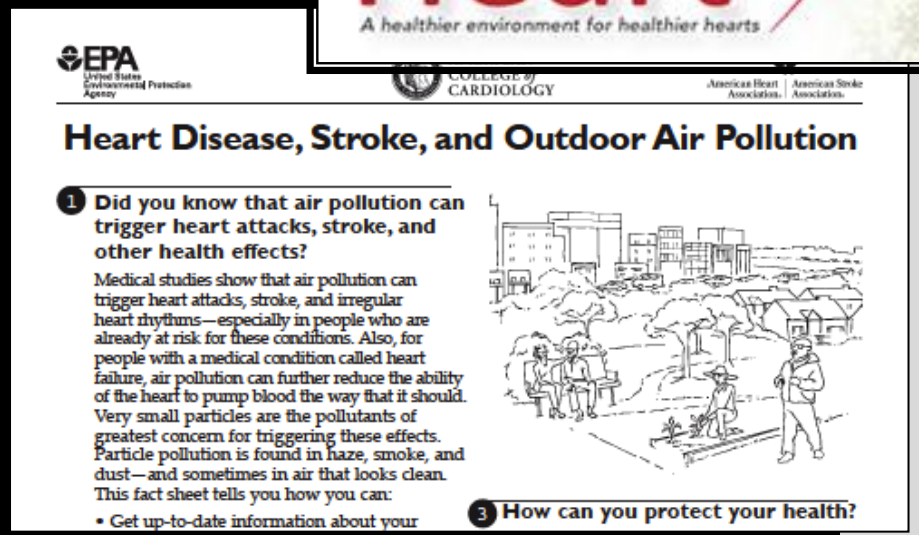
Examples of EPA Products











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 website and 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

EPA's Healthy Heart Program

Increasing Environmental Health Literacy

EPA United States Environmental Protection Agency

Search EPA.gov

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

Air Research

- Air Monitoring & Emissions
- Air Quality Modeling
- Wildland Fires
- Health Effects from Air Pollution
- Air & Energy
- Outreach, Tools & Resources

Contact Us About Air Research

Healthy Heart Toolkit and Research

Heart Facts

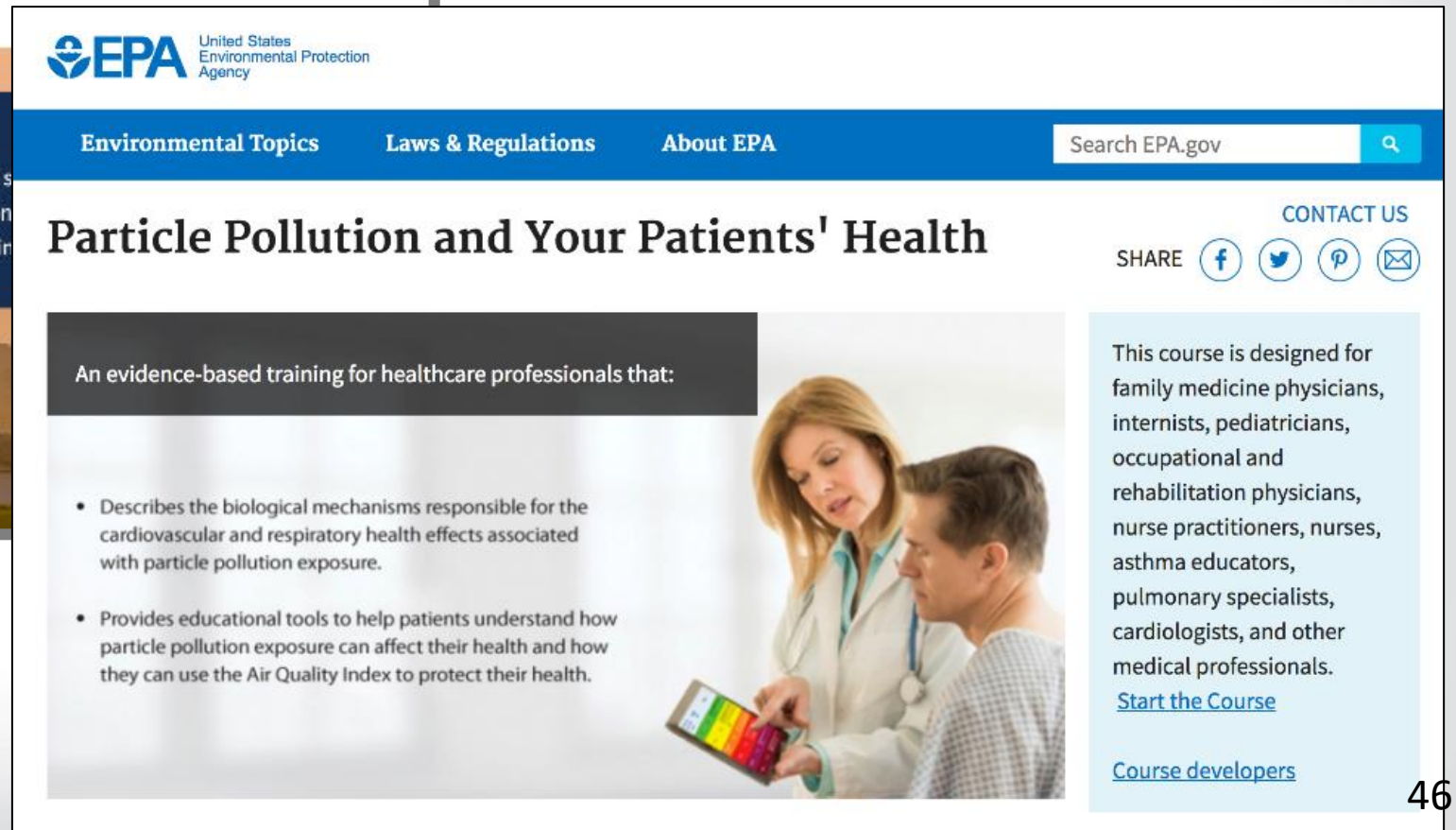
- Heart disease and stroke are the first and fourth leading causes of death in the U.S.
- Air pollution can affect heart health and can trigger heart attacks and strokes that cause disability and death in those predisposed.
- One in three American adults has heart or blood vessel disease and is at higher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

EPA is raising awareness of heart disease and its link to air pollution and other environmental factors as a partner in Million Hearts, a national initiative to prevent heart attacks and strokes.

CME for Health Care Professionals

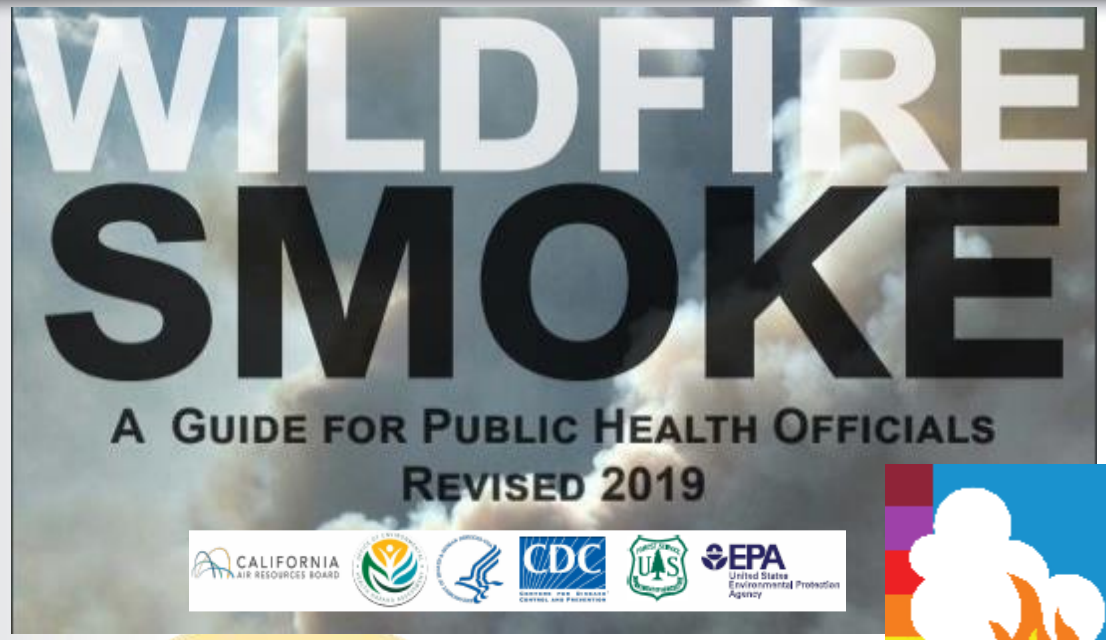
Particle Pollution and Your Patients' Health

https://www.epa.gov/ozone-pollution-and-your-patients-health



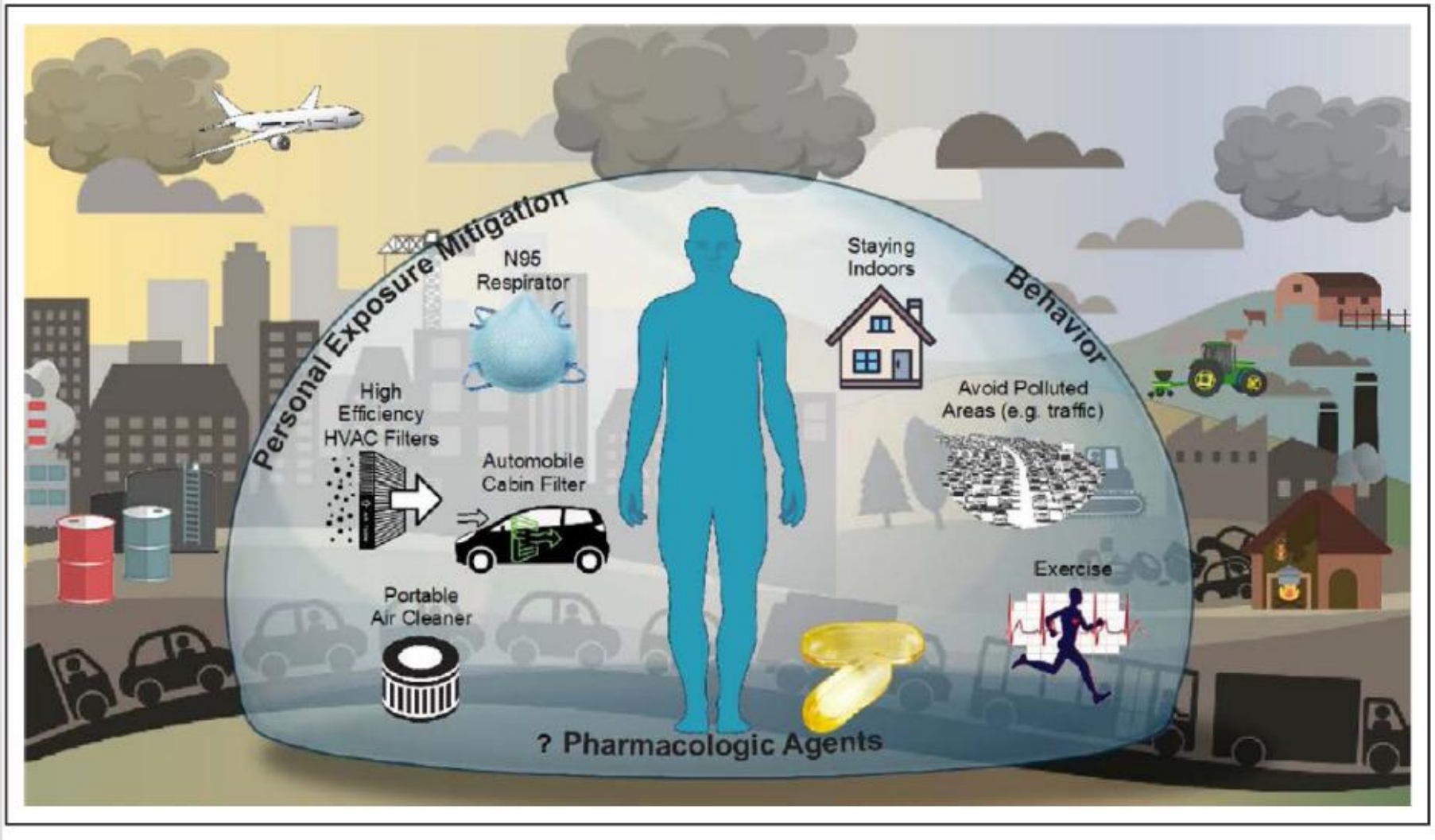
www.epa.gov/particle-pollution-and-your-patients-health

Public Awareness of Wildland Fire Smoke



- **Public health outreach**: helping the public understand how fires impact their health, including providing real-time information during fire events.
  - AirNow- Fire and Smoke Map
  - https://www.airnow.gov/publications/wildfire-smoke-guide/wildfire-smoke-a-guide-for-public-health-officials/
  - Smoke Ready Communities
  - Wildfire Emissions, Wildland Fire Effects | Chemical Insights WUI
- **Preparedness resources**
  - Clean Air Spaces
  - Respirator Use
  - DIY Air Cleaners: https://www.epa.gov/air-research/research-diy-air-cleaners-reduce-wildfire-smoke-indoors
  - evaluation
- **Information Clearinghouse**: Smoke Ready Toolbox
- **Continuing Medical Education (CME) Courses**
  - Particle Pollution and Your Patients' Health
  - Wildfire Smoke and Your Patients' Health

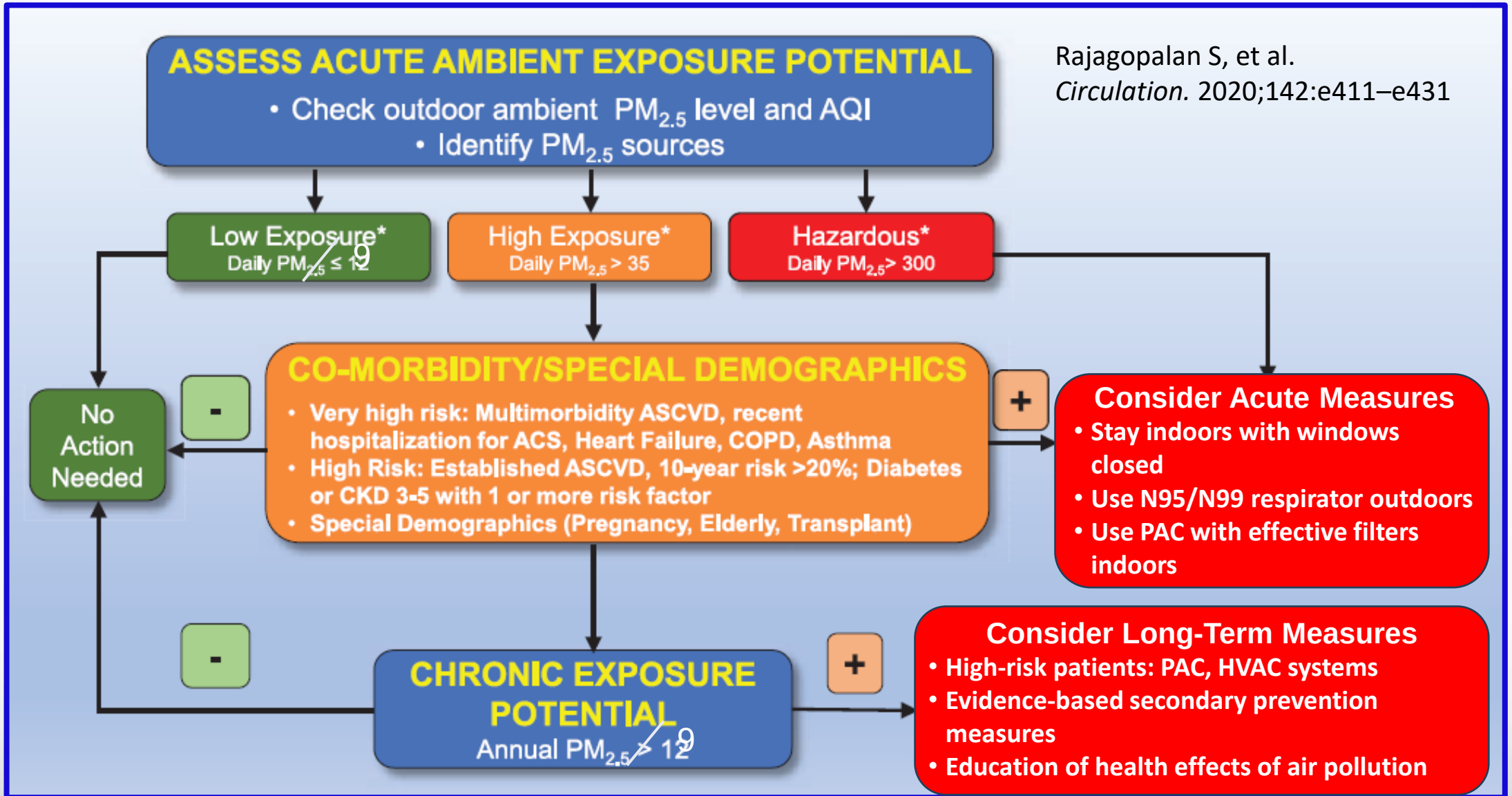
Individual Exposure Mitigation Strategies



- **Personal Exposure Mitigation**
  - Portable air cleaners
  - N95/N99 respirators
  - High efficiency HVAC filters
  - Automobile cabin filter
- **Behavior**
  - Staying indoors
  - Avoid polluted areas (e.g. traffic)
  - Exercise
- **Pharmacological Agents**

Rajagopalan S, et al. *Circulation.* 2020;142:e411–e431.

Potential Clinical Approach to Determine if Personal-Level Interventions are Needed



Rajagopalan S, et al.
Circulation. 2020;142:e411–e431

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**
- **Few at-risk patients take action to reduce exposure**
- **Cardiopulmonary rehabilitation professionals have an opportunity to educate their patients about the risks and mitigations strategies to limit exposure and protect health**

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

Email: cascio.wayne@epa.gov

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