



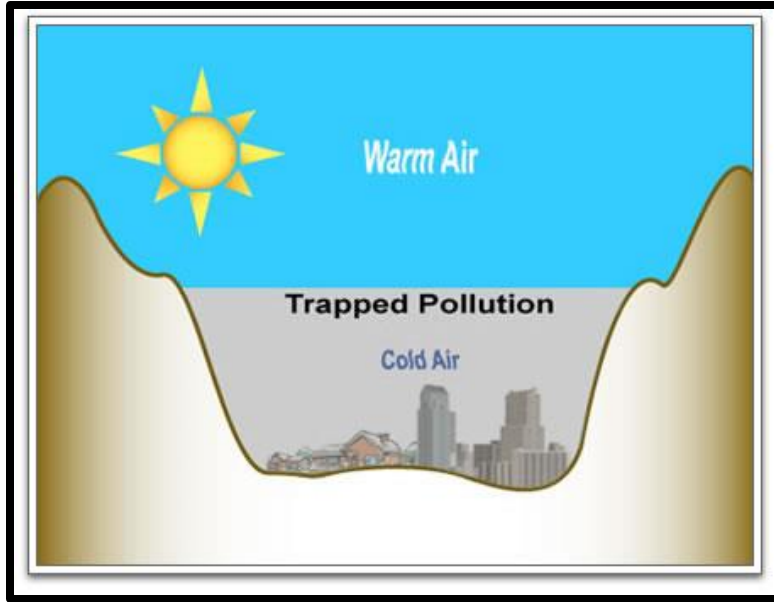
# Effect of Air Quality on Health & Performance

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FAMSSM***

Senior Medical Director  
Wellness & Nutrition  
Intermountain Healthcare



# Inversion



- Inversions trap a dense layer of cold air under a layer of warm air.
- The warm layer acts like a lid, trapping pollutants in the cold air near the valley floor.
- The Wasatch Front valleys and their surrounding mountains act like a bowl, keeping this cold air in the valleys
- The condition is called an inversion because it is the reverse of a normal air pattern (i.e., cooler air above, warmer air below).



# Utah Had The Worst Air In The World Today — Here's What You Need To Know To Be Safe

KUER 90.1 | By [Lexi Peery](#)

Published August 6, 2021 at 5:35 PM MDT



August 6, 2021

# Outline

- Relationship between exposure to Particulate matter (PM) pollution and health outcomes
- Too much bad ozone, not enough good ozone, and why this affects health
- The effects of air pollution on exercise and exercise performance
- Intermountain Healthcare's Air Quality and Health program



# Airborne PM is categorized by aerodynamic diameter

- **Coarse: PM<sub>10</sub>** Larger than 10  $\mu\text{m}$ 
  - Not considered harmful to airways since they are primarily filtered at the nasopharyngeal region
- **Fine: PM<sub>2.5</sub>** Between 2.5  $\mu\text{m}$  and 10  $\mu\text{m}$ 
  - Considered harmful to health
- **Ultrafine: PM<sub>0.1-1.0</sub>** Between 0.5 and 1.0  $\mu\text{m}$ 
  - Not yet recognized by the US Environmental Protection Agency (EPA)
  - Are considered to be the most harmful
  - High in freshly generated exhaust and can penetrate deep within the lung



Image courtesy of the U.S. EPA

# Adverse Health Effects of PM Exposure

- **Respiratory**
  - Bronchitis, Asthma, COPD exacerbation
- **Cardiovascular**
  - Acute ischemia, Heart failure
- **Neurological**
  - Stroke
  - Dementia
- **Obstetric**
  - Miscarriage





# Air Pollution and Asthma

- Children > adults
- Poor air quality is associated with increase in outpatient care, ED visits and hospitalizations<sup>1</sup>
- In utero and early life exposure to traffic-related pollution may increase the likelihood of clinically significant asthma later in life<sup>2</sup>



1 To. Environmental Health Perspectives 2013

2 Dong Epidemiology. 2013

# Air Pollution COPD and Chronic Bronchitis

- Exposure to air pollution is associated with an increase in COPD hospitalizations and COPD related mortality<sup>1,2</sup>
- Chronic bronchitis (chronic AM cough and sputum production) is associated with outdoor air pollution<sup>3</sup>
  - Even among non-smokers
  - OR > 2.0 for: living next to a busy road for 30+ years; living close to a power plant

*1 Gan. Am J Respir Crit Care Med. 2013*

*2 Faustini. Epidemiology. 2012*

*3 Salameh. Int J Occup Environ Med. 2012*

# Coronary Heart Disease

## Ischemic Heart Disease Events Triggered by Short-Term Exposure to Fine Particulate Air Pollution

C. Arden Pope III, PhD; Joseph B. Muhlestein, MD; Heidi T. May, MSPH; Dale G. Renlund, MD;  
Jeffrey L. Anderson, MD; Benjamin D. Horne, PhD, MPH

- Evaluate the role of short-term ( $\leq 24$  hour exposure) particulate exposure in triggering acute ischemic heart disease events
- 12,865 patients (drawn from the cardiac catheterization registry of the Intermountain Heart Collaborative Study) who lived on the Wasatch Front in Utah

*Circulation. 2006;114:2443-2448*

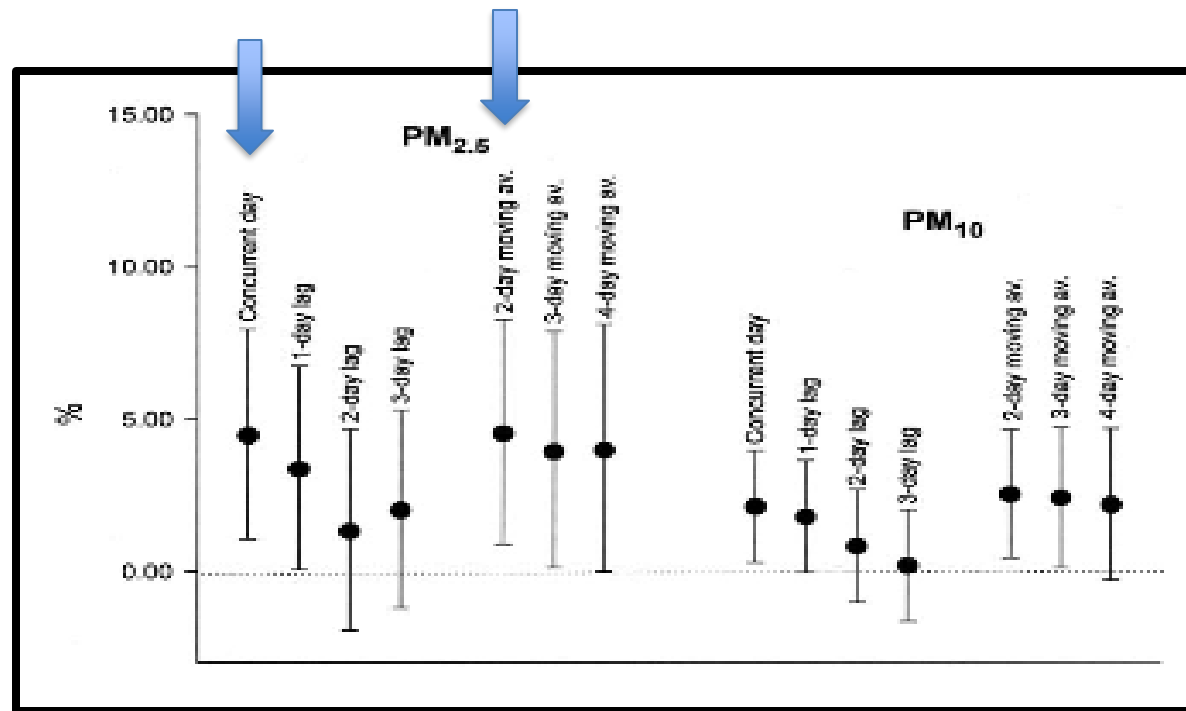
# Hypothesis

- Short-term elevated PM exposures and related inflammation may contribute to acute complications of atherosclerosis by increasing the risk of atherosclerotic plaque rupture, thrombosis, and precipitation of acute ischemic events.





# Results



- PM<sub>2.5</sub> >> PM<sub>10</sub>
- Exposure to 10  $\mu\text{g}/\text{m}^3$  increase in PM<sub>2.5</sub> associated with a 4.5% increased risk of an acute coronary event (unstable angina or MI)
- Strongest associations were for concurrent-day exposure

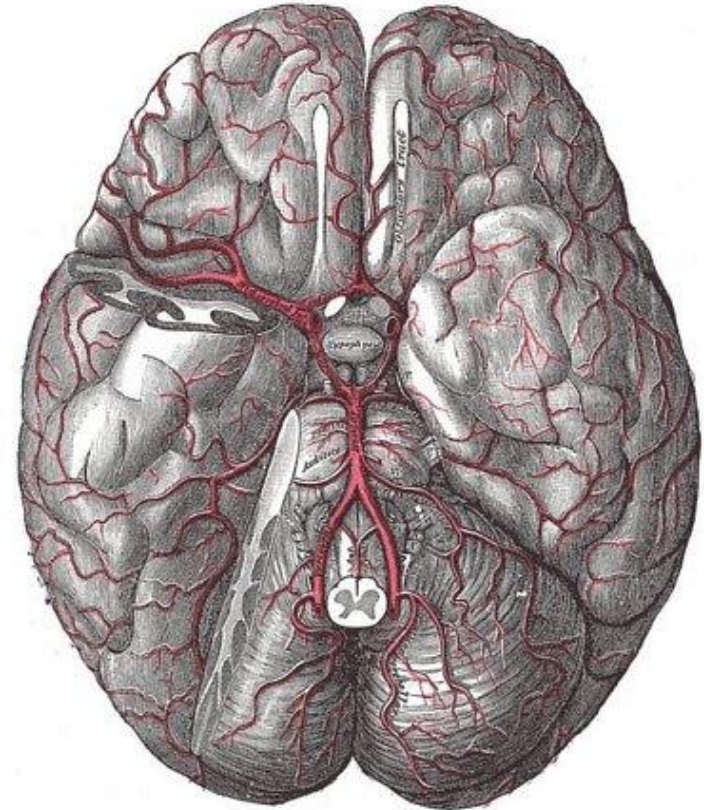
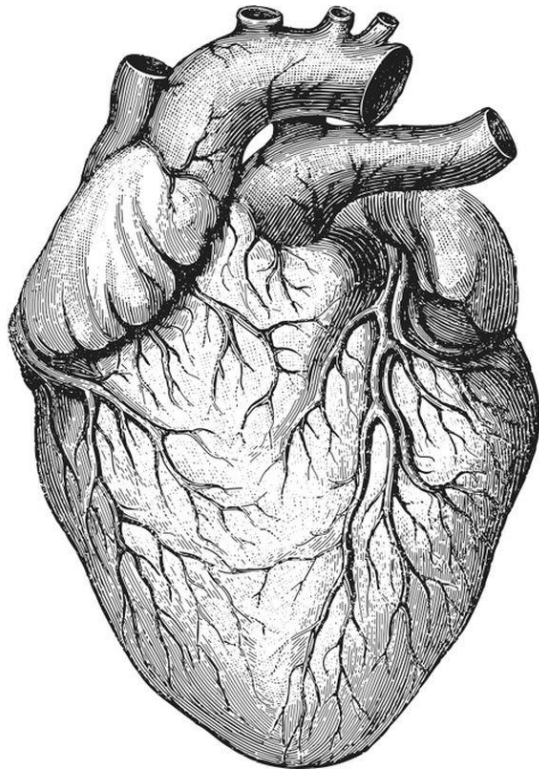
# Clinical Implications

*“On the basis of these results, patients with established heart disease might do well to move to areas with a lower burden of fine particulate air pollution levels. If moving is not possible, patients may at least be wise to stay indoors during the more polluted days and to ensure adequate filtering of their indoor air.”*



# What's Bad for the Heart, Is Bad for the Brain

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# Air Pollution and Stroke



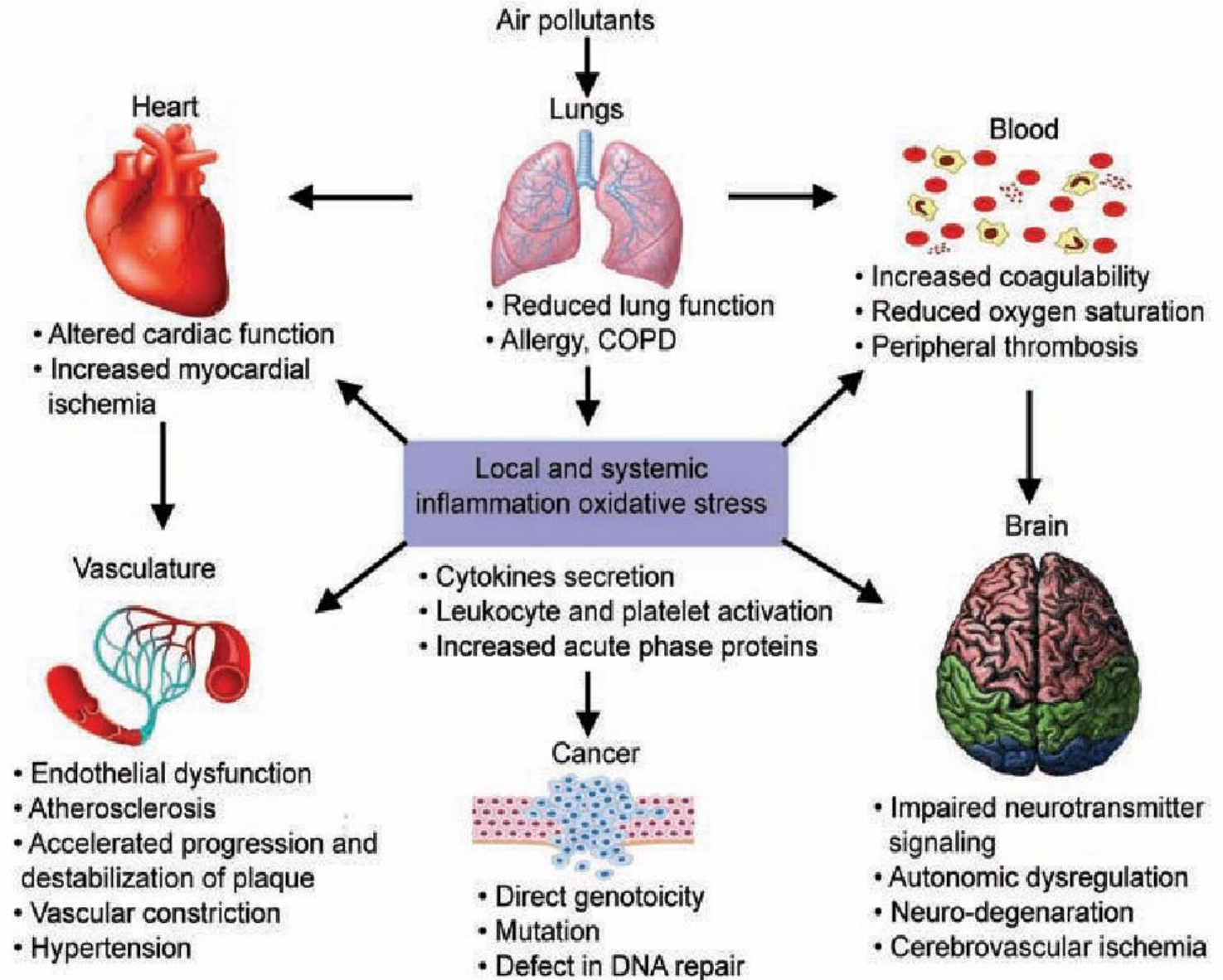
- Exposure to elevated levels of particulate pollution and ozone increases the number of stroke events on subsequent days.
  - Especially true in persons with a prior h/o stroke<sup>1</sup>
  - Persons with a greater number of cardiac risk factors<sup>2</sup>

<sup>1</sup> Oudin. *Epidemiology* 23(3) 2012

<sup>2</sup> Henrotin. *Heart* 96. 2010



# Air pollution ↓ Inflammation



# Air Pollution and Dementia: A Systematic Review

Ruth Peters<sup>a,b,\*</sup>, Nicole Ee<sup>b</sup>, Jean Peters<sup>c</sup>, Andrew Booth<sup>c</sup>, Ian Mudway<sup>d</sup>  
and Kaarin J. Anstey<sup>a,b</sup>

<sup>a</sup>University of New South Wales, Australia

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<sup>d</sup>MRC-PHE Centre for Environment and Health, NIHR Health Protection Research Unit in Health Impact of Environmental Hazards, Faculty of Life Sciences and Medicine, King's College London, London, UK

Accepted 31 December 2018

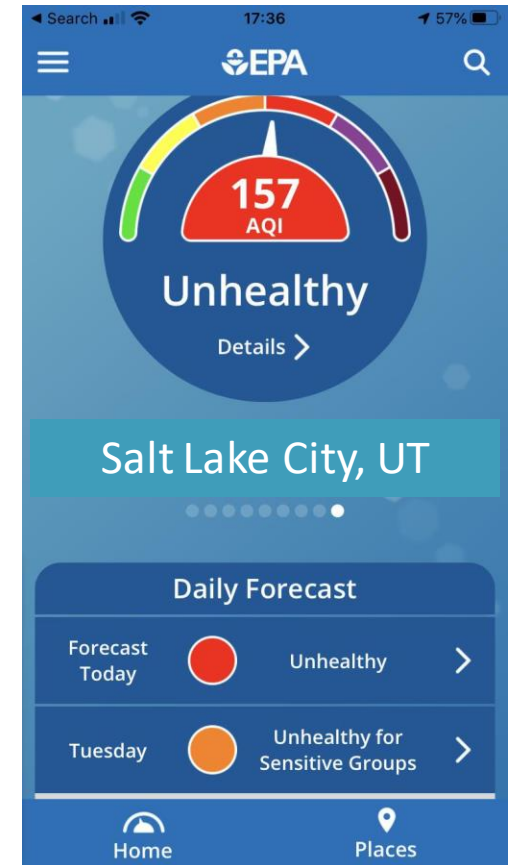
## DISCUSSION

Overall, the evidence from longitudinal cohort studies pointed towards an association between greater exposure to pollutants, in particular PM<sub>2.5</sub>, NO<sub>2</sub>/NO<sub>x</sub> and increased risk of dementia. The evidence for cognitive decline was more equivocal than that for the dementia outcomes. The pattern was mixed for O<sub>3</sub> with studies reporting positive and

that precedes it. Plausible pathways exist to support this. It is hypothesized that, when inhaled, the gas, particles, or material desorbed from the particle surface act to induce inflammatory responses, microglial activation, production of reactive oxygen species, and increased production and deposition of Aβ peptides [3, 4, 16, 17, 60–65]. Furthermore, plausible mechanisms support the potential for inhaled PM<sub>2.5</sub> or the even smaller UltraFine Particulate Matter <0.1 μm (UFFPM) reaching the brain directly via the olfactory bulb with animal studies finding ultra-fine particle penetration into the olfactory bulb, the

# "Brain Wellness" Starts Early.....and Often

- Know the AQI when planning outdoor activities – especially when performing moderate to vigorous physical activity
- For people with underlying conditions – diabetes, high blood pressure, previous stroke – being aware of the AQI and making efforts to avoid air pollution is even more important
- What about masks?????







# Quantifying the Health Benefits of Face Masks and Respirators to Mitigate Exposure to Severe Air Pollution

John K. Kodros<sup>1</sup>, Katelyn O'Dell<sup>2</sup>, Jonathan M. Samet<sup>3</sup>, Christian L'Orange<sup>1</sup>, Jeffrey R. Pierce<sup>2</sup>, and John Volckens<sup>1,4</sup>

<sup>1</sup>Department of Mechanical Engineering, Colorado State University, Fort Collins, CO, USA, <sup>2</sup>Department of Atmospheric Science, Colorado State University, Fort Collins, CO, USA, <sup>3</sup>Department of Environmental & Occupational Health, Colorado School of Public Health, Aurora, CO, USA, <sup>4</sup>Department of Environmental and Radiological Health Sciences, Colorado State University, Fort Collins, CO, USA

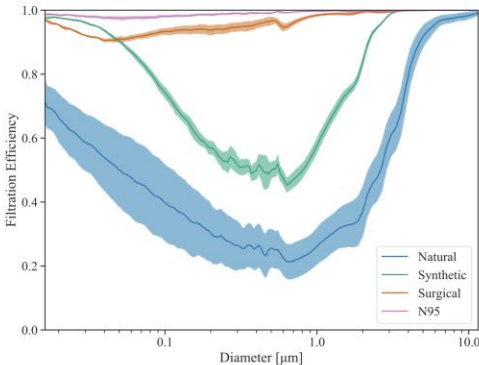
**Abstract** Familiarity with the use of face coverings to reduce the risk of respiratory disease has increased during the coronavirus pandemic; however, recommendations for their use outside of the pandemic remains limited. Here, we develop a modeling framework to quantify the potential health benefits of wearing a face covering or respirator to mitigate exposure to particulate air pollution. This framework accounts for the wide range of available face coverings and respirators, fit factors and efficacy, air pollution characteristics, and exposure-response data. Our modeling shows that N95 respirators offer robust protection against different sources of particulate matter, reducing exposure by more than a factor of 14 when worn with a leak rate of 5%. Synthetic-fiber masks offer less protection with a strong dependence on aerosol size distribution (protection factors ranging from 4.4 to 2.2), while natural-fiber and surgical masks offer reductions in the exposure of 1.9 and 1.7, respectively. To assess the ability of face coverings to provide population-level health benefits to wildfire smoke, we perform a case study for the 2012 Washington state fire season. Our models suggest that although natural-fiber masks offer minor reductions in respiratory hospitalizations attributable to smoke (2%–11%) due to limited filtration efficiency, N95 respirators and to a lesser extent surgical and synthetic-fiber masks may lead to notable reductions in smoke-attributable hospitalizations (22%–39%, 9%–24%, and 7%–18%, respectively). The filtration efficiency, bypass rate, and compliance rate (fraction of time and population wearing the device) are the key factors governing exposure reduction potential and health benefits during severe wildfire smoke events.

- Key Points:**
- We developed a framework to quantify potential health benefits of wearing a face mask or respirator during episodes of severe air pollution
  - N95 respirators offer protection against wildfire PM<sub>2.5</sub>, reducing exposure by more than a factor of 14 and hospitalizations by 22%–39%
  - Natural-fiber (e.g., cotton) masks offer only minor protection against wildfire PM<sub>2.5</sub>, reducing hospitalizations by only 2%–11%

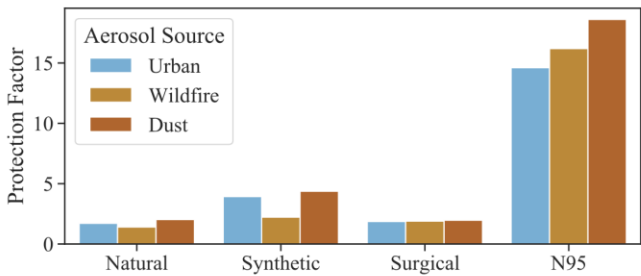
**Supporting Information:**  
Supporting Information may be found in the online version of this article.

**Correspondence to:**  
J. K. Kodros,  
Jack.Kodros@colostate.edu

**Citation:**  
Kodros, J. K., O'Dell, K., Samet, J. M., L'Orange, C., Pierce, J. R., & Volckens, J. (2021). Quantifying the health benefits of face masks and respirators to mitigate exposure to severe air pollution. *GeoHealth*, 5, e2021GH000482. <https://doi.org/10.1029/2021GH000482>



**Figure 1.** Measurements of mask filtration efficiency as a function of volume-equivalent diameter. The shaded regions represent one standard deviation in the measurements.



**Figure 2.** Calculated protection factors for each mask type exposed to aerosol size distributions representative of urban (or fossil-fuel combustion), biomass burning, and dust when assuming default bypass rates (Table 1).



Yes



Maybe

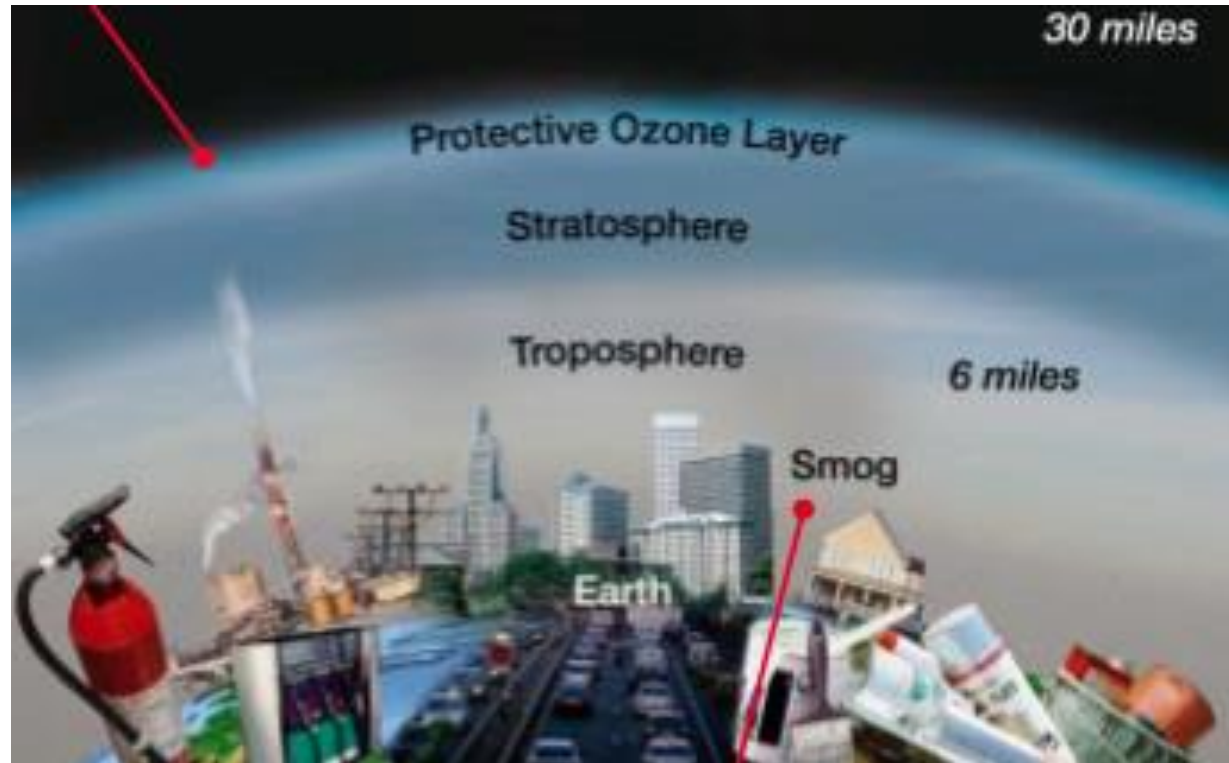


No



# Ozone: Good Up High, Bad Nearby

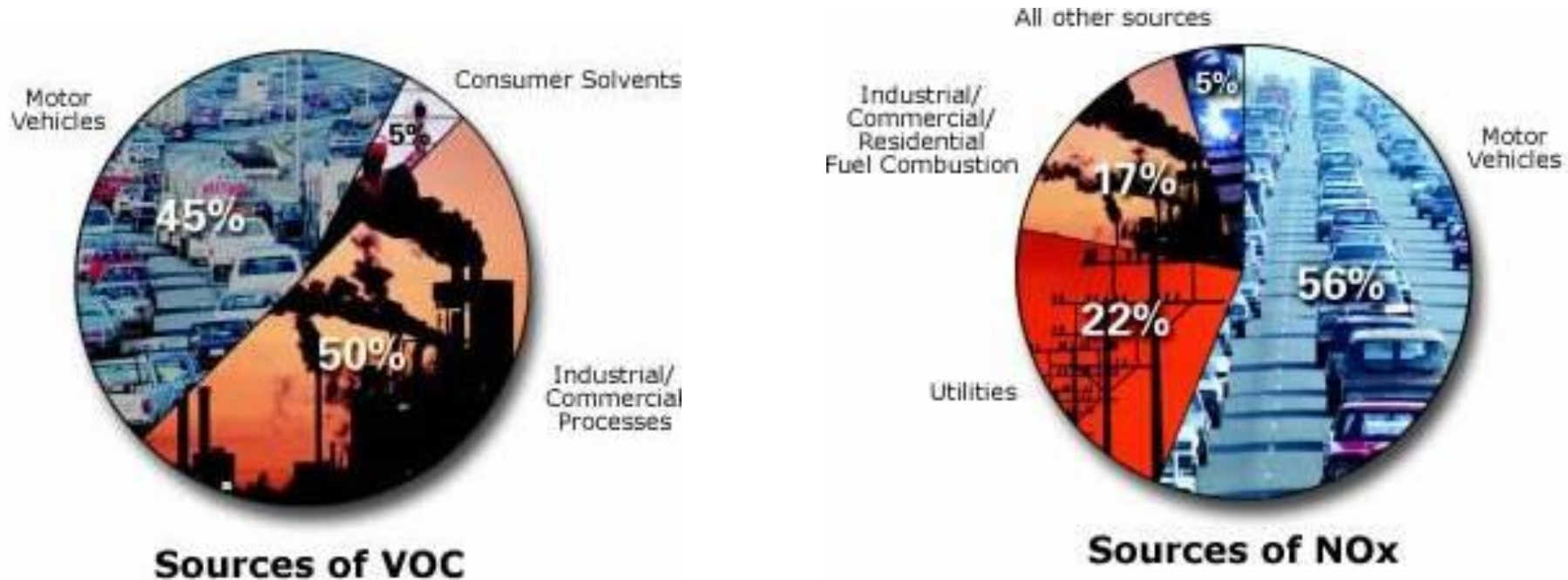
Too little there... Many popular consumer products like air conditioners and refrigerators involve CFCs during either manufacture or use. Over time, these chemicals damage the earth's protective ozone layer.



Too much here... Cars, trucks, power plants and factories all emit air pollution that forms ground-level ozone, a primary component of smog.

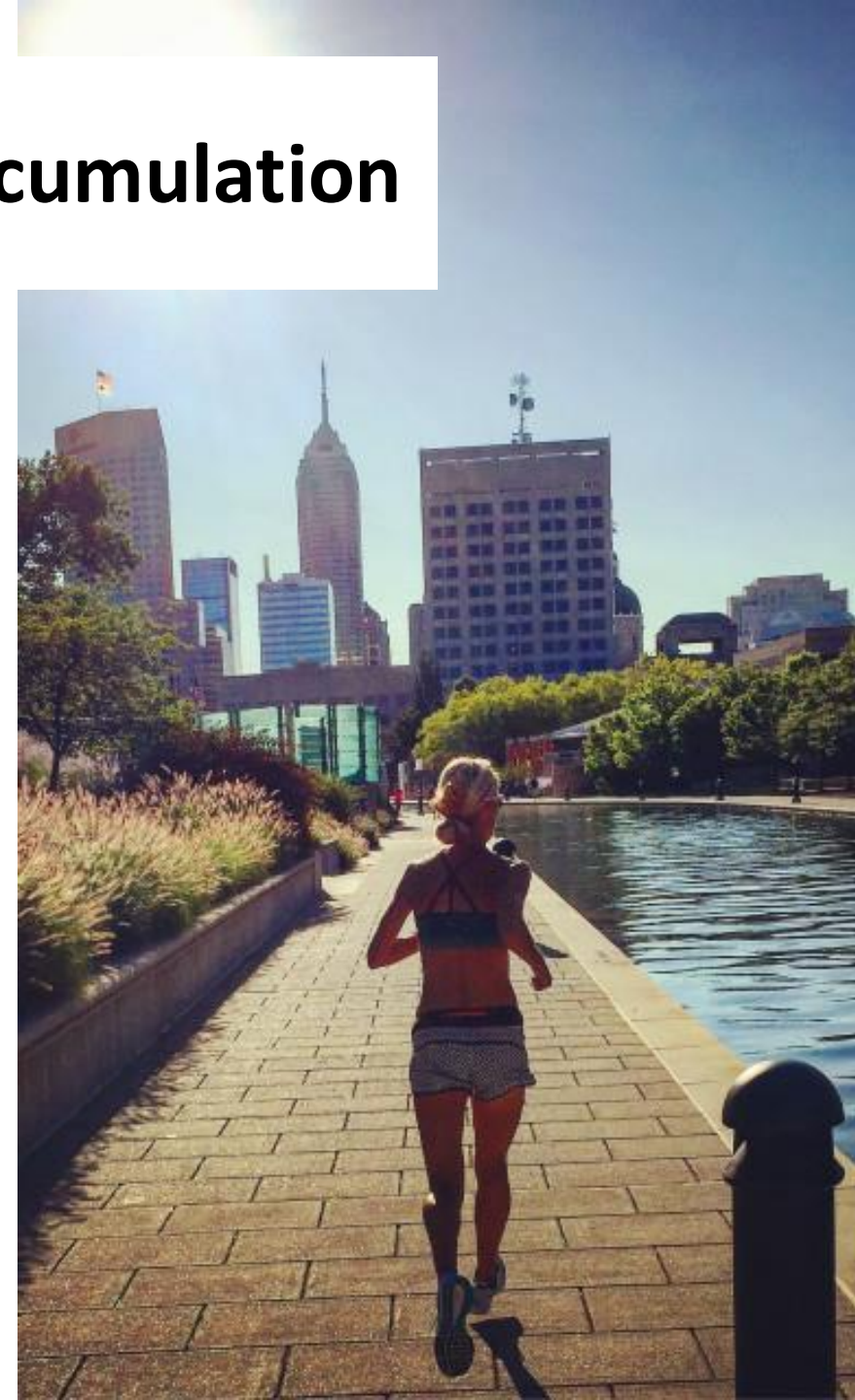
# Ground level “bad” ozone:

- Created by chemical reactions between oxides of nitrogen (NO<sub>x</sub>) and volatile organic compounds (VOC) in the presence of sunlight

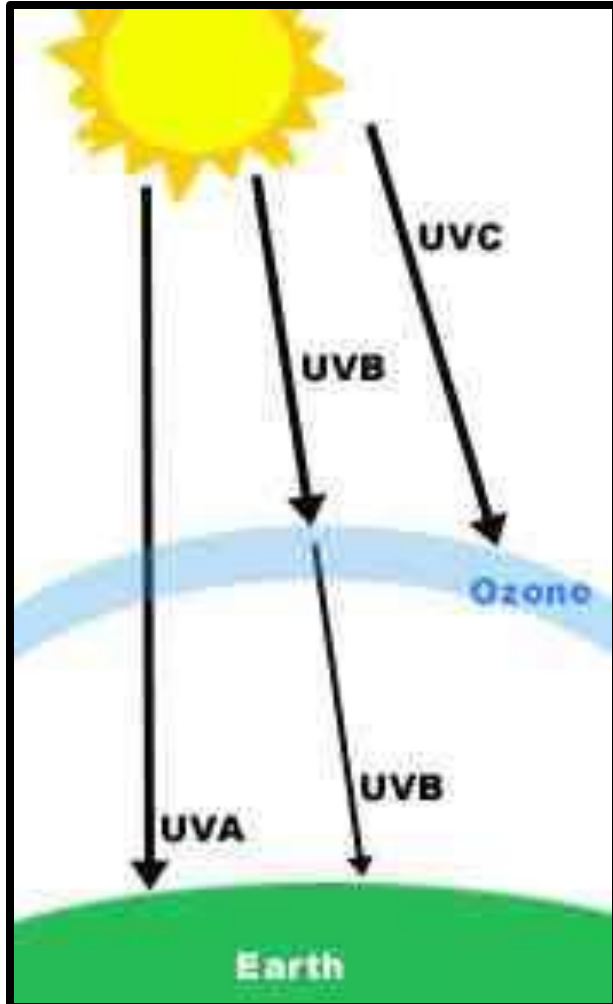


# Health Consequences of “Bad” Ozone Accumulation

- Worsen bronchitis, COPD, and asthma
- Reduce lung function and inflame lung tissue
- Repeated exposure may permanently scar lung tissue
- Because ozone forms in hot weather, anyone who spends time outdoors in the summer may be affected, particularly children, outdoor workers and **people exercising**



# Health Consequences of “Good” Ozone Depletion



- More cases of skin cancer, cataracts, and impaired immune systems.
- Overexposure to UV is believed to be contributing to the increase in **melanoma**.
- Since 1990, the risk of developing melanoma has more than doubled

<http://www.epa.gov/sunwise/uvandhealth.html>



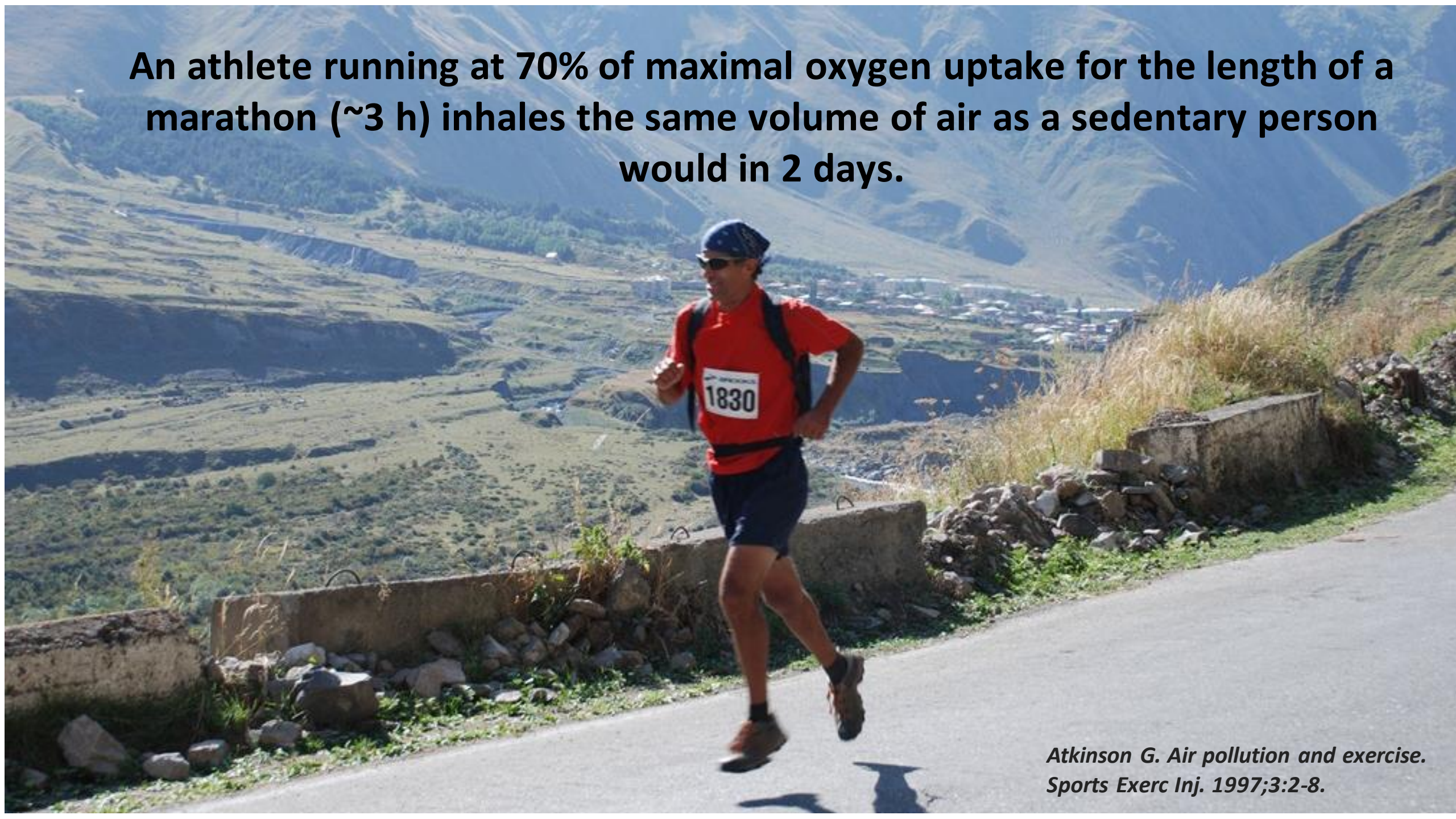


**More than 4 in 10 Americans live in places with unhealthy levels of air pollution.**

**137 million people**



**An athlete running at 70% of maximal oxygen uptake for the length of a marathon (~3 h) inhales the same volume of air as a sedentary person would in 2 days.**

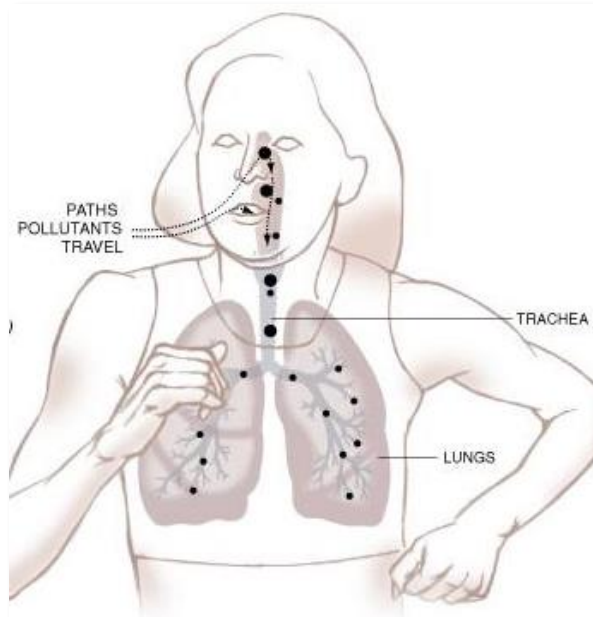


*Atkinson G. Air pollution and exercise.  
Sports Exerc Inj. 1997;3:2-8.*

# During Exercise

- Elevated ventilation rate
- Switch from nasal to mouth breathing
- Increased airflow velocity

carry pollutants deeper into the lungs and further amplify the runner's dose of pollutants.



Effect may be worse in women runners



# Effect of Air Pollution on Marathon Running Performance

- Analyzed the level of pollutants present during the 168 race years.  
[Boston, New York, Chicago, Twin Cities, Grandma's, California International, and Los Angeles marathons.]
- Rarely exceeded the health limits set by the EPA or the levels known to affect lung function during exercise in laboratory situations.
- Low levels of PM<sub>10</sub> were significantly associated with decrease in performance for women but not for men.
  - For every 10  $\mu\text{m}/\text{m}^3$  increase in PM<sub>10</sub>, women's marathon performance decreased by 1.4%.



# #GSMHARF



**I SIGNED UP FOR THE GREAT SMOKY MOUNTAINS EVENTS!**

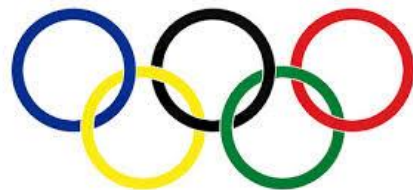
**SEPTEMBER 9-10, 2022**

- Great Smoky Mountains National Park has the **highest rates of nitrogen and sulfur pollution of any monitored location in North America**, resulting in park rainfall that is 5 - 10 times more acidic than normal.
- Many trees in the park are dead or dying, and the water is too acidic to support some native fish.
- The park also suffers from among the highest levels of ozone in the Eastern U.S.
  - Since 1990, ozone health limits have been exceeded on more than 300 days.
  - 90% of black cherry trees and milkweed plants in numerous park locations show symptoms of ozone damage
- Average visibility in the park has been cut by about 40% in winter and 80% in summer, and sometimes less than one mile, meaning visitors may not even see surrounding mountains.

*National Parks Conservation Association*

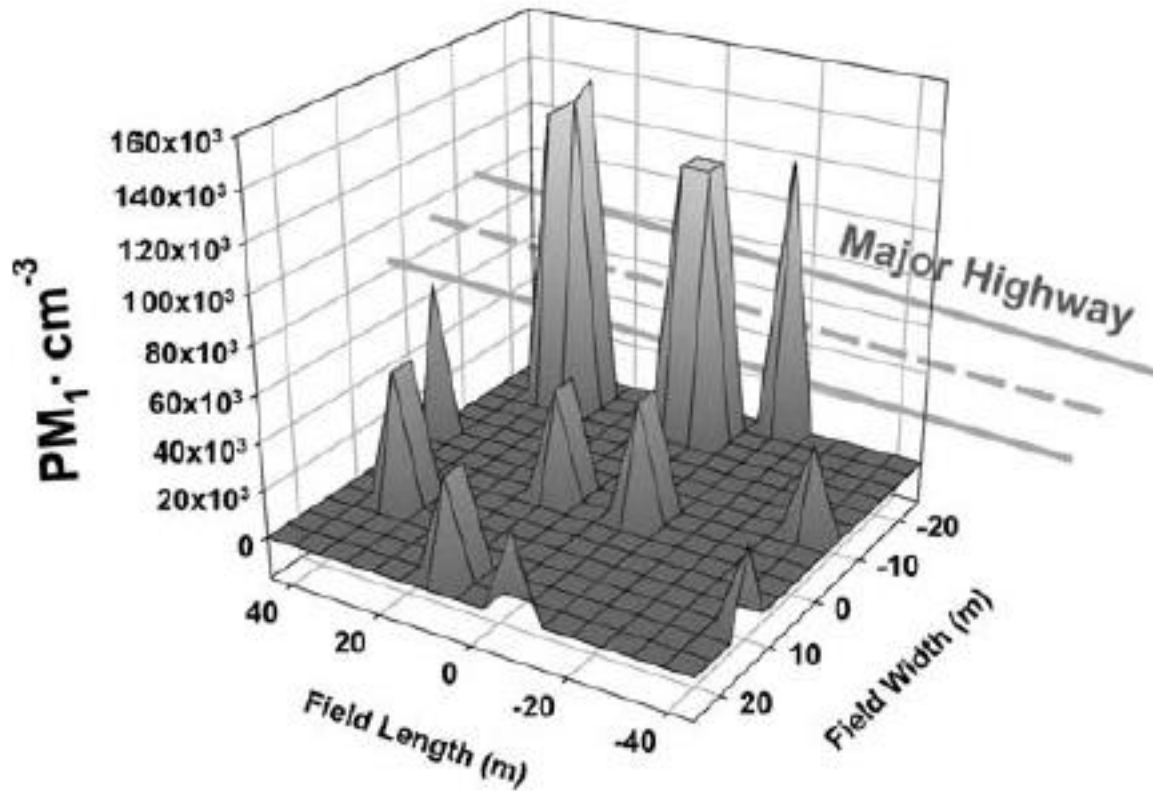
# Air pollution, athletic health and performance at the Olympic Games

*“For each of these seven Olympic Games, monitoring AQ was far below current acceptable standards and for the majority, minimal or no data on major pollutants was available. From what can be ascertained, at these Games, AQ varied but was less than optimal in most if not all.”*





# Vehicular Air Pollution, Playgrounds, and Youth Athletic Fields



Rundell K, et al. *Inhalation Toxicology* 2006



## Environmental exposure to combustion-derived air pollution is associated with reduced functional capacity in apparently healthy individuals

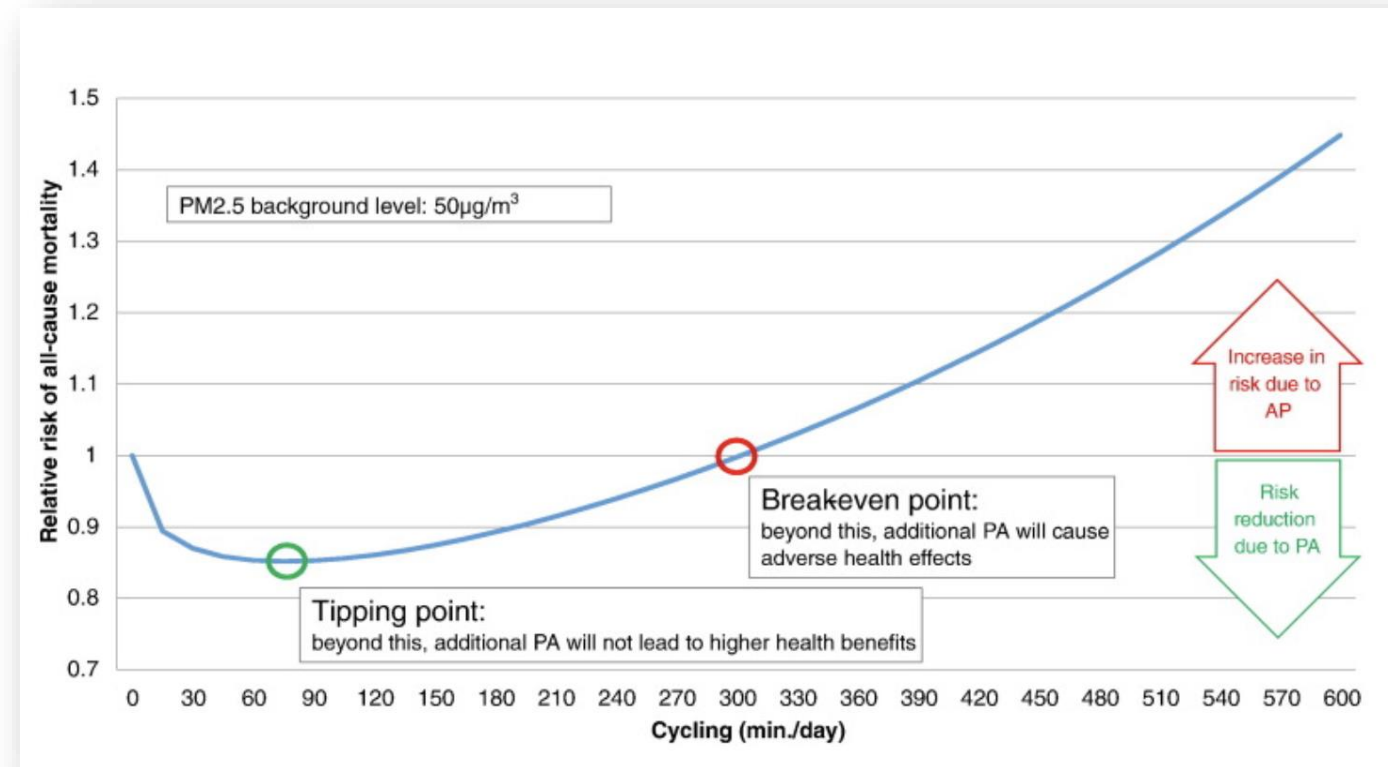
- Health adults living within 11 km from air quality monitoring station - 6,612 individuals (4,201 males and 2,411 females) underwent exercise testing
- Found a statistically significant short- and long-term negative correlation between exposure to air pollutants, mainly CO and NO<sub>2</sub> and between the metabolic equivalents achieved. A similar short-term effect was found for SO<sub>2</sub>.

*Steinvil A. Clin Res Cardiol. 2013*



# Can air pollution negate the health benefits of cycling and walking?

- Examined the risk–benefit balance between active travel related PA and exposure to air pollution across a range of air pollution and PA scenarios.
- “*Breakeven point*” = risk from air pollution start to out-weigh the benefits of PA
- This study indicates that air pollution risks will not negate the health benefits of active travel in urban areas in the vast majority of settings worldwide.
- Even in areas with high background PM2.5 concentrations, such as 100  $\mu\text{g}/\text{m}^3$ , up to 1 h 15 min of cycling and 10 h 30 min of walking per day will lead to net reduction in all-cause mortality



Tainio M. Preventive Med 2016 Jun;87:233-36.



**ESC**

European Society  
of Cardiology

European Heart Journal (2021) **42**, 2498–2500

doi:10.1093/eurheartj/ehab227

**EDITORIAL**

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# Running in polluted air is a two-edged sword — physical exercise in low air pollution areas is cardioprotective but detrimental for the heart in high air pollution areas

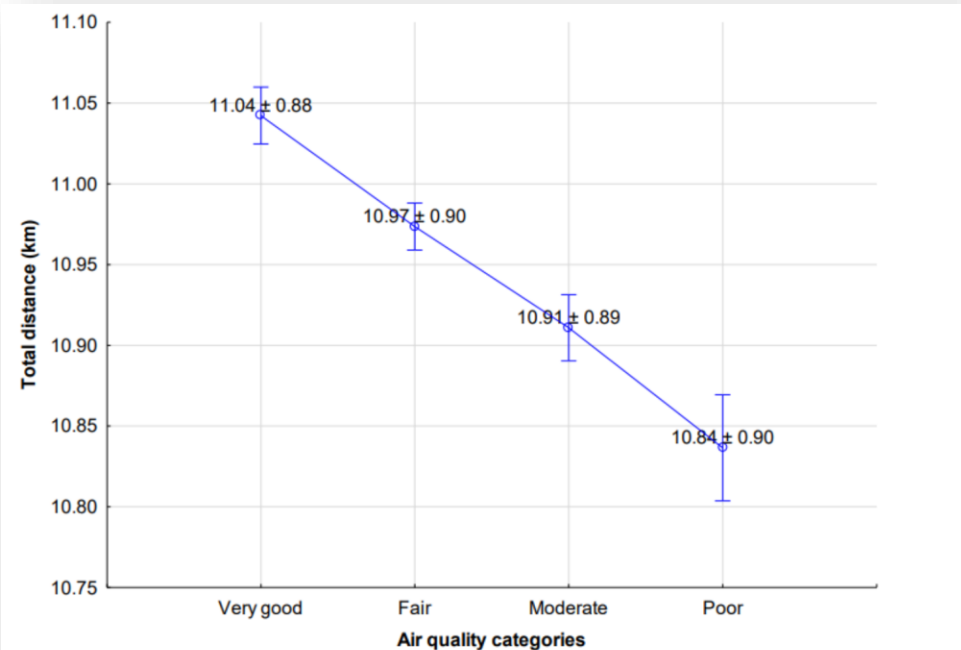
**Thomas Münzel**  <sup>1,2\*</sup>, **Omar Hahad**  <sup>1,2</sup>, and **Andreas Daiber**  <sup>1,2</sup>



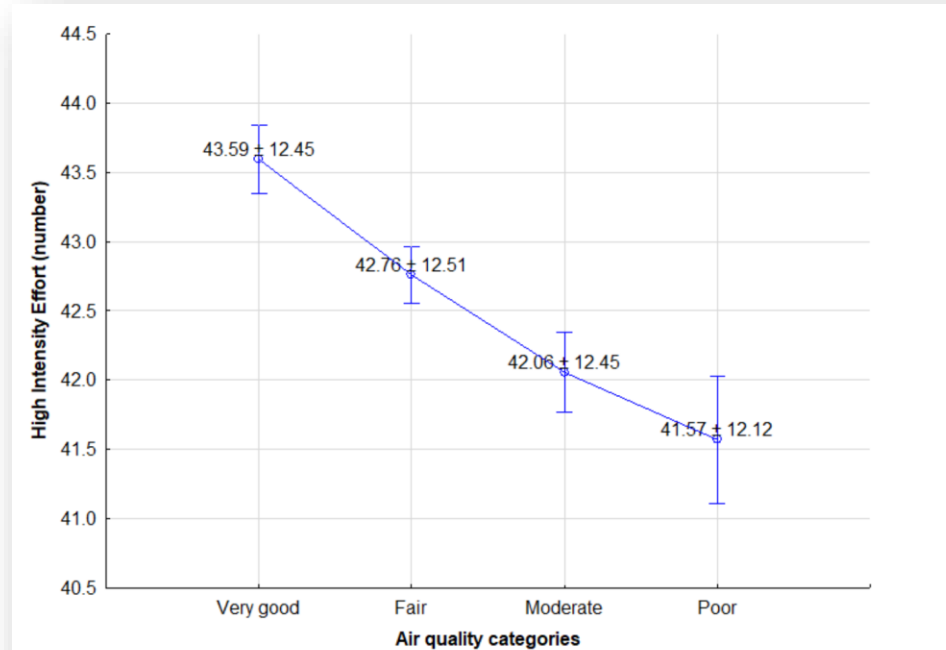
Article

# Air Pollutants Reduce the Physical Activity of Professional Soccer Players

Michał Zacharko <sup>1,\*</sup> , Robert Cichowicz <sup>2</sup> , Marcin Andrzejewski <sup>3</sup> , Paweł Chmura <sup>1</sup> , Edward Kowalczyk <sup>4</sup>, Jan Chmura <sup>1</sup> and Marek Konefał <sup>1</sup>



**Figure 1.** Differences in total distance covered by soccer players in relation to changes in air quality categories (mean ± SE). Differences statistically significant between very good vs. fair  $p = 0.01$ , fair vs. moderate  $p = 0.01$ , and moderate vs. poor  $p = 0.05$  (Source: own elaboration).

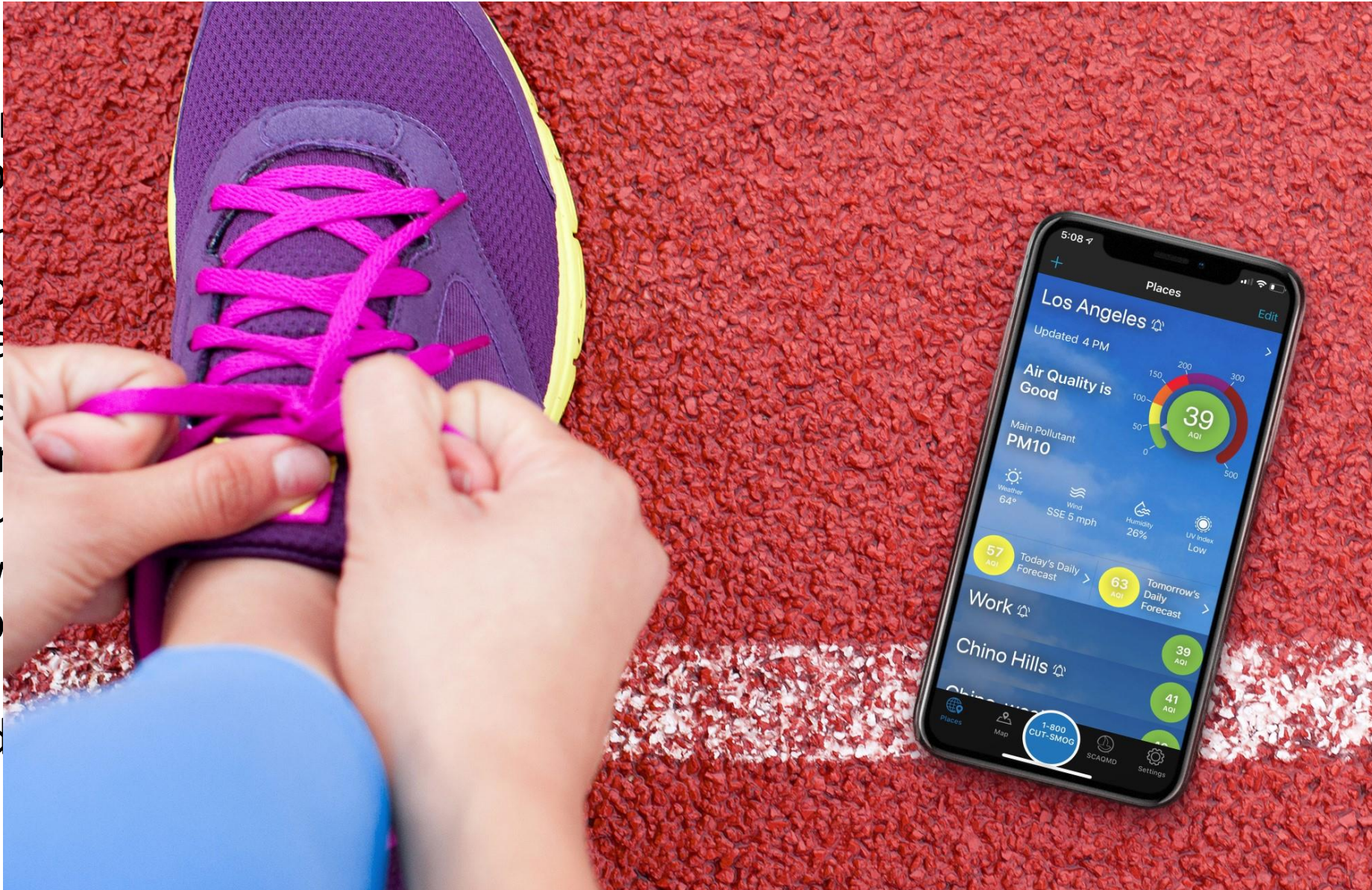


**Figure 2.** Differences in high-intensity effort of soccer players in relation to changes in air quality categories (mean ± SE). Differences statistically significant between very good vs. fair  $p = 0.01$  and fair vs. moderate  $p = 0.05$  (Source: own elaboration).



# Bottom Line

- Health time and suscep
- Guidance for the pregnant
- Modes appear without  
– How imp indi
- Should US Air



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## Outdoor Air Quality and Childhood Asthma

Poor air quality is unhealthy for everyone, but especially for children because they breathe faster, they play outside more often, and they are more likely to develop asthma to develop in a child who did not have asthma — and can make symptoms come on faster.

**NOW**

- Worse asthma symptoms
- More severe respiratory infections

The Air Quality Index (AQI) is a number for reporting how clean or unhealthy your air is every day. You can find it on the Internet at [AirNow.gov](http://AirNow.gov). It's also reported in local news sources.

When AQI is:

1-50  
**GOOD**

51-100  
**MODERATE**

101-150  
**UNHEALTHY**  
for sensitive groups

151-200  
**UNHEALTHY**

201-300  
**VERY UNHEALTHY**

Limit time of outdoor activities

Play indoors

## Outdoor Air Quality and Adult Asthma

Poor air quality is unhealthy for everyone, but especially for people with asthma. Poor air quality can be a trigger for your asthma — and can make symptoms come on faster. People who are sensitive to air pollution, especially sensitive groups should take action, this includes:

**NOW**

- Worse asthma symptoms
- More severe respiratory infections
- More severe respiratory infections

The Air Quality Index (AQI) is a number for reporting how clean or unhealthy your air is every day. You can find it on the Internet at [AirNow.gov](http://AirNow.gov). It's also reported in local news sources.

When AQI is:

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101-150  
**UNHEALTHY**  
for sensitive groups

151-200  
**UNHEALTHY**

201-300  
**VERY UNHEALTHY**

Limit time of outdoor activities

Reduce or avoid outdoor exercise

Avoid all outdoor exercise

## Outdoor Air Quality and Coronary Artery Disease

Poor air quality is unhealthy for everyone, but especially for people with coronary artery disease. The recommendations below relate to your specific health condition for how much you exercise. For people with coronary artery disease:

**NOW**

- Shortness of breath
- Chest pain
- Heart attack
- More severe respiratory infections

The Air Quality Index (AQI) is a number for reporting how clean or unhealthy your air is every day. You can find it on the Internet at [AirNow.gov](http://AirNow.gov). It's also reported in local news sources.

When AQI is: A person with coronary artery disease should:

1-50  
**GOOD**

51-100  
**MODERATE**

101-150  
**UNHEALTHY**  
for sensitive groups

151-200  
**UNHEALTHY**

201-300  
**VERY UNHEALTHY**

Enjoy usual outdoor activities

Take it easy outdoors

Plan necessary outdoor activities at times of day when air quality is better (usually morning)

Avoid outdoor air in places with a lot of traffic

## Outdoor Air Quality and Stroke

Poor air quality is unhealthy for everyone, but especially for older adults and people at risk for stroke. If you have had a stroke in the past, poor air quality can make you more likely to have another one. For people at risk for stroke, poor air quality can cause:

**NOW**

- Stroke
- Heart attack
- More hospital and emergency visits

**LONG TERM**

- Greater risk of stroke, blood clots, heart attack, and early death

The Air Quality Index (AQI) is a number for reporting how clean or unhealthy your air is every day. You can find it on the Internet at [AirNow.gov](http://AirNow.gov). It's also reported in local news sources.

When AQI is: A person at risk for stroke should:

1-50  
**GOOD**

51-100  
**MODERATE**

101-150  
**UNHEALTHY**  
for sensitive groups

151-200  
**UNHEALTHY**

201-300  
**VERY UNHEALTHY**

Enjoy usual outdoor activities

Reduce outdoor exercise — not as long, not as hard. If you have symptoms, stay indoors.

Plan necessary outdoor activities at times of day when air quality is better (usually morning)

Avoid outdoor air in places with a lot of traffic

Exercise indoors

If you have a sudden problem with:

- Balance
- Eyes
- Face drooping
- Arm weakness
- Speech

Get emergency help immediately

Always take your medications as prescribed by your doctor, especially when air quality is unhealthy

## When AQI is:

## People sensitive to ozone should:

(These include children, older adults, people with asthma or other lung diseases, and people working or exercising outdoors)

1–50

**GOOD**



Enjoy usual outdoor activities



51–100

**MODERATE**



Consider reducing outdoor exercise — not as long, not as hard, not in afternoon

101–150

**UNHEALTHY**

for sensitive groups



Reduce or avoid outdoor exercise



Plan outdoor activities before noon or after 6 PM — when ozone levels are lower



Whenever possible, don't exercise outdoors in places with a lot of traffic

151–200

**UNHEALTHY**

for all

Avoid all outdoor exercise

Moving even a few blocks away can help

201–300

**VERY UNHEALTHY**

for all



## Outdoor Air Quality and Health

September 2015

The Air Quality and Health Team, under the guidance of Intermountain Live Well and the Office of the Sustainability, developed this care process model (CPM) to provide evidence-based guidelines on the health effects of air quality. It is primarily intended to help providers counsel patients about outdoor physical activity when air quality is poor. This CPM is based on guidelines from the U.S. Environmental Protection Agency, current research on air quality and health, and advice from Intermountain experts.

### ► Why Focus on OUTDOOR AIR QUALITY?

- **Everyone is affected.** Air quality affects the entire population we care for. All providers need to know how to counsel patients on how to respond. Because exposure to polluted air cannot be measured in the individual patient, it is usually not apparent as a contributor to acute and chronic health conditions. The World Health Organization (WHO) estimates, however, that 2 million premature deaths may be attributable to air pollution each year.<sup>WHO</sup>
- **A high proportion of Utah's population is at risk.** People at increased risk for adverse health outcomes from exposure to poor air include children, the elderly, and people with existing asthma, lung disease, cardiovascular disease, and stroke. One-third of Utah's population is either 18 and under or 65 and older; about 230,000 have asthma; and nearly 500,000 have cardiovascular disease.
- **Utah's air can be especially bad.** The American Lung Association's *State of the Air 2015* report ranked the Salt Lake City-Provo-Orem area as the 7th worst in the U.S. for short-term spikes in particle pollution, a regular occurrence during wintertime temperature inversions. Logan was ranked 8th.<sup>ALA</sup>
- **Clear, objective evidence** can aid healthcare providers in counseling patients. This CPM provides evidence-based recommendations, acknowledges gaps in our current understanding of the health effects of air pollution, and helps clinicians better understand susceptible groups for whom a more precautionary approach may be advised.

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### ► GOALS

- The goals of this CPM are to:
- Improve clinicians' knowledge of the impact of air quality on health outcomes.
  - Help clinicians provide evidence-based recommendations to their patients.



# Outdoor Air Quality and Health Care Process Model



Care Process Model SEPTEMBER 2015



## Outdoor Air Quality and Health

September 2015

The Air Quality and Health Team, under the guidance of Intermountain LiVe Well and the Office of the Sustainability, developed this care process model (CPM) to provide evidence-based guidelines on the health effects of air quality. It is primarily intended to help providers counsel patients about outdoor physical activity when air quality is poor. This CPM is based on guidelines from the U.S. Environmental Protection Agency, current research on air quality and health, and advice from Intermountain experts.

► **Why Focus on OUTDOOR AIR QUALITY?**


- **Everyone is affected.** Air quality affects the entire population we care for. All providers need to know how to counsel patients on how to respond. Because exposure to polluted air cannot be measured in the individual

► **WHAT'S INSIDE**

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### Outdoor Air Quality and Health - Intermountain Healthcare

Sep 3, 2015 — The **Air Quality and Health** Team, under the guidance of **Intermountain** ... this **care process model** (CPM) to provide evidence-based guidelines ...



## ► POLLUTANTS

The table below lists “criteria pollutants,” or pollutants with national air quality standards that define allowable concentrations in ambient air. Click on each pollutant name to link to more detailed information from the U.S. Environmental Protection Agency.

Pollutant	What it is	Mechanisms of harm and populations at risk
<a href="#">Particulate matter (PM)</a>	<p>Particulate matter (PM) is a complex mixture of particles and liquid droplets of varied constituents, including acids, organic chemicals, metals, soil, and dust. PM is categorized by size, which in turn dictates health effects.</p> <ul style="list-style-type: none"> <li>• <b>PM<sub>10</sub></b> — coarse particles, such as those found in the dust of roadways, agriculture, or construction sites, and are between 2.5 µm (micrometers) and 10 µm in diameter.</li> <li>• <b>PM<sub>2.5</sub></b> — fine particles, such as those found in smoke and haze, are less than 2.5 µm in diameter. These are formed from gas and condensation of high temperature vapors during combustion.</li> <li>• <b>PM<sub>1.0</sub></b> — ultrafine particles, a subset of fine particles, are less than 1.0 µm in diameter. The leading source is motor vehicles, especially those powered by diesel engines.</li> </ul> <p><b>Sources:</b> Human and natural activities, including vehicle emissions, industrial processes, agricultural operations, combustion of wood and fossil fuels, construction activities, road dust, windblown dust, wind erosion, and wildfires.</p>	<p>Particle size and composition influence the toxicity of PM.</p> <p>PM<sub>10</sub> uses gravity to settle in the nasal or oral cavities, pharynx, larynx, and upper trachea and relies on mucociliary clearance for removal.</p> 
<a href="#">Ground-level ozone (O<sub>3</sub>)</a>	<p>Ground-level ozone (O<sub>3</sub>) is a major component of smog. (Atmospheric ozone is a natural part of the atmosphere.) Ground-level ozone is created by a chemical reaction between nitrogen oxides (NO<sub>x</sub>) and volatile organic compounds (VOCs) in the presence of sunlight. It's most common later in the day. In high-altitude areas like the Colorado Plateau, Valley and Uintah Basin, ground-level ozone is worse in urban environments and can travel miles by wind.</p> <p><b>Sources:</b> Emissions from motor vehicle exhaust, gas stoves, and other sources that burn fossil fuels.</p>	<p>Including airway inflammation in healthy people and increased respiratory symptoms in people with asthma.</p> <p><b>Populations at greatest risk:</b> people with asthma, children, and older adults.</p>
<a href="#">Sulfur dioxide (SO<sub>2</sub>)</a>	<p>SO<sub>2</sub> reacts with other compounds to form sulfate particles.</p> <p><b>Sources:</b> Vehicle emissions, power plants, and other sources that burn fossil fuels.</p>	<p>CO exposure initiates pulmonary and systemic oxidative stress, leading to a cascade of physiological responses that can instigate cardiovascular events such as congestive heart failure, cerebrovascular disease, anemia, and COPD.<sup>100</sup> Large quantities of CO inhibit the ability of hemoglobin to deliver oxygen to the body.</p> <p><b>Populations at greatest risk:</b> people with cardiovascular disease or lung disease, pregnant women and their fetuses, and young infants.</p>
<a href="#">Nitrogen oxides (NO<sub>x</sub>)</a>	<p>NO<sub>x</sub> contributes to the formation of ground-level ozone and particulate matter.</p> <p><b>Sources:</b> Emissions of motor vehicles, power plants, gas appliances, and other sources that burn fossil fuels.</p>	<p>CO exposure initiates pulmonary and systemic oxidative stress, leading to a cascade of physiological responses that can instigate cardiovascular events such as congestive heart failure, cerebrovascular disease, anemia, and COPD.<sup>100</sup> Large quantities of CO inhibit the ability of hemoglobin to deliver oxygen to the body.</p> <p><b>Populations at greatest risk:</b> people with cardiovascular disease or lung disease, pregnant women and their fetuses, and young infants.</p>
<a href="#">Carbon monoxide (CO)</a>	<p>CO is a toxic gas that is colorless, odorless, and tasteless. In addition to the conditions described at right, it can cause sudden illness or death.</p> <p><b>Sources:</b> Vehicle exhaust, fuel-burning appliances (wood stoves, gas water heaters, gas stoves, improperly used generators in enclosed spaces, unvented gas or kerosene heaters), cars idling in enclosed spaces, and smoking.</p>	<p>CO exposure initiates pulmonary and systemic oxidative stress, leading to a cascade of physiological responses that can instigate cardiovascular events such as congestive heart failure, cerebrovascular disease, anemia, and COPD.<sup>100</sup> Large quantities of CO inhibit the ability of hemoglobin to deliver oxygen to the body.</p> <p><b>Populations at greatest risk:</b> people with cardiovascular disease or lung disease, pregnant women and their fetuses, and young infants.</p>

### Pollutant

### Particulate matter (PM)

### What it is

Particulate matter (PM) is a complex mixture of particles and liquid droplets of varied constituents, including acids, organic chemicals, metals, soil, and dust. PM is categorized by size, which in turn dictates health effects.

- **PM<sub>10</sub>** — coarse particles, such as those found in the dust of roadways, agriculture, or construction sites, and are between 2.5 µm (micrometers) and 10 µm in diameter.
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- **PM<sub>1.0</sub>** — ultrafine particles, a subset of fine particles, are less than 1.0 µm in diameter. The leading source is motor vehicles, especially those powered by diesel engines.

**Sources:** Human and natural activities, including vehicle emissions, industrial processes, agricultural operations, combustion of wood and fossil fuels, construction activities, road dust, windblown dust, wind erosion, and wildfires.

### Mechanisms of harm and populations at risk

Particle size and composition influence the toxicity of PM.

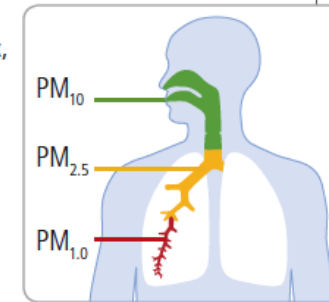
PM<sub>10</sub> uses gravity to settle in the nasal or oral cavities, pharynx, larynx, and upper trachea and relies on mucociliary clearance for removal.

PM<sub>2.5</sub> deposits on the surface of epithelial cells in the bronchioles and alveoli, and are phagocytosed by alveolar macrophages.

PM<sub>1.0</sub> deposition depends largely on diffusion and may have unique effects because of translocation into the bloodstream, with transport to other organs, including the heart and brain.

Both PM<sub>2.5</sub> and PM<sub>1.0</sub> have been implicated in inducing pulmonary and systemic inflammation and oxidative stress, and may be associated with various cardiovascular endpoints, including vascular and endothelial dysfunction, alterations in heart rate variability, coagulation, and cardiac autonomic function.

**Populations at greatest risk:** people with heart or lung disease, previous stroke, older adults, and children.



Particle size determines level of deposition.

## ▶ HEALTH EFFECTS OF POOR AIR QUALITY

TABLE 1. Health effects of poor air

Acute effects of **short-term** exposure

Long-term effects of **repeated or chronic** exposure

### Heart

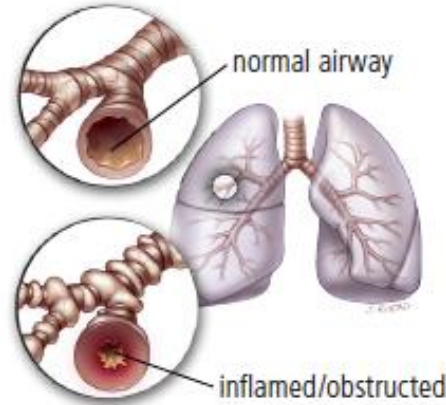
- PM is associated with changes in heart rate variability, blood pressure, vascular tone, blood coagulability, and destabilization and rupture of existing coronary artery plaque.<sup>488</sup>
- CO reduces the oxygen-carrying capacity of the blood.



- PM exposure may accelerate the progression of atherosclerosis. Many of these effects are mediated through proinflammatory pathways and the generation of reactive oxygen species.<sup>489</sup>

### Lungs

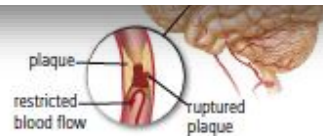
- PM is associated with significant inflammatory response even in healthy controls, and with increased asthma symptoms in those with asthma.<sup>541</sup>
- Ozone is associated with decreased lung function and inflamed lung tissue, leading to neural shortness of breath, chest pain, cough, throat irritation, and congestion.
- NO<sub>2</sub> is associated with airway inflammation in people with and without asthma.



- PM exposure is associated with pulmonary inflammation, airway obstruction, and increased susceptibility to respiratory infection and sensitivity to allergens, increased childhood wheeze,<sup>510</sup> and asthma development.<sup>508</sup> It is also associated with increased risk of lung cancer.<sup>485</sup>
- In children, repeated short-term ozone exposure damages developing lungs and may lead to reduced lung function in adulthood.
- In adults, ozone exposure may permanently scar lung tissue and accelerate the natural decline in lung function that occurs with age.<sup>504</sup>

Both stroke exposure and history risk factors.<sup>488</sup>

- Systemic effects known to impact lung and cardiovascular disease also impinge on central nervous system health.<sup>492</sup>



of ischemic stroke, Alzheimer's disease, and Parkinson's disease.<sup>492</sup>

- PM has been associated with insidious effects on structural brain aging, even in dementia-free and stroke-free persons.<sup>491</sup>

### Pregnancy, infant, young child

- Researchers suspect that lung inflammation initiates a biochemical response that may cause placental insufficiency.<sup>192</sup>
- High levels of PM or CO during pregnancy may interfere with placental development and subsequent oxygen and nutrient delivery to the fetus.
- CO complicates the delivery of oxygen to the developing fetus.<sup>489</sup>



- PM exposure is associated with premature delivery and low birth weight.<sup>192</sup>
- Maternal PM exposure during pregnancy may contribute to higher rates of infant mortality.<sup>192</sup>
- Children are at greatest risk from ozone exposure, as their lungs are still developing and they are more likely to be active outdoors when ozone levels are high.<sup>192</sup>



**AVOIDING OR REDUCING EXPOSURE**

The factors listed below increase health risk from poor air. Most recommended patient counselling revolves around these issues.

- **Prolonged exertion** is outdoor activity, either continued or intermittent, over several hours that causes a person to breathe harder than normal. Examples include working in the yard for part of the day, doing outdoor work, or prolonged exercise.
  - Counsel patients to reduce activity time or schedule activity early in the day when pollution is less.
- **Heavy exertion.** Intense outdoor activity that causes a person to breathe hard.
  - Counsel patients to exercise indoors, early in the day, or at an altitude above the inversion.
- **Increased pollution levels.** Ambient air pollution is generally worse near roads with heavy traffic and during commute hours, when more vehicles are on the road.
  - Counsel patients to avoid exposure to outdoor air near heavy road traffic whenever possible, and to schedule outdoor activities early in the day.<sup>40</sup>
- **Individual susceptibility.** Patients should be taught to pay attention to how they feel and learn their personal sensitivity to each risk level of the Air Quality Index (see page 7).
  - Counsel patients to pay attention to places and situations that induce reactions. People who experience any unusual coughing, chest discomfort, wheezing, breathing difficulty, or unusual fatigue should reduce their activity level or move inside. Persistent symptoms should prompt medical attention.

**WHAT WE DON'T KNOW**

Exposure to poor quality air varies greatly among individuals. We don't know enough to be able to provide detailed advice on safe:

- Duration of exposure
- Chronicity of exposure
- Intensity of activity

**▶ COUNSELLING PATIENTS**

Poor quality air can affect all people, but certain populations are at increased risk. The guidelines outlined below are designed to help providers recommend reasonable safety precautions without causing undue alarm. The handouts pictured in each section provide guidance for patients. See page 8 for ordering instructions.

**Pregnant women and developing fetuses**

**What we know:** Prenatal exposure to high levels of polluted air can increase the risk of preterm birth, intrauterine growth retardation (IUGR), and low birth weight (LBW).<sup>41</sup> Women exposed to high levels of ozone during the second and third trimesters are at particular risk for IUGR.<sup>42</sup> In utero and early life exposure to traffic-related pollution may increase the likelihood of clinically significant asthma later in life.<sup>43</sup>

**What remains unclear:** Existing evidence does not allow precise identification of specific pollutants and timing of exposure that can result in birth defects.<sup>44</sup> A recent study found that higher maternal exposure to PM<sub>2.5</sub> during pregnancy, in particular the third trimester, was associated with greater odds of having a child with autism spectrum disorder.<sup>45</sup> Further study is needed before this association can be confirmed.

**What to do:** Counsel patients to adjust activity or stay indoors during inversions and other periods of high AQI, and to quit smoking. Give the [patient fact sheet](#).



**Very young children**

**What we know:** Young children are especially vulnerable due to ongoing lung development, incomplete metabolic systems, immature host defenses, and activity patterns that lead to higher exposure.<sup>46</sup> Chronic exposure to air pollution may increase the risk of respiratory infections.<sup>47</sup>

- Ambient air pollution is associated with increased upper and lower respiratory symptoms, reduced lung growth rates and lung function, aggravation of asthma, and increased cough and bronchitis.<sup>48</sup>
- Children with underlying chronic lung diseases, particularly asthma and cystic fibrosis, are especially vulnerable later in childhood.<sup>49</sup>

**What remains unclear:** Existing evidence does not show whether there is an increased risk of allergic sensitization in otherwise healthy children.

**What to do:** Counsel parents to keep very young children indoors during inversions and other periods of high AQI. Give the [patient fact sheet](#).



**Children with asthma**

**What we know:** The effect of poor air quality on asthma is greater in children than adults due to ongoing development of lungs, brain, and immune systems.

- Short-term exposure is associated with exacerbation of existing asthma; increased severity of respiratory symptoms; increased use of outpatient care, emergency department visits, and hospitalizations.<sup>50</sup>
- Long-term exposure is associated with development of new asthma<sup>51</sup>; possible delay of lung development<sup>52</sup>; Repeated short-term ozone damage to may lead to reduced lung function in adulthood.<sup>53</sup>

**What remains unclear:** Existing evidence does not show which element of pollution is most responsible, or whether day-by-day prevention is possible.

**What to do:** Manage acute exacerbations triggered by air pollution clinically in the same manner as those triggered by other factors. Counsel patients to follow their asthma action plan, adhere to medications, and to avoid playing/exercising outdoors when AQI is high. Give the [patient fact sheet](#).



**People exercising or working outdoors**

**What we know:** During exercise, elevated ventilation rate, mouth breathing, and increased airflow velocity carry pollutants deeper into the lungs and amplify the dose of pollutants. The effect may be worse in women.<sup>54</sup>

- People exercising may be at particular risk of ozone exposure, due to heavier exertion in summer.
- The benefits of exercise outweigh the risks. Individuals should change location or timing of exercise, not quit.

**What remains unclear:** It is not clear how much exposure is a danger, or how long a person needs to be exposed. Further research is needed to better understand the role of PM and athlete performance on respiratory and cardiovascular disease.<sup>55</sup>

**What to do:** Counsel patients to adjust activity and exercise indoors when possible. Give the [patient fact sheet](#).



**Adults with asthma**

**What we know:**

- Short-term exposure is associated with exacerbation of preexisting asthma; increased susceptibility to allergens<sup>56</sup>; reduced lung function and airway inflammation<sup>57</sup>; and increased use of asthma-related health services.<sup>58</sup> Patients with asthma have increased sensitivity to ozone, even at low levels of exposure.<sup>59</sup>
- Long-term exposure is associated with development of new asthma<sup>60</sup>; acceleration of age-related decline in lung function.

**What remains unclear:** Existing evidences does not show which elements of pollution are most responsible, or whether day-by-day prevention is possible.

**What to do:** Manage acute exacerbations triggered by air pollution clinically in the same manner as those triggered by other factors. Counsel patients to follow their asthma action plan, adhere to medications (especially when AQI is high), adjust activity, and quit smoking. Give the [patient fact sheet](#).



**Adults with lung disease (COPD, chronic bronchitis)**

**What we know:**

- Short-term exposure is linked to exacerbation of preexisting disease; increased coughing and wheezing; increase in COPD hospitalizations and COPD-related mortality.<sup>61</sup> Ambient air pollution, including traffic-related fine PM and wood smoke, is associated with increased risk of COPD<sup>62</sup> and chronic bronchitis.<sup>63</sup>
- COPD patients are especially susceptible to PM<sub>2.5</sub> and NO<sub>2</sub>.<sup>64</sup>

**What remains unclear:** Limited data exist in examining the relationship between air pollution exposure, physical activity, and resultant respiratory disease.

**What to do:** Manage acute exacerbations triggered by air pollution clinically in the same manner as those triggered by other factors. Counsel patients to adhere to medications (especially during periods of inversion), to adjust activity, and to quit smoking. Give the [patient fact sheet](#).



**Adults with existing cardiovascular conditions (CAD, CHF, unstable angina)**

**What we know:**

- Short-term exposure to poor air is linked to exacerbation of preexisting heart disease, increased hospitalization, and mortality due to cardiovascular disease, especially in persons with congestive heart failure, frequent arrhythmias, or both.<sup>65,66</sup>
- Short-term elevated PM exposures and related inflammation may contribute to acute ischemic events by increasing the risk of plaque rupture and thrombosis.<sup>67</sup> Exposure to particulate air pollution may play a role in precipitating heart failure symptoms in otherwise well-managed patients.<sup>68</sup>
- Long-term exposure to air pollutants (especially PM<sub>2.5</sub> sulfate particles, and SO<sub>2</sub>) has been linked to death from cardiovascular disease. There also appears to be an association between cardiopulmonary mortality and summertime ozone. Air pollution is associated with both ischemic and nonischemic cardiovascular events.<sup>69</sup>

**What remains unclear:** Limited data exist in examining the relationship between air pollution exposure, physical activity, and new onset cardiovascular disease.

**What to do:** Manage acute exacerbations triggered by air pollution clinically in the same manner as those triggered by other factors. Counsel patients to adhere to medications (especially when AQI is high), to adjust activity, and to quit smoking. Give the [patient fact sheet](#).



**Adults with existing neurological conditions (stroke, TIA)**

**What we know:**

- Short-term exposure to elevated levels of particulate matter and ozone increases the number of ischemic cerebrovascular events on subsequent days, especially in patients with prior history of stroke<sup>70</sup> and cardiac risk factors.<sup>71</sup> Recent PM<sub>2.5</sub> and ozone exposure has been associated with stroke/TIA risk even in a community with relatively low pollutant levels.<sup>72</sup>
- Long-term, chronic exposure to air pollution is also associated with increased risk of stroke. The association is stronger for fatal than nonfatal stroke, and stronger for ischemic than hemorrhagic stroke.<sup>73</sup>

**What remains unclear:** The pathways for such an increased susceptibility are unknown.

**What to do:** Manage acute exacerbations triggered by air pollution clinically in the same manner as those triggered by other factors. Counsel patients to adhere to medications (especially when AQI is high), to adjust activity, and to quit smoking. Give the [patient fact sheet](#).



**KEY RECOMMENDATIONS**

- Guidance related to air pollution exposure should not discourage physical activity, except for those with known cardiopulmonary disease.
- Counsel patients to adjust activity and/or exercise indoors as recommended in patient handout.
- Give patient fact sheet at visit. To pre-order color copies of fact sheets, see [Instructions on page 8](#).

**OLDER ADULTS ARE ALSO AT GREATER RISK**

Older adults are considered to be particularly susceptible to short-term risk. This may be due to the fact that they are more likely to have undiagnosed cardiovascular or respiratory conditions.



## ► COUNSELLING PATIENTS

Poor quality air can affect all people, but certain populations are at increased risk. The guidelines outlined below are designed to help providers recommend reasonable safety precautions without causing undue alarm. The handouts pictured in each section provide guidance for patients. *See page 8 for ordering instructions.*

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### Very young children

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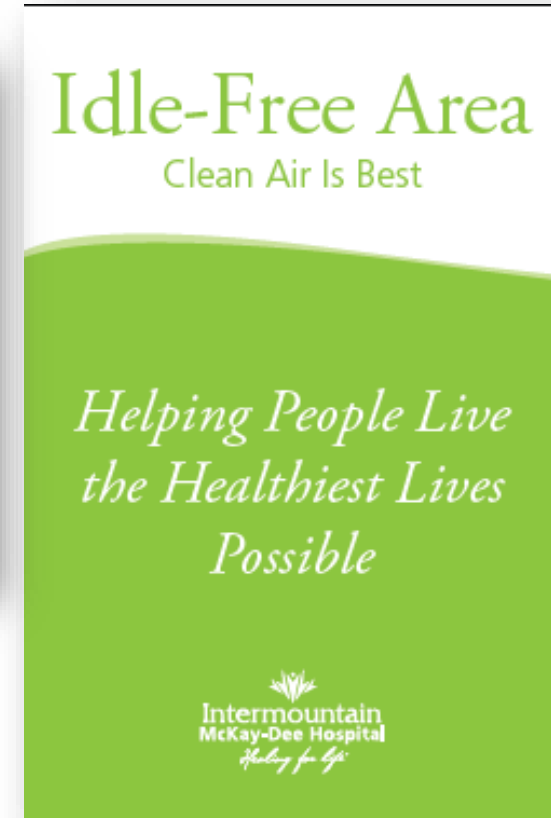
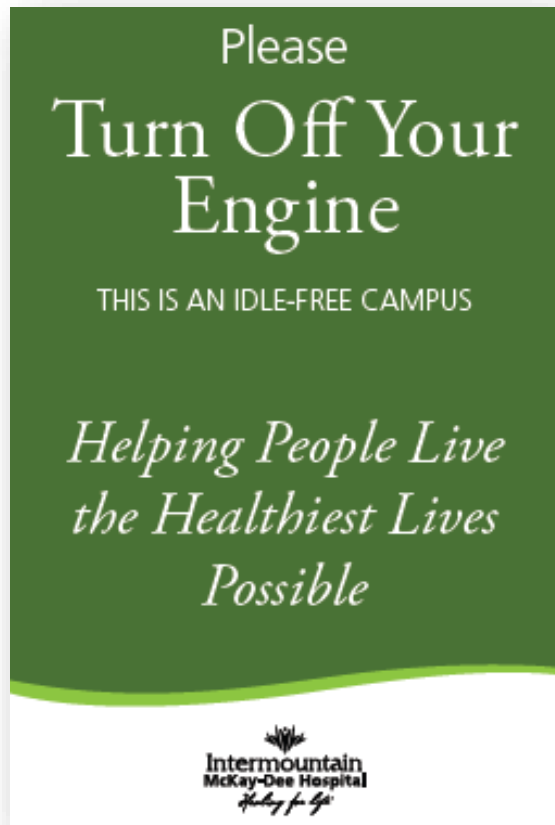
- Ambient air pollution is associated with increased upper and lower respiratory symptoms, reduced lung growth rates and lung function, aggravation of asthma, and increased cough and bronchitis.<sup>WHO</sup>
- Children with underlying chronic lung diseases, particularly asthma and cystic fibrosis, are especially vulnerable later in childhood.<sup>WHO</sup>

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# Idle-Free Campaign at Intermountain Hospitals



You two need to go  
inside and get some  
fresh air



Thank You [Liz.Joy@imail.org](mailto:Liz.Joy@imail.org)