Air Pollution: Breath, Heart, Mind

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What is Air Pollution?

"Air pollution is the introduction of harmful substances including particulates and biological molecules into Earth's atmosphere."

"It may cause diseases, allergies or death in humans; it may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment. Human activity and natural processes can both generate air pollution."

https://en.wikipedia.org/wiki/Air_pollution

Air Pollution from Saharan Dust, Austin, TX, June 2020

https://www.reddit.com/r/Austin/comments/hgibup/before_and_after_of_saharan_dust_cloud_in_austin/

Salt Lake City, UT

http://www.time-science.com/timescience/projects_meteo.asp

Types of Pollutants

- Primary (produced directly)
  - Particles
    - PM10, PM2.5, ultrafine
  - Gases
    - Sulfur oxides (SOx), nitrogen oxides (NOx), VOCs, etc
- Secondary (produced by chemical reactions involving primary pollutants)
  - Classic example is ozone formed from NOx and VOCs

Image from EPA website

Sources of Air Pollution

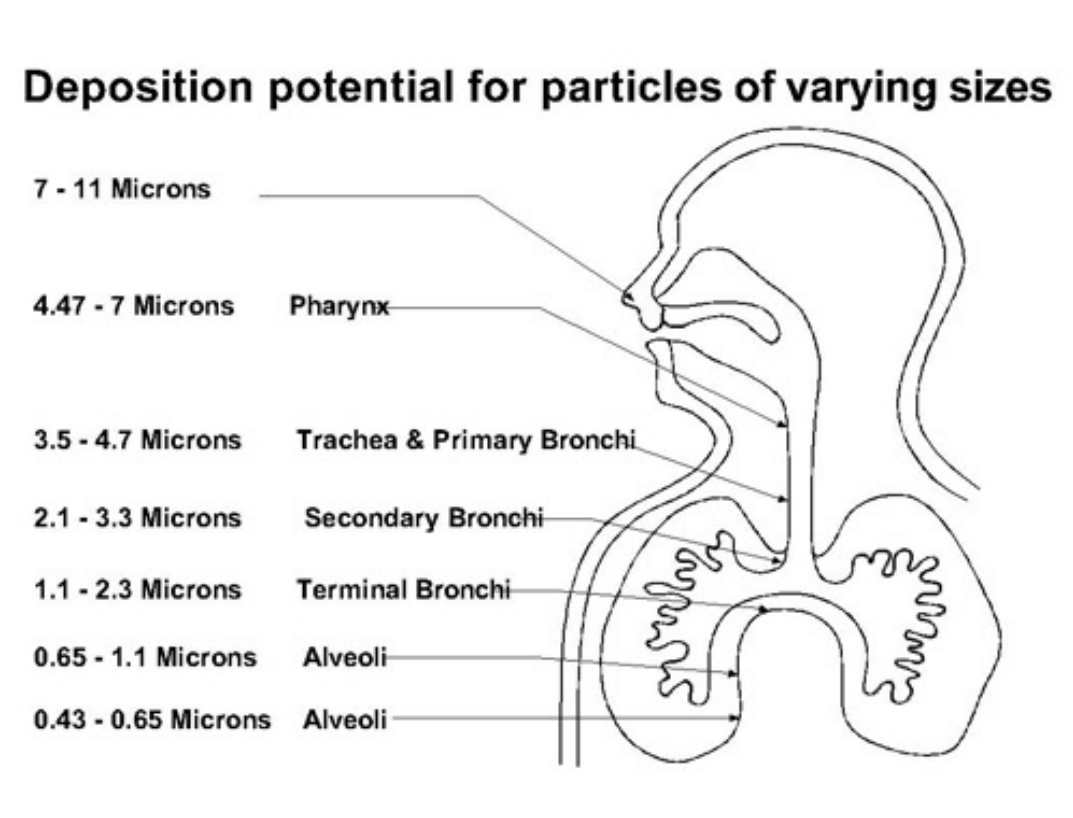
- Mobile: cars, buses, planes, trains, trucks, etc.
- Stationary: power plants, oil refineries, industrial facilities, factories
- Area: agricultural areas, cities
- Natural: dust events, wildfires, volcanoes

What is TRAP?

- Exhaust from motor vehicles
  - carbon dioxide (CO_2), carbon monoxide (CO)
  - hydrocarbons (HC)
  - nitrogen oxides (NO_X)
  - particulate matter (PM)
  - mobile-source air toxics (MSATs)- e.g. benzene, formaldehyde, acetaldehyde, 1,3-butadiene
- Non-combustion
  - Resuspended road dust, tire wear, brake wear
  - With increasing emissions controls for exhaust PM, proportion of TRAP PM from noncombustion sources increases
- Secondary pollutants: e.g. ozone
- Contribution to ambient air pollution: “In U.S. cities, the results show that motor-vehicle contributions range from 5% in Pittsburgh, Pa., under conditions with very high secondary aerosol, to 49% in Phoenix, Ariz., and 55% in Los Angeles, Calif.”

https://www.healtheffects.org/publication/traffic-related-air-pollution-critical-review-literature-emissions-exposure-and-health

Exposure occurs via airways & has systemic effects



- Nanoparticles enter circulation and can cause direct effects
- Some of these have been found in human brain (http://www.pnas.org/content/113/39/10797)

http://www.acrd.bc.ca/particulate-matter

Biologic markers of exposure or effect

- Marking of DNA - epigenetics
- Visualization of particles in olfactory nerve, brain, placenta
- Elevation of blood, airway, and urinary markers of inflammation

Bove et al, Nature communications. https://www.nature.com/articles/s41467-019-11654-3
Maher et al, PNAS https://www.ncbi.nlm.nih.gov/pubmed/27601646

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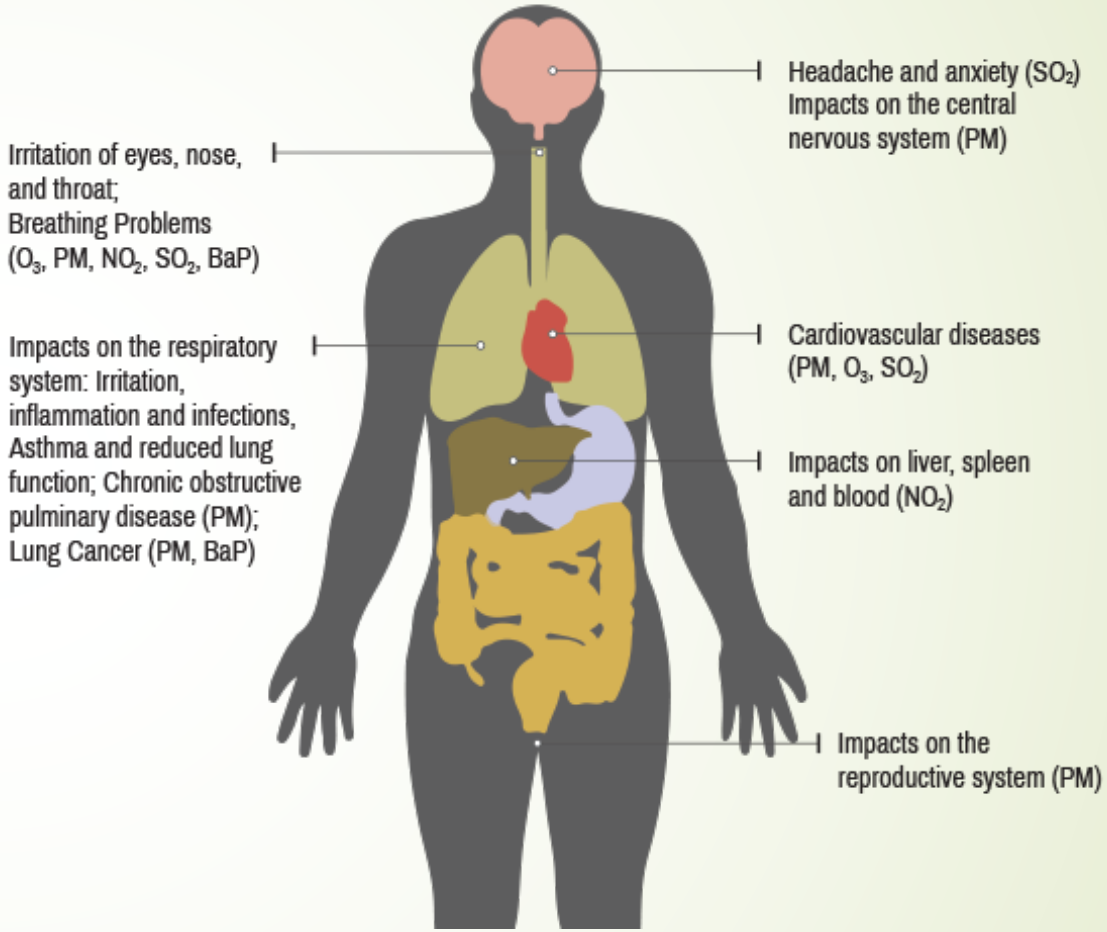
What are the health effects of outdoor air pollution?

- 7 million premature deaths worldwide every year
- ~88% of those premature deaths in low- and middle-income countries
  - ~72% of premature deaths due to ischemic heart disease and strokes
  - ~14% to chronic obstructive pulmonary disease or acute lower respiratory infections
  - ~14% of deaths due to lung cancer



https://wp.nyu.edu/cas-alicegw/2019/09/19/environmental-racism-and-its-connections-to-intelligence/human-health/

http://www.who.int/mediacentre/factsheets/fs313/en/

Air pollution acute health effects

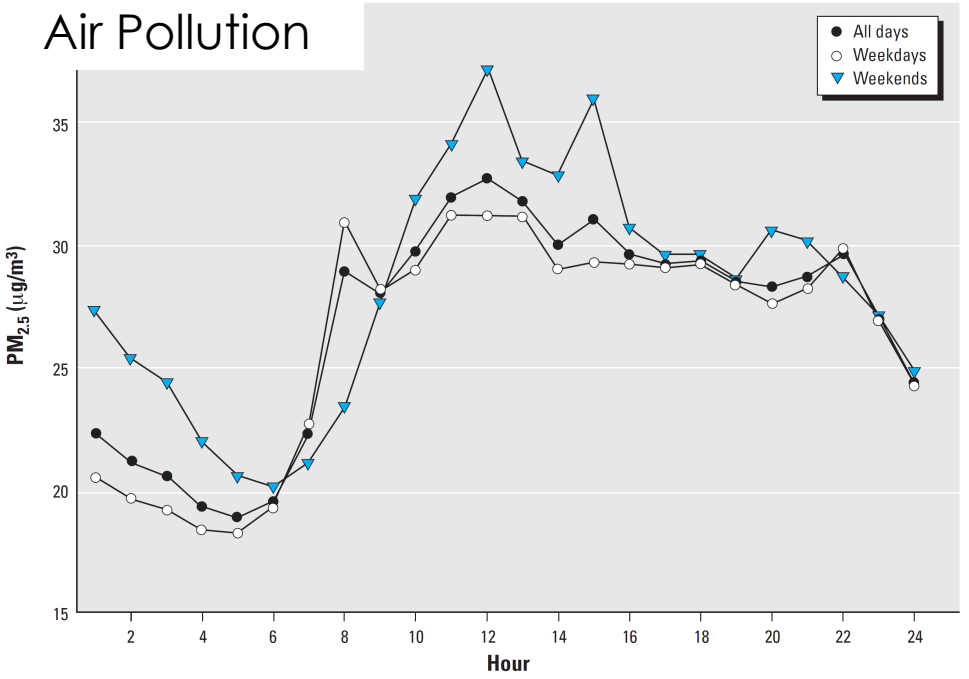
- Cardiovascular events (MI, TIA, stroke)
- Respiratory symptoms and events
  - COPD, asthma symptoms, ED visits
- Upper and lower respiratory tract infections

https://www.healtheffects.org/publication/traffic-related-air-pollution-critical-review-literature-emissions-exposure-and-health

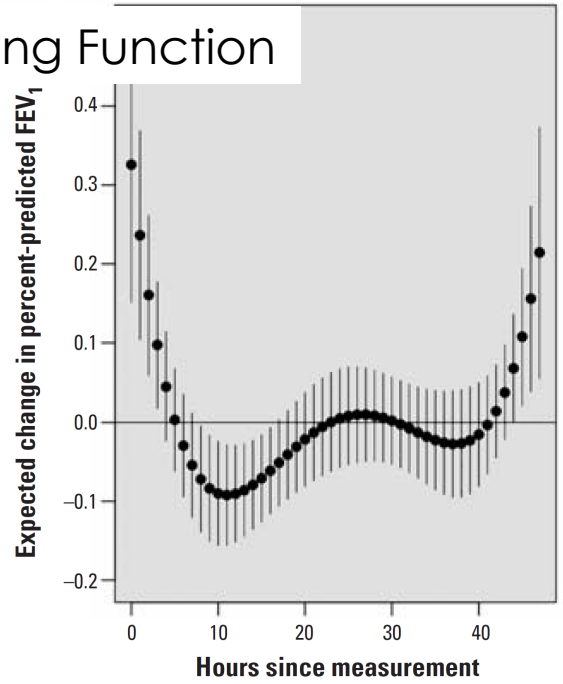
Higher PM2.5 Associated with Decreasing Lung Function

- ~50 children in Los Angeles area
- Exposure: $PM_{2.5}$ (hour maximal concentration)
  - Range from ~19-37mcg/m^3
- Outcome: Lung function, FEV_1=forced expiratory volume in 1 second
- Higher hourly personal PM2.5 associated with decreasing lung function (FEV1 % predicted)
  - Effect observed ~8-20 hours after exposure

Air Pollution

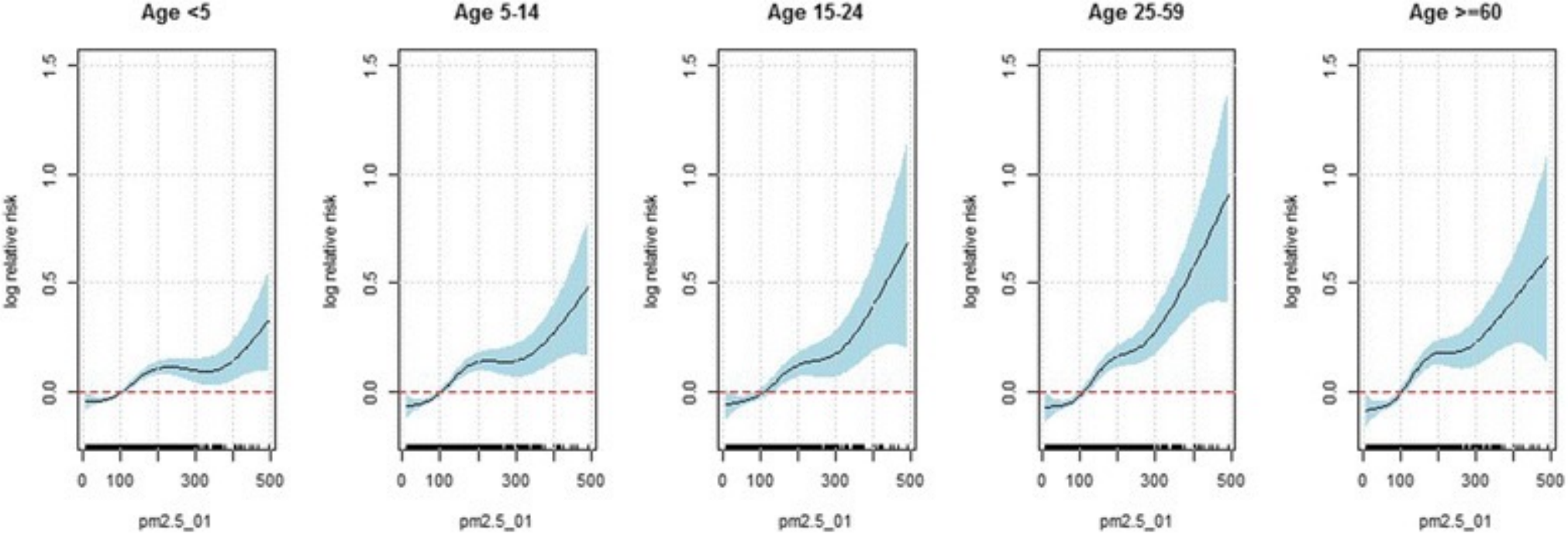


Lung Function



Delfino RJ EHP 2008

PM and influenza-like illness in Beijing



- Time-series study, Beijing
- Strong, positive association between PM2.5 and influenza-like illness during influenza season (Oct-Apr)

Feng C et al Environ Health Feb 2016

Higher PM2.5 Causes Increases in Risk of ED Visits for Asthma

The impact of PM2.5 on asthma emergency department visits: a systematic review and meta-analysis 16 studies from developed countries

- RR of asthma ED visit among children for every 10 mcg/m^3 increase in PM2.5: 1.036 (1.018-1.053)

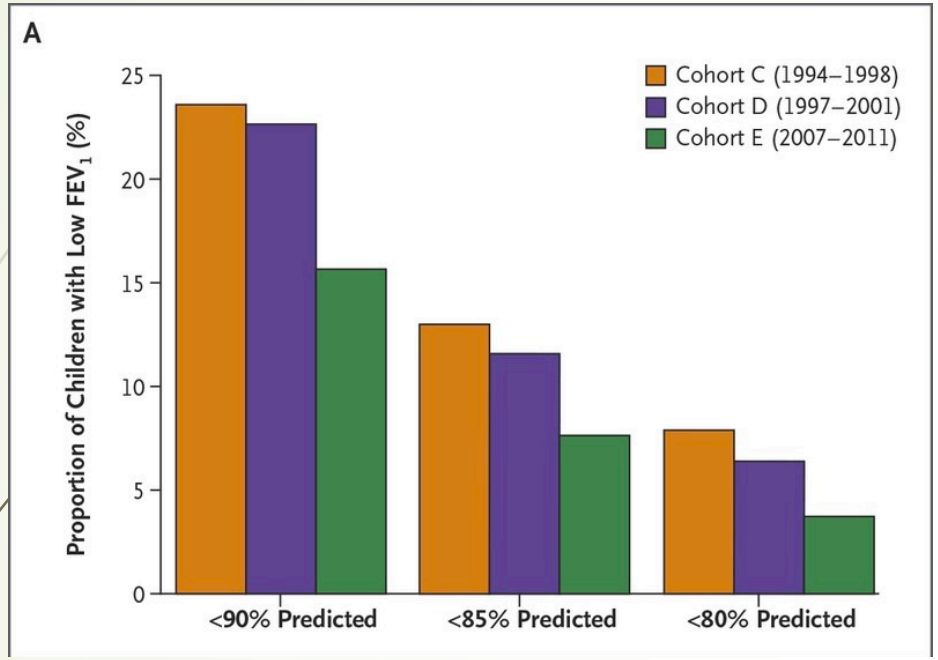
Environmental Science and Pollution Research January 2016, Volume 23, Issue 1, pp 843–850

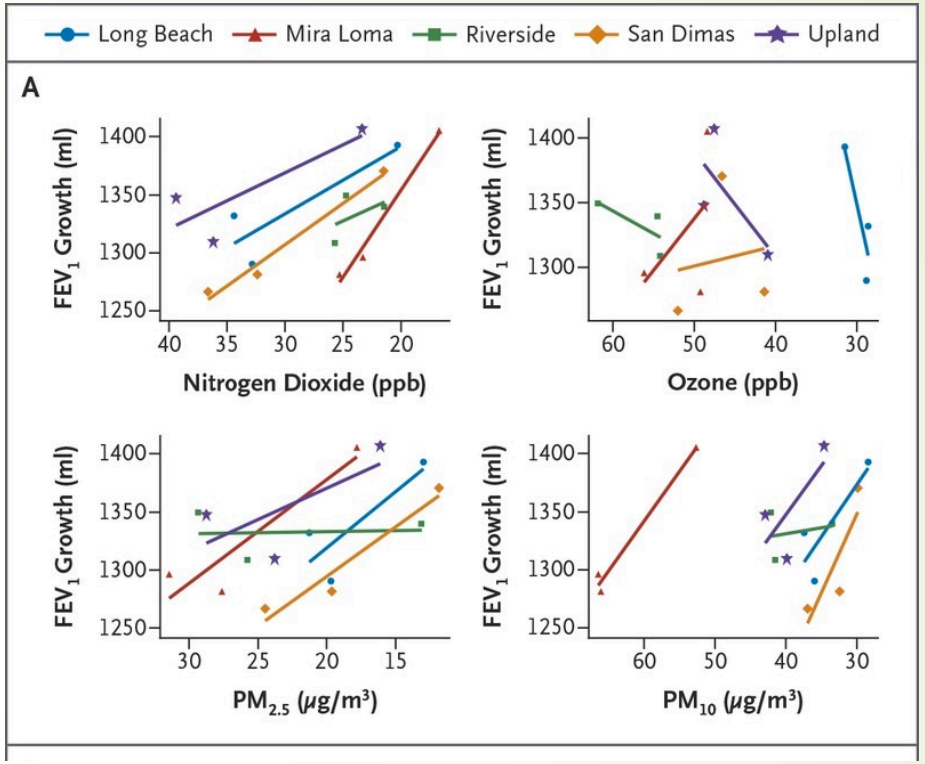
Acute Effects of Air Pollution

- Respiratory symptoms, infections, lung function, asthma and COPD exacerbations
- Cardiovascular effects – MI, TIA, stroke
- Deaths
- Some people are more susceptible than others
  - Asthma, COPD, lung disease
  - Cardiovascular disease
  - Weight
  - Stress
  - Co-exposure to cigarette smoke
  - Genetics

Air pollution chronic health effects

- Effects on outcomes that are a result of exposure over a period of months or years
- Asthma
- Lung function growth
- Birth weight, preterm birth





Air pollution & lung growth

Gauderman et al N Engl J Med Volume 372(10):905-913

Air Pollution and COVID-19 Mortality Risk

The Harvard Chan study led by Xiao Wu and Rachel Nethery and senior author Francesca Dominici found an association between air pollution over many years with an 11% increase in mortality from COVID-19 infection for every 1 microgram/cubic meter increase in air pollution (for comparison, many Americans breathe air with 8 micrograms/cubic meter of particulate matter).

While the study does not show that air pollution directly affects an individual's likelihood of dying from COVID-19 because individual-level COVID data is not yet publicly available, it does show an association between long term exposure to air pollution and higher COVID-19 mortality rates.

https://www.hsph.harvard.edu/c-change/subtopics/coronavirus-and-pollution/

Emerging air pollution effects on the brain

- Dementia
- Developmental disorders
  - Autism spectrum disorder
  - ADHD
- Psychosis

Liang et al, Environ Pollut 2019. https://www.ncbi.nlm.nih.gov/pubmed/30326384
Suades-González et al. Endocrinology 2015
https://www.ncbi.nlm.nih.gov/pubmed/26241071

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More Emerging Air Pollution Health Effects Science

- Obesity
- Diabetes
- Anthropogenic air pollution may prove to be more toxic
- Non criteria pollutants, meaning those not regulated by EPA, have important health effects
- Recent data points to health effects at lower concentrations than regulation standards

What Are Particulate Matter (PM) Air Quality Standards?

National Ambient Air Quality Standards (NAAQS) for PM pollution specify a maximum amount of PM to be present in outdoor air. There are different standards for PM_{10} and $PM_{2.5}$ (see Particulate Matter (PM) Basics to learn about particle types). Limiting PM pollution in the air protects human health and the environment.

Criteria Air Pollutants

The Clean Air Act requires EPA to set National Ambient Air Quality Standards (NAAQS) for six common air pollutants (also known as "criteria air pollutants"). These pollutants are found all over the U.S. They can harm your health and the environment, and cause property damage.

Learn how EPA sets, reviews and revises standards (primary standards and secondary standards), determines whether areas meet the standards, and works with areas to attain and maintain the standards.

Ground-level Ozone

- Ozone Pollution
- Setting and Reviewing Standards
- Scientific and Technical Documents
- Implementing the Standards
- Air Quality Designations

Particulate Matter

- Particle Pollution
- Setting and Reviewing the Standards
- Scientific and Technical Documents
- Implementing the Standards
- Air Quality Designations

Carbon Monoxide

- Carbon Monoxide Pollution
- Setting and Reviewing Standards
- Scientific and Technical Documents
- Implementing the Standards
- Air Quality Designations

Lead

- Lead Pollution
- Setting and Reviewing Standards
- Scientific and Technical Documents
- Implementing the Standards
- Air Quality Designations

Sulfur Dioxide

- Sulfur Dioxide Pollution
- Setting and Reviewing Standards
- Scientific and Technical Documents for Primary Standards
- Scientific and Technical Documents for Secondary Standards
- Implementing the Standards

Nitrogen Dioxide

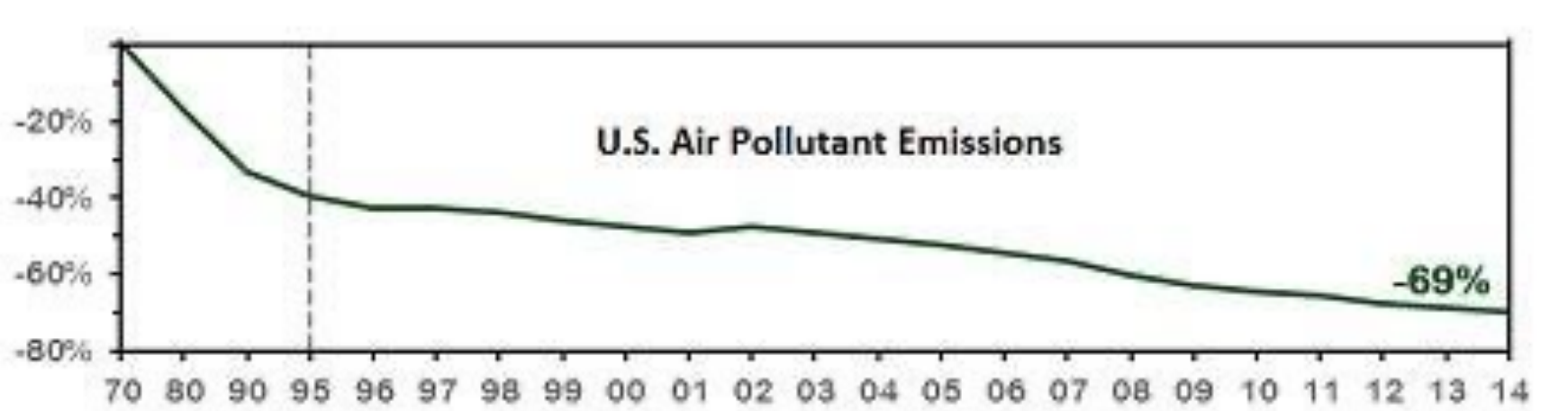
- Nitrogen Dioxide Pollution
- Setting and Reviewing Standards
- Scientific and Technical Documents for Primary Standards
- Scientific and Technical Documents for Secondary Standards
- Implementing the Standards

US Air Pollution Regulation

https://www.epa.gov/pm-pollution/setting-and-reviewing-standards-control-particulate-matter-pm-pollution

Impact of Clean Air Act

EPA: Aggregate emissions of six common pollutants dropped 69% between 1970 and 2014.



	Year 2020 (in cases)
Adult Mortality - particles	230,000
Asthma Exacerbation	2,400,000
Chronic Bronchitis	75,000
Emergency Room Visits	120,000
Heart Disease - Acute Myocardial Infarction	200,000
Infant Mortality - particles	280

New WHO Global Air Quality Guidelines aim to save millions of lives from air pollution

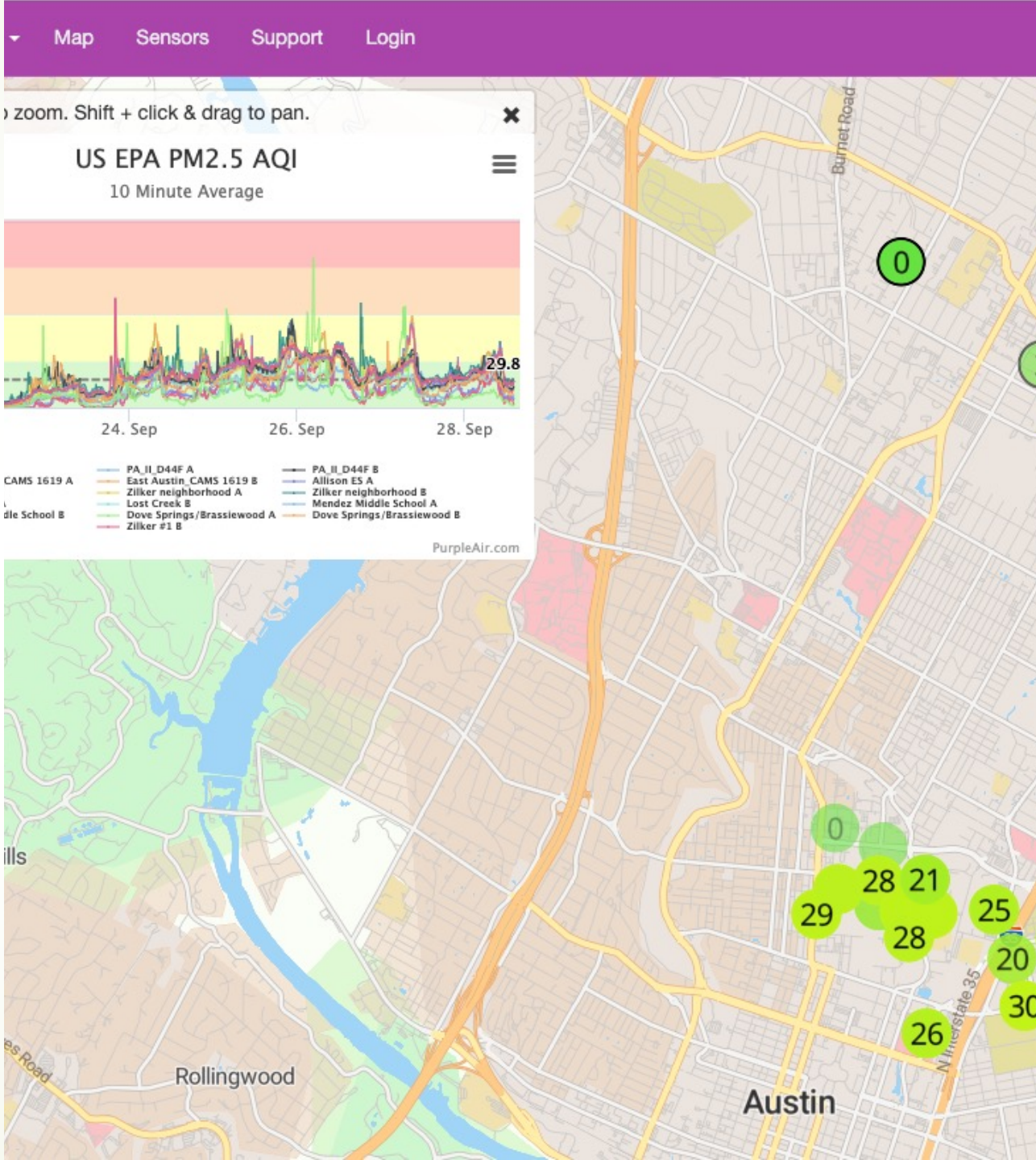
Air pollution is one of the biggest environmental threats to human health, alongside climate change.

22 September 2021 | News release | Copenhagen and Geneva | Reading time: 4 min (1078 words)

Table 0.1. Recommended AQG levels and interim targets

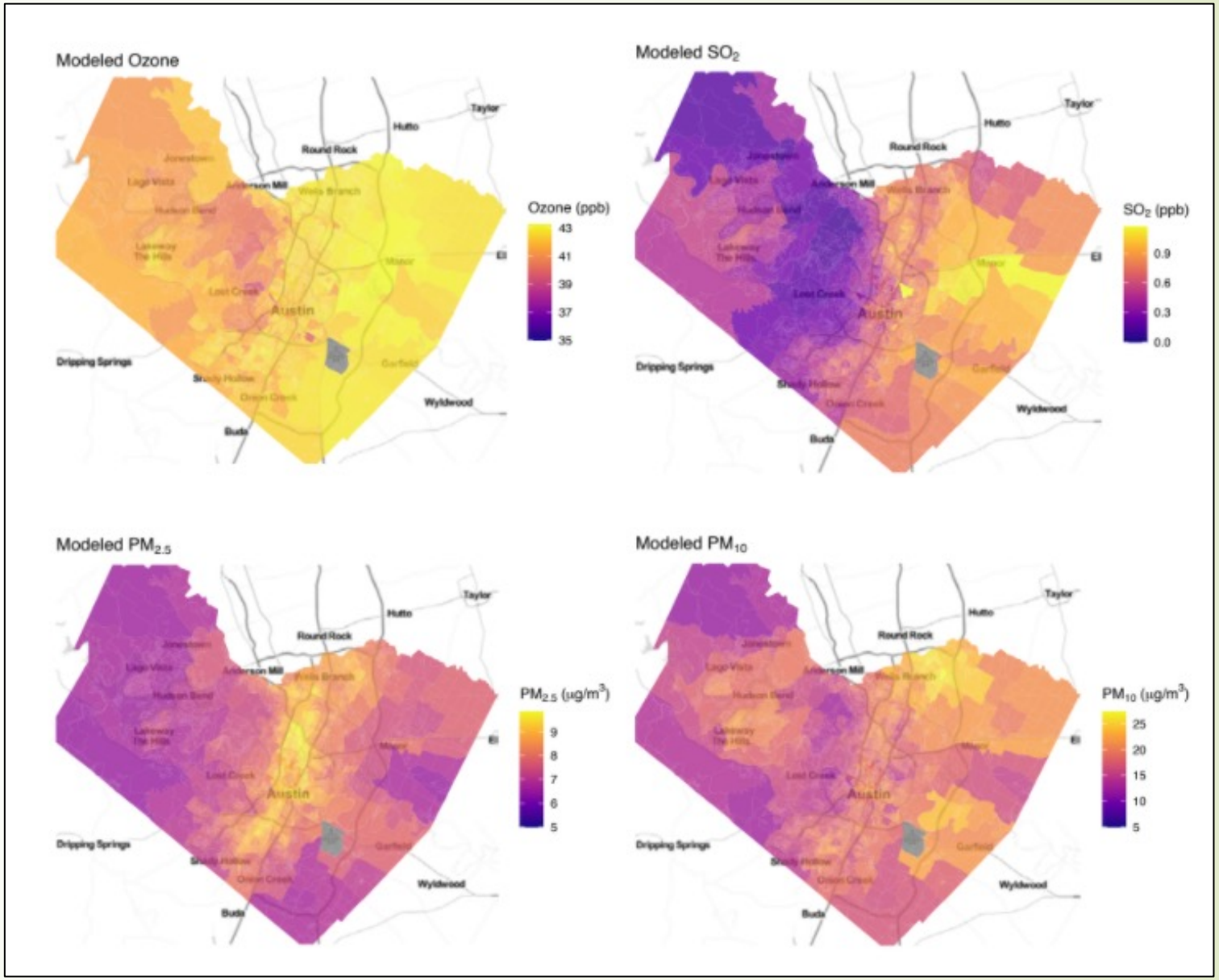
Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
$PM_{2.5}$, μg/m³	Annual	35	25	15	10	5
	24-hour[a]	75	50	37.5	25	15

Consumer-grade air quality monitoring



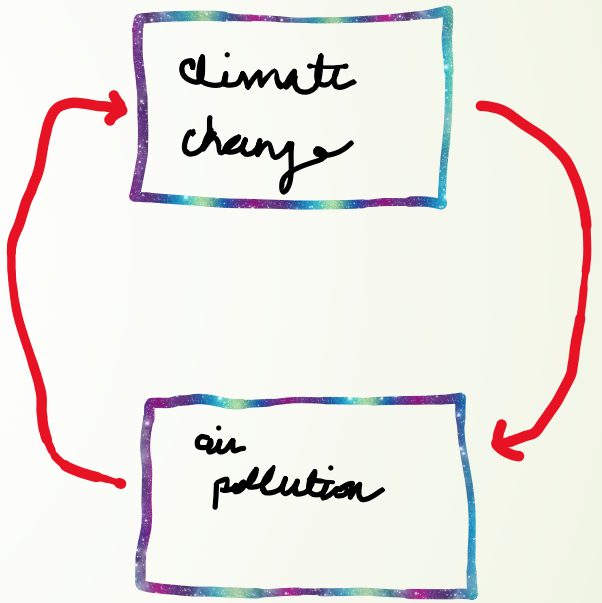
Environmental Injustice in Travis County, TX

(figure credit: Sarah Chambliss, PhD)



Climate Change & Air Pollution Are Inextricably Linked

- Climate disruption → extreme weather patterns (heat waves, droughts, thunderstorms, heavier precipitation, hurricanes, etc.)
  - Consequences→worsening air quality due to high temperatures, forest fires, dust storms, stagnation events
- Pollutants contribute to rising temperatures:
  - Black carbon PM released from fossil fuel, biomass, forest burning→absorbs solar radiation→increases temperature



Climate Change, Forest Fires, & Wildfire Smoke

Environmental Health

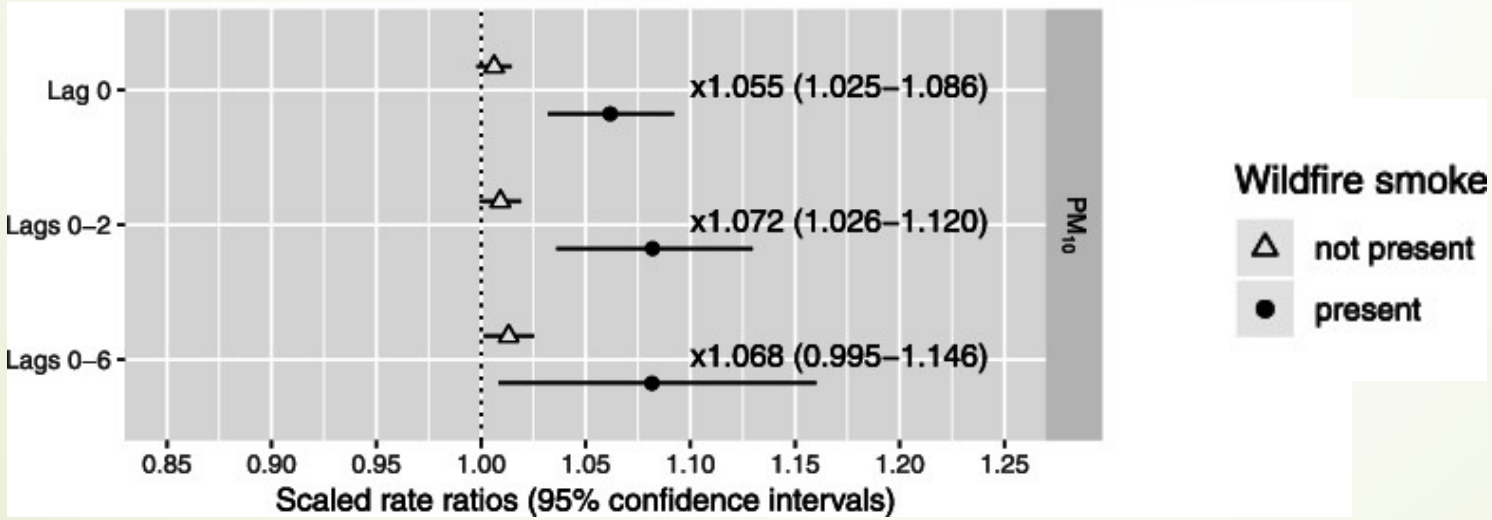
BMC

Particulate matter and emergency visits for asthma: a time-series study of their association in the presence and absence of wildfire smoke in Reno, Nevada, 2013–2018

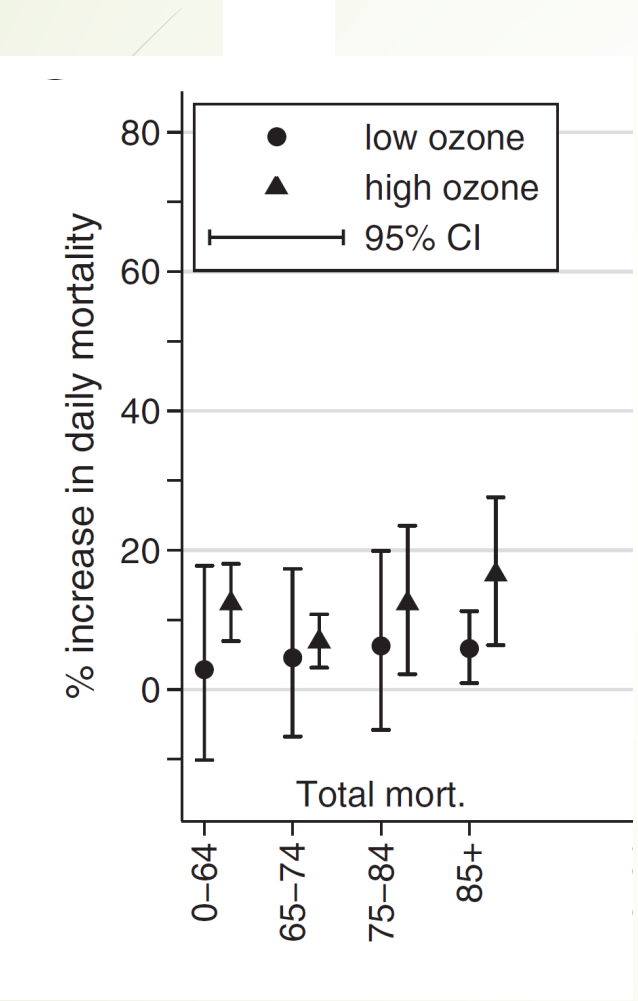
Daniel Kiser, William J. Metcalf, [...], and Joseph Grzymski

Conclusions

Since we found significantly stronger associations of $PM_{2.5}$ and PM_{10} with asthma visits when wildfire smoke was present, our results suggest that wildfire PM is more hazardous than non-wildfire PM for patients with asthma.



Heat, pollution have synergistic effects on health



Risk of death on heat wave days is higher when ozone concentrations are high

Analitis et al Epidemiology 2014

In Landmark Ruling, Air Pollution Recorded as a Cause of Death for British Girl

Legal and environmental experts hailed a coroner's ruling that, for the first time in Britain, directly linked a specific person's death to air pollution.

Take-home messages

- Air pollution kills & has profound effects on health and quality of life
- It disproportionately affects disadvantaged communities – those living in poverty and racial and ethnic minority communities
- Air pollution & climate change are inextricably linked
- There are policy level and individual actions that can be taken

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CHEER is a hub for multidisciplinary environmental health sciences research and education. Housed within the UT Austin Dell Medical School, the center brings together experts from across the University of Texas at Austin.

Director: Elizabeth Matsui, MD MHS
Steering Committee: Kate Calder, Lydia Contreras, Catherine Cubbin, Andrea Gore, Kerry Kinney, Cory Zigler

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What is the U.S. Air Quality Index (AQI)?

The U.S. AQI is EPA's index for reporting air quality.

How does the AQI work?

Think of the AQI as a yardstick that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 or below represents good air quality, while an AQI value over 300 represents hazardous air quality.

For each pollutant an AQI value of 100 generally corresponds to an ambient air concentration that equals the level of the short-term national ambient air quality standard for protection of public health. AQI values at or below 100 are generally thought of as satisfactory. When AQI values are above 100, air quality is unhealthy: at first for certain sensitive groups of people, then for everyone as AQI values get higher.

The AQI is divided into six categories. Each category corresponds to a different level of health concern. Each category also has a specific color. The color makes it easy for people to quickly determine whether air quality is reaching unhealthy levels in their communities.

AQI Basics for Ozone and Particle Pollution

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.