A Green AQI Means "Healthy" ...or Does it?

Good 0-50
Moderate 51-100
Unhealthy for Sensitive Groups 101-150
Unhealthy 151-200
Very Unhealthy 201-300
Hazardous 301-500

Baylor College of Medicine

Winifred ("Winnie") J. Hamilton, PhD, SM (Emerita)
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Regional Air Quality Planning Advisory Committee (RAQPAC) Meeting
Houston, TX , June 27, 2024

Setting the Stage

- PM and O3 responsible for ~8.43M deaths every year
- 5.13M of the 8.43M (61%) attributable to fossil fuel use
- Causes of death
  - - CM conditions 52%
  - - COPD 16%
  - - Other 16% (e.g., HTN)
  - - Stroke 16%
- ~ 62% of these deaths from PM2.5
- *Annual* air pollution-attributable deaths > cumulative COVID deaths to date (WHO)


RESEARCH

OPEN ACCESS

Check for updates

Air pollution deaths attributable to fossil fuels: observational and modelling study

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ABSTRACT

OBJECTIVES

To estimate all cause and cause specific deaths that are attributable to fossil fuel related air pollution and to assess potential health benefits from policies that replace fossil fuels with clean, renewable energy sources.

DESIGN

Observational and modelling study.

METHODS

An updated atmospheric composition model, a newly developed relative risk model, and satellite based data were used to determine exposure to ambient air pollution, estimate all cause and disease specific mortality, and attribute them to emission categories.

DATA SOURCES

Data from the global burden of disease 2019 study, observational fine particulate matter and population data from National Aeronautics and Space Administration (NASA) satellites, and atmospheric chemistry, aerosol, and relative risk modelling for 2019.

RESULTS

Globally, all cause excess deaths due to fine particulate and ozone air pollution are estimated at 8.34 million (95% confidence interval 5.63 to 11.19) deaths per year. Most (52%) of the mortality burden is related to cardiometabolic conditions, particularly ischaemic heart disease (30%). Stroke and chronic obstructive pulmonary disease both account for 16% of mortality burden. About 20% of all cause mortality is undefined, with arterial hypertension and neurodegenerative diseases possibly implicated. An estimated 5.13 million (3.63 to 6.32) excess deaths per year globally are attributable to ambient air pollution from fossil fuel use and therefore could potentially be avoided by phasing out fossil fuels. This figure corresponds to 82% of the maximum number of air pollution deaths that could be averted by controlling all anthropogenic emissions. Smaller reductions, rather than a complete phase-out, indicate that the responses are not strongly non-linear. Reductions in emission related to fossil fuels at all levels of air pollution can decrease the number of attributable deaths substantially. Estimates of avoidable excess deaths are markedly higher in this study than most previous studies for these reasons: the new relative risk model has implications for high income (largely fossil fuel intensive) countries and for low and middle income countries where the use of fossil fuels is increasing; this study accounts for all cause mortality in addition to disease specific mortality; and the large reduction in air pollution from a fossil fuel phase-out can greatly reduce exposure.

CONCLUSIONS

Phasing out fossil fuels is deemed to be an effective intervention to improve health and save lives as part the United Nations' goal of climate neutrality by 2050. Ambient air pollution would no longer be a leading, environmental health risk factor if the use of fossil fuels were superseded by equitable access to clean sources of renewable energy.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Ambient air pollution is the leading environmental health risk factor for morbidity and mortality

Estimates of the attributable mortality burden differ substantially between studies, primarily due to differences in the exposure-response associations and the causes of death included

Few global studies attributed mortality to specific air pollution sources; their results differ widely

WHAT THIS STUDY ADDS

A new relative risk model optimises the exposure-response association throughout the global range of ambient exposure levels

Estimates of cause specific and all cause mortality from long term exposure to particulate matter with a diameter of <2.5 μm and ozone are attributed to pollution sources

Major reductions in air pollution emissions, notably through a phase-out of fossil fuels, could have large, positive health outcomes

Results show that the mortality burden attributable to air pollution from fossil fuel use is higher than most previous estimates

Introduction

Global air quality guidelines from World Health Organization (WHO) call attention to the huge toll of air pollution on human health, leading to millions of deaths yearly, comparable to tobacco smoking.[1] The 2019 global burden of disease (GBD) study estimated that all forms of air pollution account for about 11.3% of total deaths worldwide for women and 12.2% for men.[2] Improvements to air quality contribute to many of the United Nations' sustainable development goals for 2030, and air pollution is directly mentioned in two targets to achieve these goals.[3 4] Previous studies have suggested that transitioning from fossil fuels to clean, renewable energy sources in the coming decades will help save many lives from air pollution and limit the global mean temperature rise caused by greenhouse gases to below 2°C, thereby meeting the Paris Climate Agreement.[5-7] However, mortality estimates attributable to air pollution and the causes of death vary widely, with few studies estimating the mortality burden from all causes.[8] We assess the consequences

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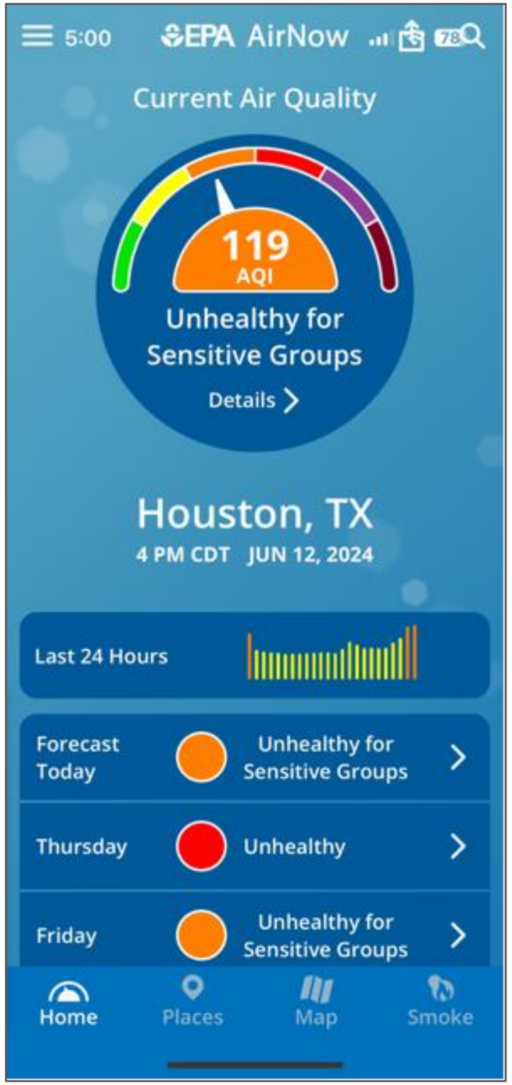
Before We Start…

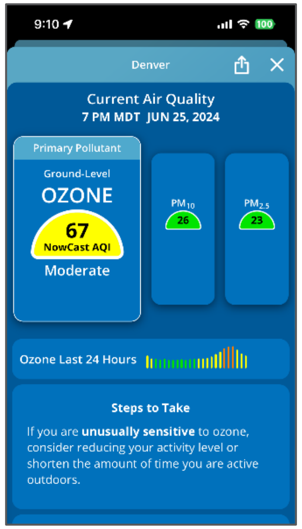
1. Have you downloaded the EPA's AirNow app onto your phone?
2. If yes, do you check AQ in the Houston region (or elsewhere) regularly?
3. If yes, have you ever changed your behavior to reduce your contribution or your exposure to PM or ozone pollution based on the AQI score?

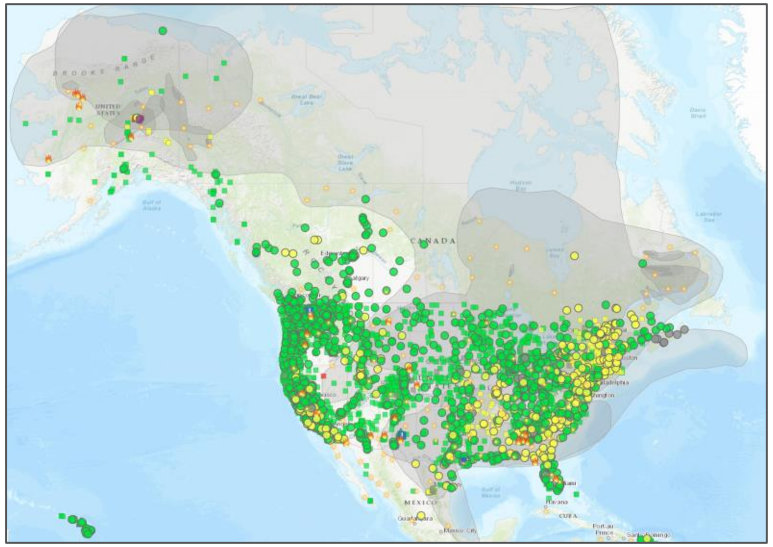
EPA's AirNow App

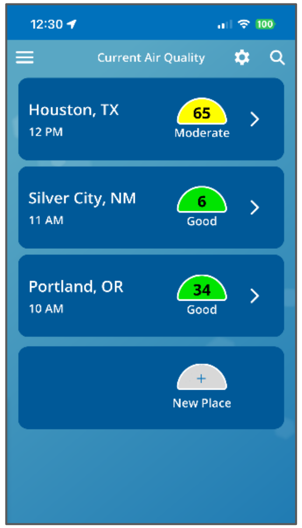
- Download it
- Use it…daily

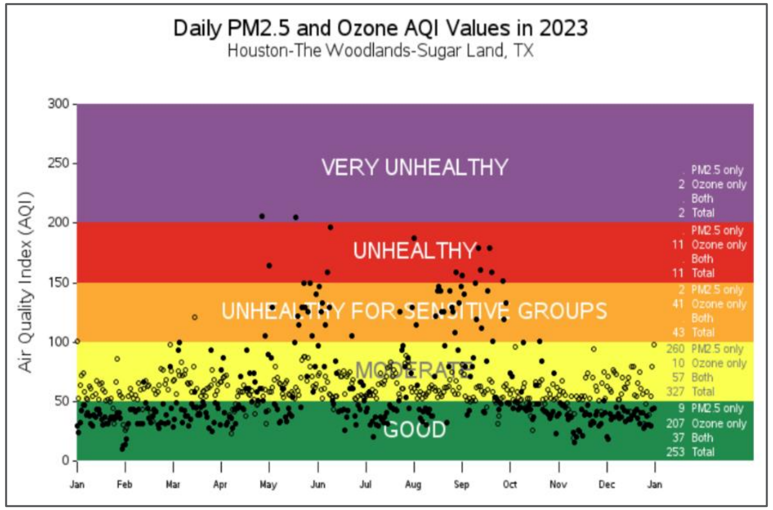
- BUT…. it does have some limitations











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AQI Limitations (aka "Outline")

- Limitations of U.S. AQI from a Health Perspective
  - U.S. AQI is not as protective as you might think…
  - U.S. AQI doesn't adjust for multipollutant exposures…
  - U.S. AQI suggests health effects thresholds…
    - Pathophysiology of PM2.5, PM0.1 and O3
  - "Sensitive Groups" include virtually everyone…
  - Exposure disparities missed by monitoring networks…
- Suggestions to Reduce Exposure on ↑ AQI Days

Good 0-50

Moderate 51-100

Unhealthy for Sensitive Groups 101-150

Unhealthy 151-200

Very Unhealthy 201-300

Hazardous 301-500

U.S. AQI vs. WHO & CAAQS

U.S. AQI Index	Good 0–50	Moderate 51–100	Unhealthy-S 101–150	Unhealthy 151–200	V-Unhealthy 201–300	Hazardous >301
U.S. NAAQS-based PM2.5 (annual/24-hr)	0–9 µg/m3	9.1–35.4 µg/m3	35.5–55.4 µg/m3	55.5–125.4 µg/m3	125.5–225.4 µg/m3	425+ µg/m3
U.S. NAAQS-based Ozone (8-hr)	0–54 ppb	55–70 ppb	71–85 ppb	86–105 ppb	106–200 ppb	201+ ppb
WHO PM2.5*	0–5 µg/m3	5.1–15 µg/m3	>15 µg/m3			
CAAQS-M PM2.5**	0–4 µg/m3	4.1–19 µg/m3	20–27 µg/m3	>27 µg/m3		
WHO Ozone*	0–30.6 ppb	30.6–51 ppb	>51 ppb			
CAAQS-M Ozone**	0–50 ppb	51–56 ppb	57–60 ppb	>54 ppb		

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U.S. AQI is not as protective as you probably think…

Multipollutant Exposures

TECHNICAL PAPER

ISSN:1047-3289 *J. Air & Waste Manage. Assoc.* **58**:435–450
DOI:10.3155/1047-3289.58.3.435

A New Multipollutant, No-Threshold Air Quality Health Index Based on Short-Term Associations Observed in Daily Time-Series Analyses

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ABSTRACT
Air quality indices currently in use have been criticized because they do not capture additive effects of multiple pollutants, or reflect the apparent no-threshold concentration-response relationship between air pollution and health. We propose a new air quality health index (AQHI), constructed as the sum of excess mortality risk associated with individual pollutants from a time-series analysis of air pollution and mortality in Canadian cities, adjusted to a 0–10 scale, and calculated hourly on the basis of trailing 3-hr average pollutant concentrations. Extensive sensitivity analyses were conducted using alternative combinations of pollutants from single and multipollutant models. All formulations considered produced frequency distributions of the daily maximum AQHI that were right-skewed, with modal values of 3 or 4, and less than 10% of values at 7 or above on the 10-point scale. In the absence of a gold standard and given the uncertainty in how to best reflect the mix of pollutants, we recommend a formulation based on associations of nitrogen dioxide, ozone, and particulate matter of median aerodynamic diameter less than 2.5 µm with mortali[…] single-pollutant models. Further sensitivity anal[…] vealed good agreement of this formulation with[…] based on alternative sources of coefficients drawn from published studies of mortality and morbidity. These analyses provide evidence that the AQHI represents a valid approach to formulating an index with the objective of allowing people to judge the relative probability of experiencing adverse health effects from day to day. Together with health messages and a graphic display, the AQHI scale appears promising as an air quality risk communication tool.

INTRODUCTION
An air quality index (AQI) is a numeric scale intended to reflect the quantity of air pollution present at a given point in time and its health significance. It is often reported both with respect to current and forecasted conditions. Numerical AQI values are often accompanied by color schemes, category labels (e.g. "good," "fair," "poor") and health advice. Most AQIs currently in use around the world are calculated by comparing each pollutant in the index to its standard, and reporting the index as the number corresponding to the pollutant that is highest

IMPLICATIONS
The AQHI is a risk communication tool intended to […] people to make more informed choices to protect t[…] selves and those in their care from short-term healt[…] pacts of air pollution. It arose out of a multifaceted pro[…] including the development of a numeric scale, assess[…] of public information needs, and development of com[…] nication materials including health messages and a gr[…] display. The AQHI provides more accurate information[…] existing index systems, specifically pertaining to refle[…] the overall impacts of the air pollution mix and the o[…] rence of effects at low levels of exposure.

- Concomitant or serial exposure to elevated air pollutants increases health risk in some studies but not all (1-pollutant AQIs estimate similar risk in many studies).
  - Canada historically used the U.S. AQI but launched a multipollutant AQHI in 2005, expanded to 122 locations across Canada in 2016.

"Air quality indices currently in use have been criticized because they do not capture additive effects of multiple pollutants or reflect the apparent no-threshold concentration-response relationship between air pollution and health."

Stieb DM, JAWMA, 2008

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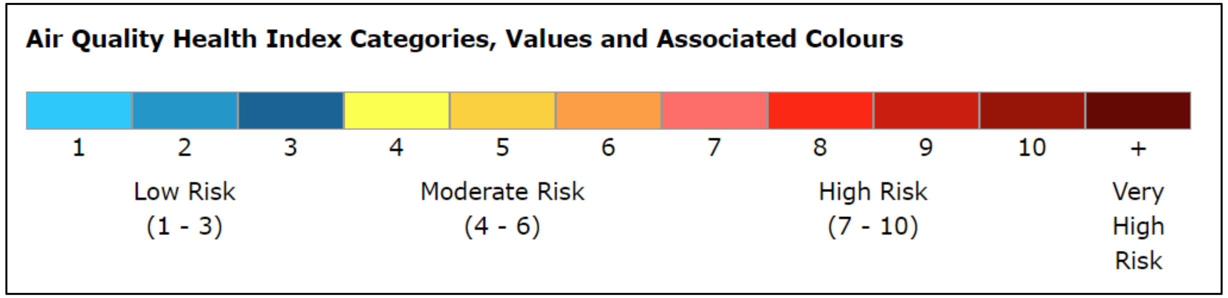
U.S. AQI doesn't adjust for multipollutant exposures…

Canadian Multipollutant AQHI

- Canadian AQHI
  - Based on 3-hour average of hourly values of NO2, O3 and PM2.5 by station, then community.

$$AQHI = (\frac{10}{10.4}) \times 100 \times [(e^{0.000537 \times O_3} - 1) + (e^{0.000871 \times NO_2} - 1) + (e^{0.000487 \times PM_{2.5}} - 1)]$$



  - Alberta (energy) uses AQHI as well as an hourly system that includes SO2, CO, H2S, TRS, odor and visibility in its calculations.

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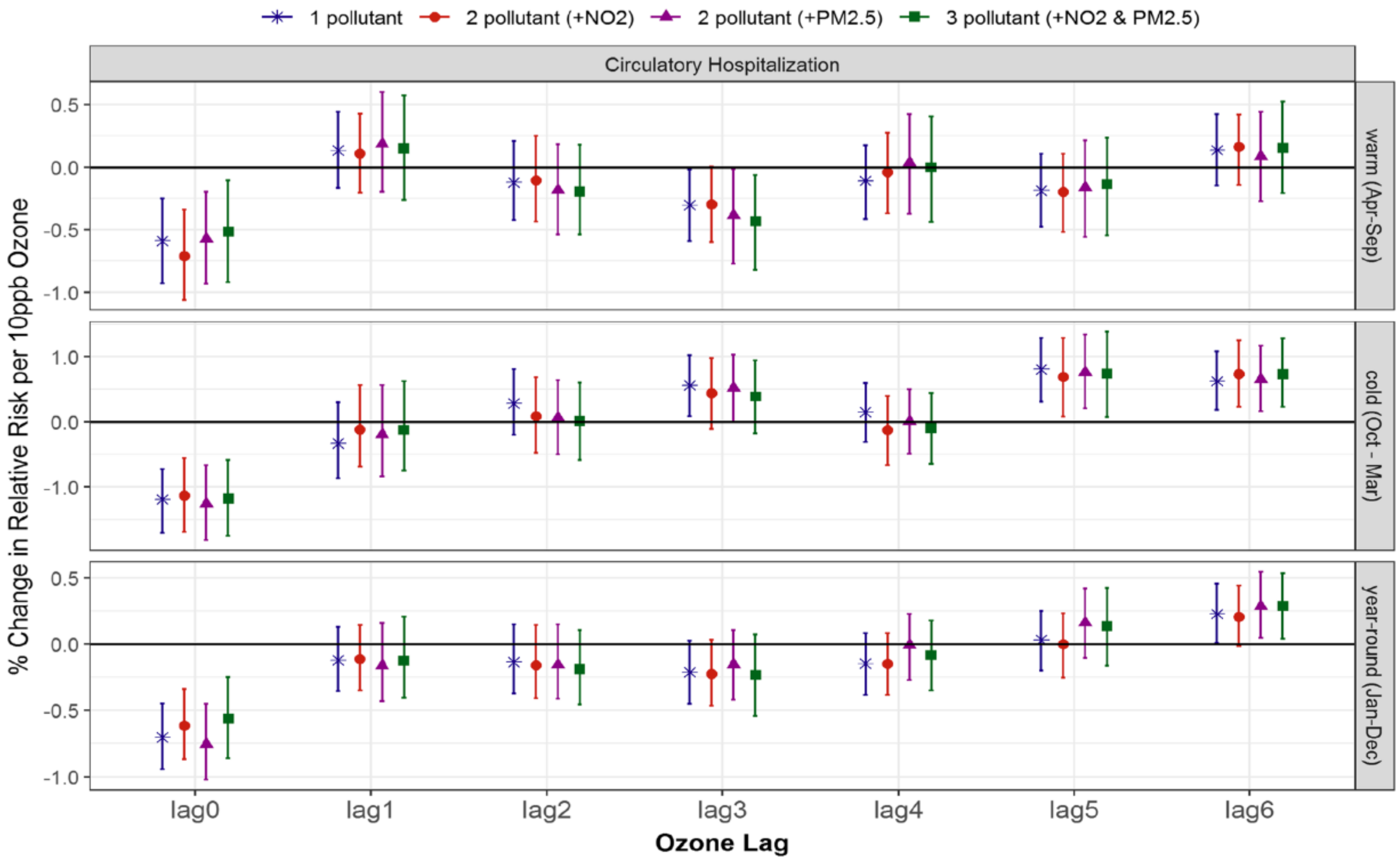
U.S. AQI doesn't adjust for multipollutant exposures…

Multipollutant Model Study

- Shin et al, 2023
  - 12 years, 24 cities
  - Canadian data
  - Circulatory hospitalizations and deaths
  - 7 lags (short-term effects)
  - Compares 4 models



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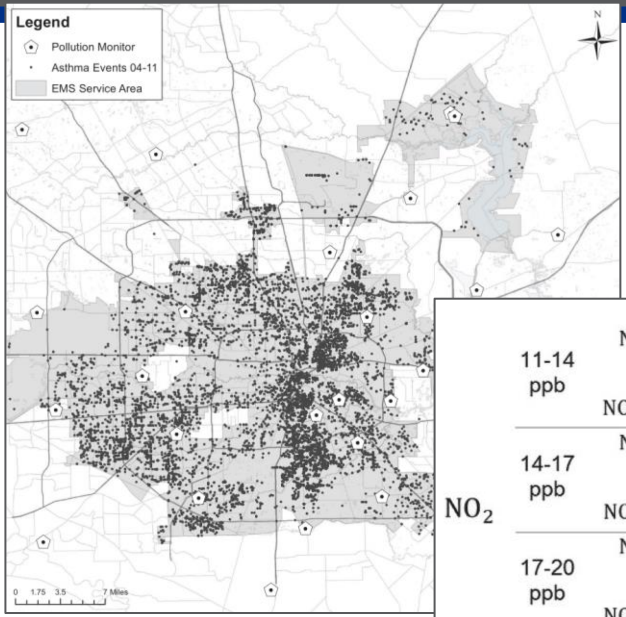
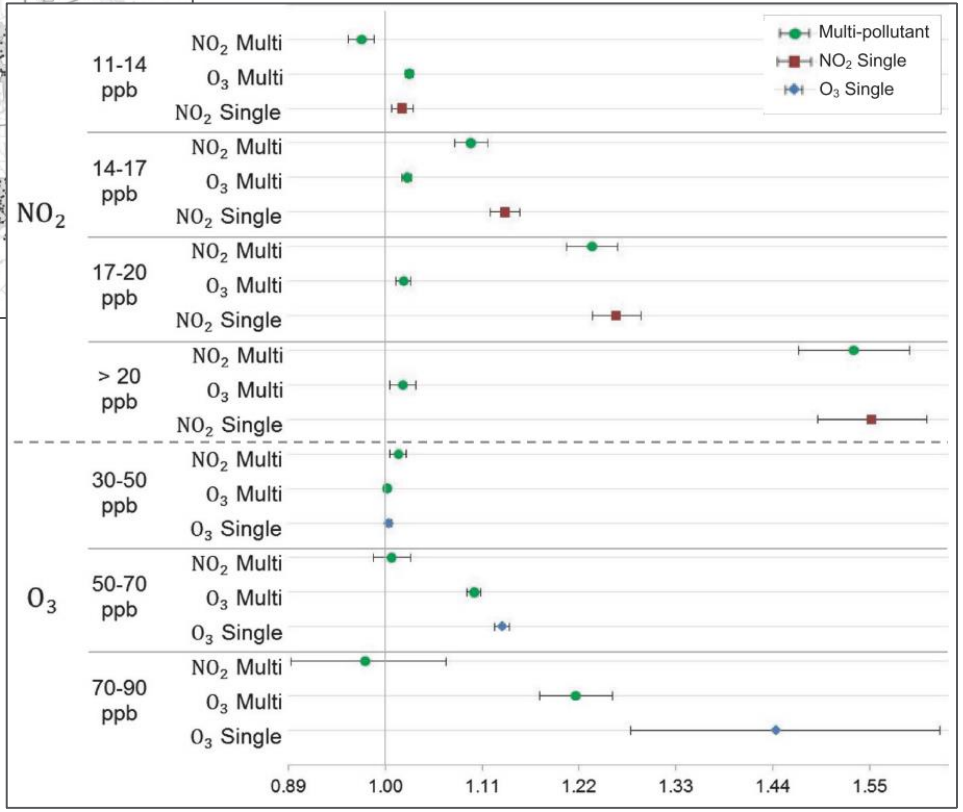
U.S. AQI doesn't adjust for multipollutant exposures…

Multipollutant Houston Study

- Raun et al, 2014
  - Data 2004–2011
    - NO_2, CO, O_3, PM2.5, SO_2
    - EMS data for 11,754 calls for asthma
    - Meteorologic (temp, RH)
  - Results
    - In Houston, O_3 (20 ppb ↑) & NO_2 (8 ppb ↑) in multipollutant model = triggered calls for EMS for asthma
      - RR 1.05 (1.00, 1.09), RR 1.10 (1.05, 1.15)





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U.S. AQI doesn't adjust for multipollutant exposures…

Linearity of AP Health Effects

- AQI health risk
  - Generally based on hospitalization/death shortly after exposure
- This is changing. E.g., Great Smog of London (Dec 5-9, 1952)
  - Lasted 5 days (then suddenly cleared)
  - Attributed health effects
    - 1952: ~4,000–6,000 died over 2 wk (at-risk)
    - 1953/2004: ~12,000 died over 90 days (infection)
    - 2023: Those in utero/infancy during episode (N=36,281) ~ 50 yr later have significantly lower intelligence & compromised respiratory health, relative to comparative group

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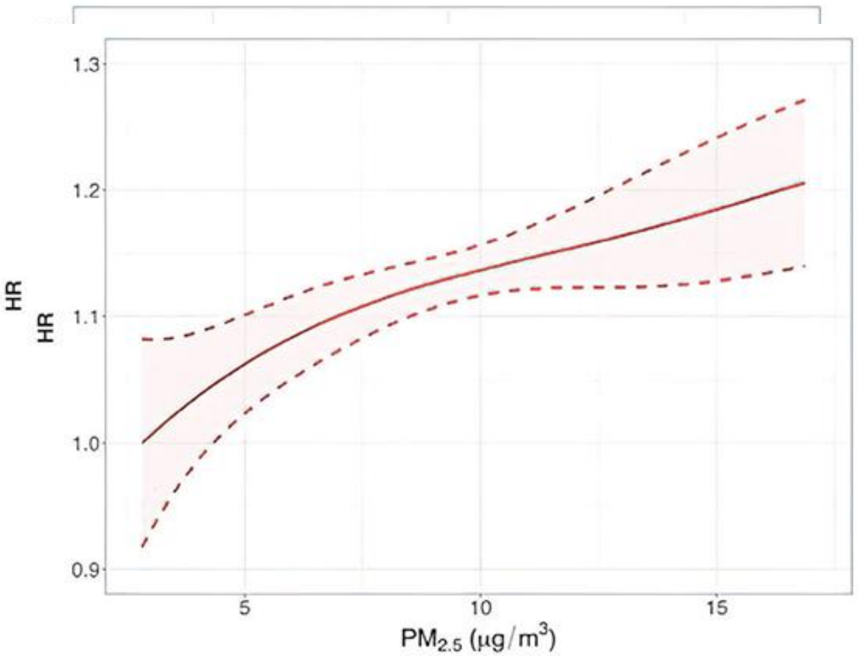
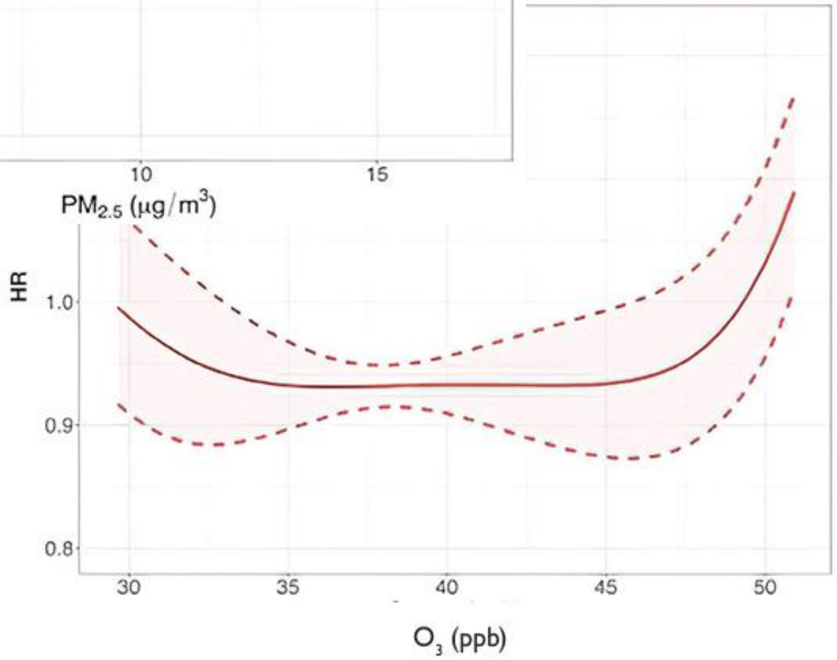
U.S. AQI suggests health-effects thresholds…

Linearity of AP Health Effects

- Dominici et al, 2022
  - Aim:
    - Predict short- & long-term exposure to PM2.5, NO2, O3 for U.S. 2000–2016 & apply to Medicare beneficiaries
  - Key Findings
    - Risk of death > in those always exposed to PM2.5 < 12 µg/m3
    - PM2.5 curve linear, even below PM standard; O3 U-shaped





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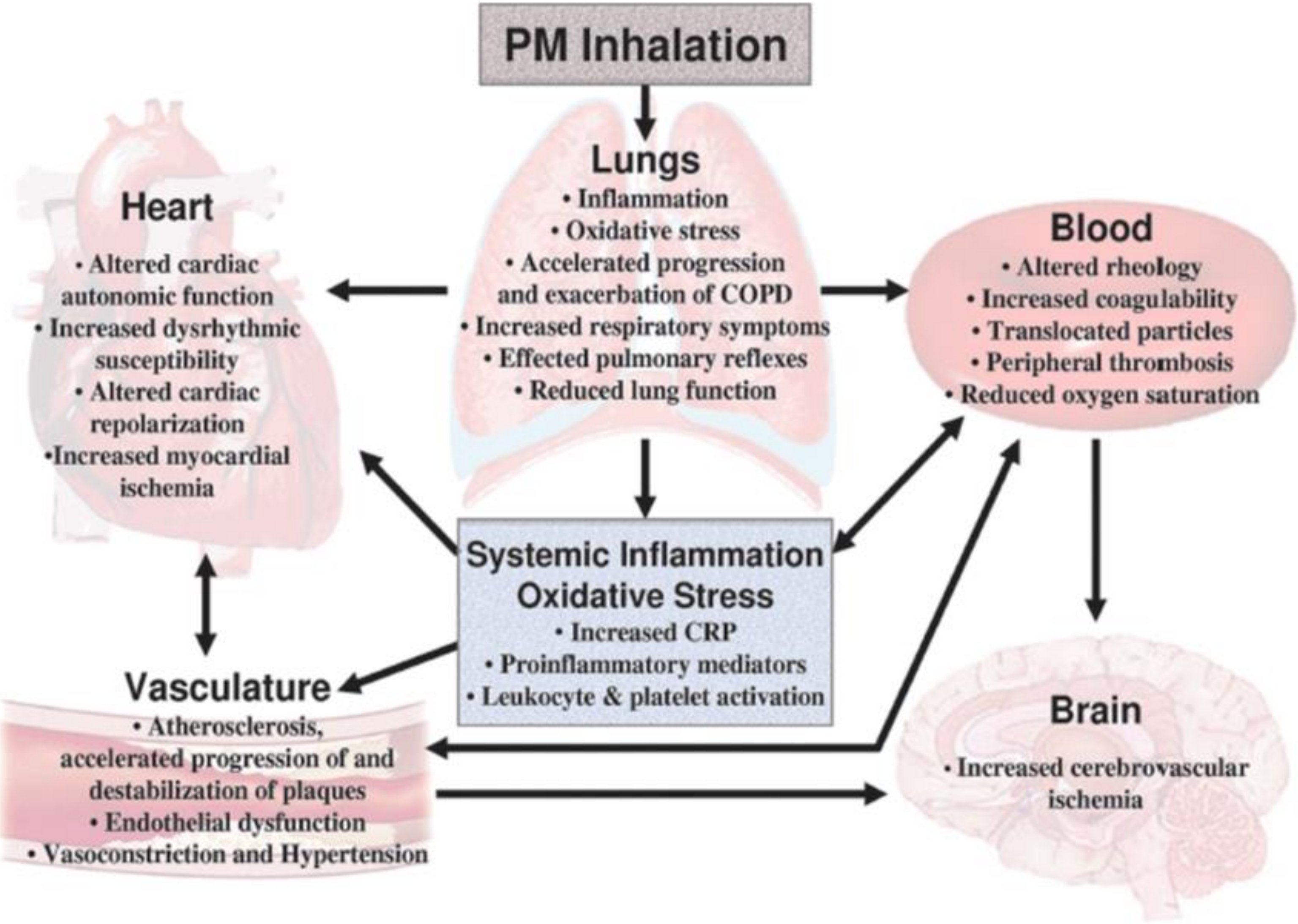
U.S. AQI suggests health-effects thresholds…

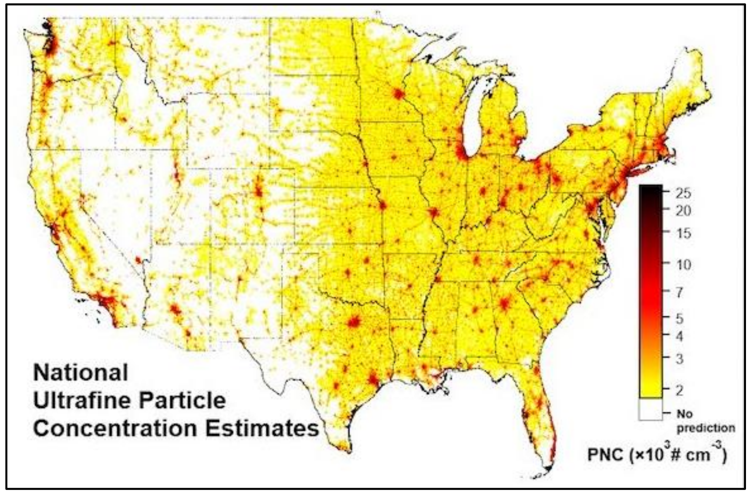
Pathophysiology of AP: PM

- Factors of toxicity:
  - Size
    - PM10, PM2.5, PM0.1, Nano
  - Charge
  - Solubility
  - Surface area
  - Ability to react with tissue and generate ROS



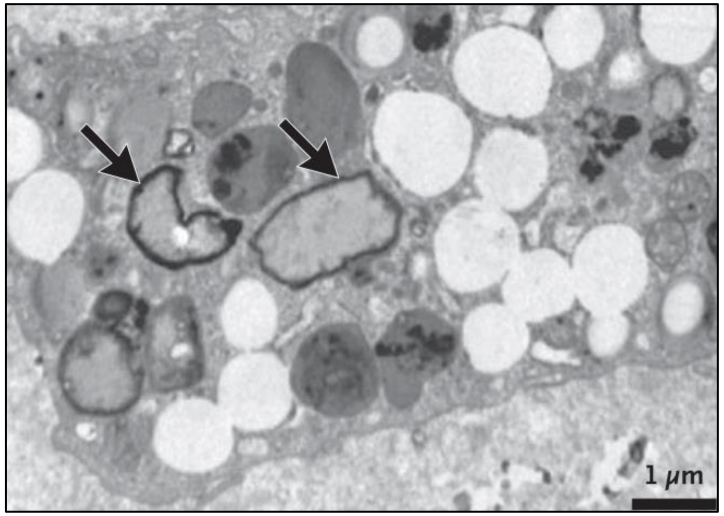
Pathophysiology of AP: UFP

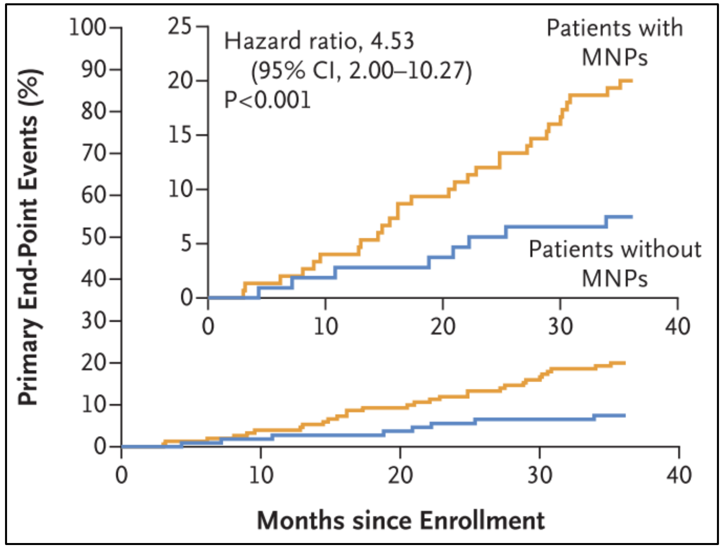
- UFP (PM0.1) are particularly dangerous
  - Enter blood stream, cross BBB
  - More chronic effects than PM2.5
    - E.g., Hypertension, atherosclerosis, heart failure, autonomic dysfunction, kidney disease, depression, dementia, ADHD…
  - Unknown if PM2.5 controls also reduce UFP
  - Levels ↑ in urban areas; sources thought to be similar to PM2.5
    - Car exhaust, agricultural burning, tire wear, printers, air traffic, vacuum cleaners, manufactured nanoparticles (e.g., silver impregnation), etc.



Pathophysiology of AP: UFP

- Micro/nanoplastics in carotid atherosclerotic plaque (Marfella et al , NEJM, 2024)
  - 257 carotid endarterectomy patients
    - Specimens analyzed for MNPs
    - 150 w polyethylene, 31 w polyvinyl chloride
    - Patients w MNPs 4.53x (HR) more likely to have a myocardial infarction, stroke or to die during FU (mean 33.7 mo) than those w/o MNP in their plaque
    - ↑inflammatory markers in those with MNPs





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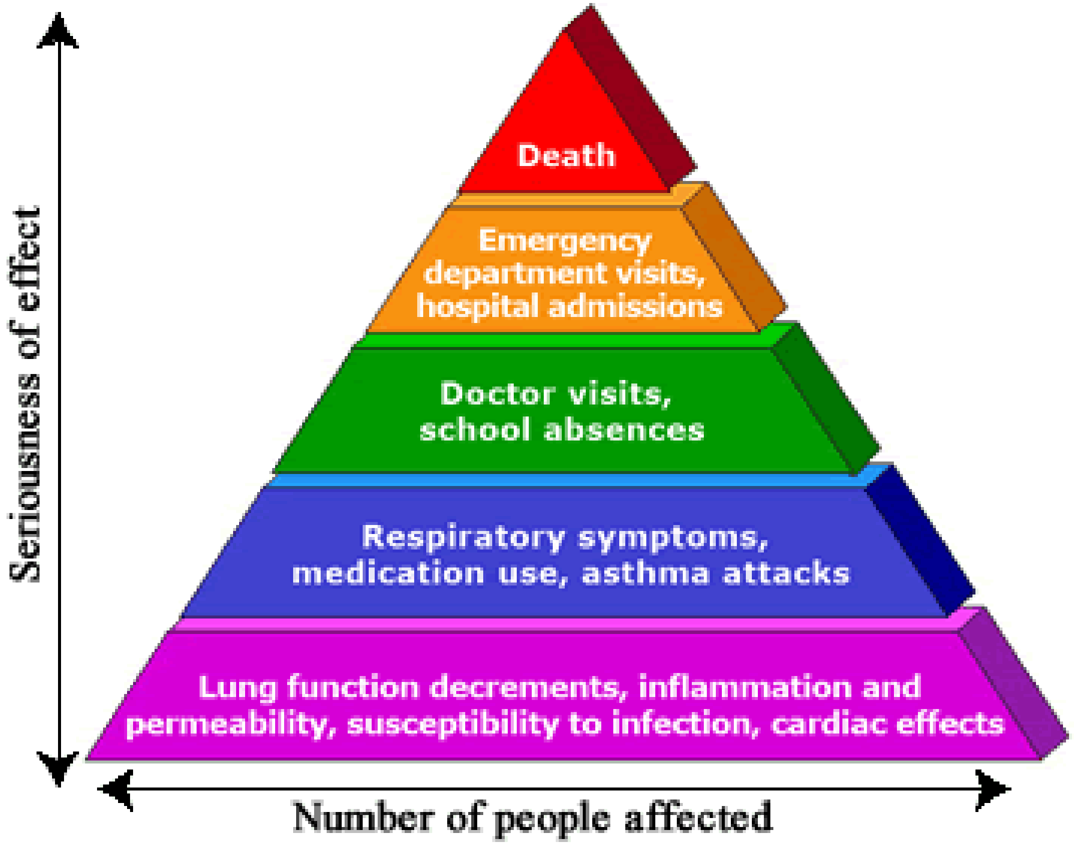
Pathophysiology of O3

- Ozone (from precursor pollutants)
  - O3: highly reactive ("burns" airways)
    - Creates ROS, inflammation, injury to epithelial cells, leaking, scarring
    - Can trigger airway narrowing
    - Excess mucus can "plug" airways
    - Deactivates cilia (defense system)
    - Can cause SOW, reduced lung function, cough, reduced O2 sat
    - Makes lungs more susceptible to infection, other toxins



EPA's "Sensitive Groups"

- Those with
  - Cardiovascular disease
    - CAD, hypertension, diabetes, heart failure, diastolic dysfunction, arrhythmia, atrial fibrillation, PAD, hx of angina or heart attack, stent or by-pass surgery, stroke or TIA
  - Lung disease
    - Asthma, COPD, allergies, hx of respiratory infections
  - Others
    - Older adults, pregnant women, fetuses, children, outdoor athletes and workers, persons who have an immune disorder or who are overweight

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"Sensitive Groups" include virtually everyone…

Exposure Disparities

- Lack of monitor coverage
  - Largely cost but also politics
- Regional emissions profile
  - Toxicity differences
- Environmental in-justice
- Microenvironments
  - Time in a car / with cars
  - Personal care products (MNPs, VOCs)
  - BBQ, gas stove, dry cleaning, generators

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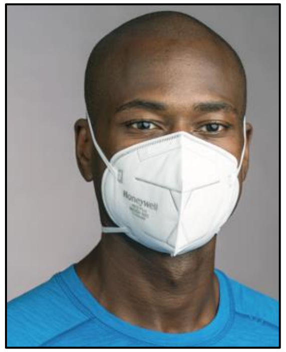
Exposure disparities missed by monitoring networks…

Reducing Exposure on ↑ AQI Days

- PM2.5
  - Stay indoors with filtered air
    - HEPA (to ~0.3 μ) or hyperHEPA filtration (to ~0.003 μ)
  - Don’t use or reduce any combustion near home
    - Gas stove, car, mowers/leaf blowers, fireplace, candles, incense
  - Avoid vacuuming
  - Avoid driving car if possible, don’t idle
  - Wear N94/N95 mask (reduces PM inhaled)



Reducing Exposure on ⬆ AQI Days

- O3
  - Stay inside during peak O3 hours (usually ~2–5 pm; check AirNow)
  - Avoid things that produce ozone
  - Reduce outdoor activity levels
  - Avoid driving car if possible
  - N94/N95 masks are minimally helpful for ozone (~30% reduction in exposure) unless has a carbon filter
  - Avoid known high O3 areas

Resources & References

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Comments or Questions?

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