



Air Pollution and Health

John R. Balmes, MD
University of California,
San Francisco and Berkeley



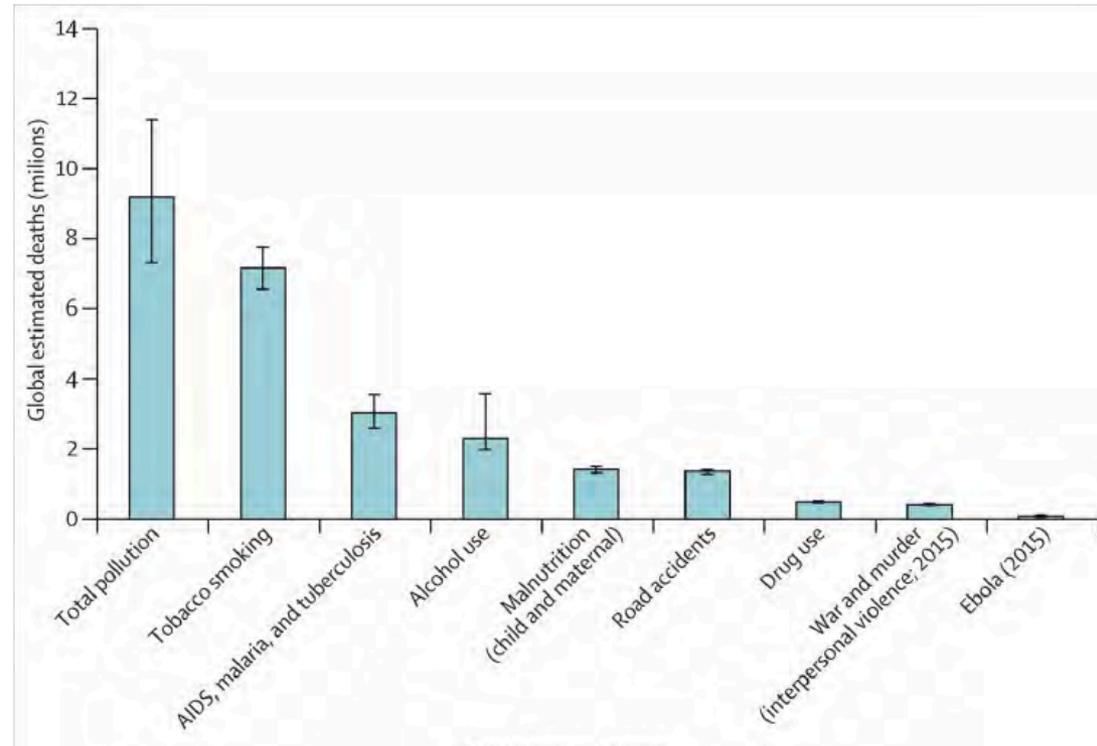
Outline

- Outdoor Air Pollution
- Air Pollution and the Acute Respiratory Distress Syndrome
- Air Pollution and COVID-19

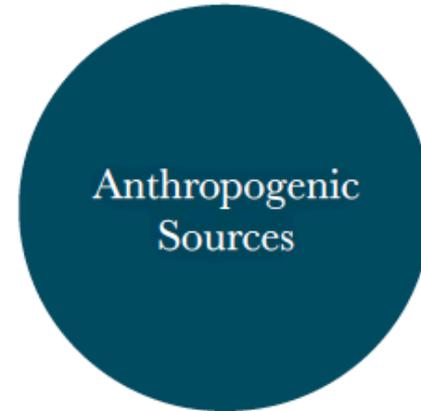
THE LANCET

COMMISSION ON POLLUTION AND HEALTH

Pollution is the largest environmental cause of disease and premature death in the world today. Diseases caused by pollution were responsible for an estimated 9 million premature deaths in 2015 — 16% of all deaths worldwide — three times more deaths than from AIDS, tuberculosis, and malaria combined and 15 times more than from all wars and other forms of violence. In the most severely affected countries, pollution-related disease is responsible for more than one death in four.



Sources of Air Pollution



Stationary



Mobile

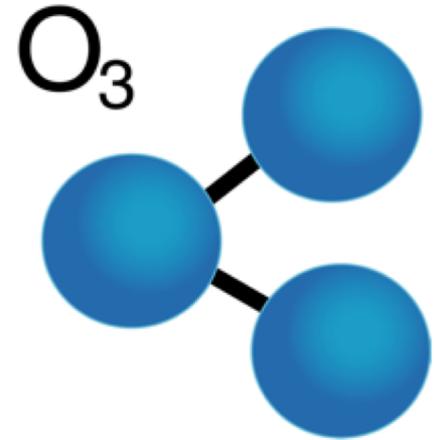
Outdoor Air Pollution



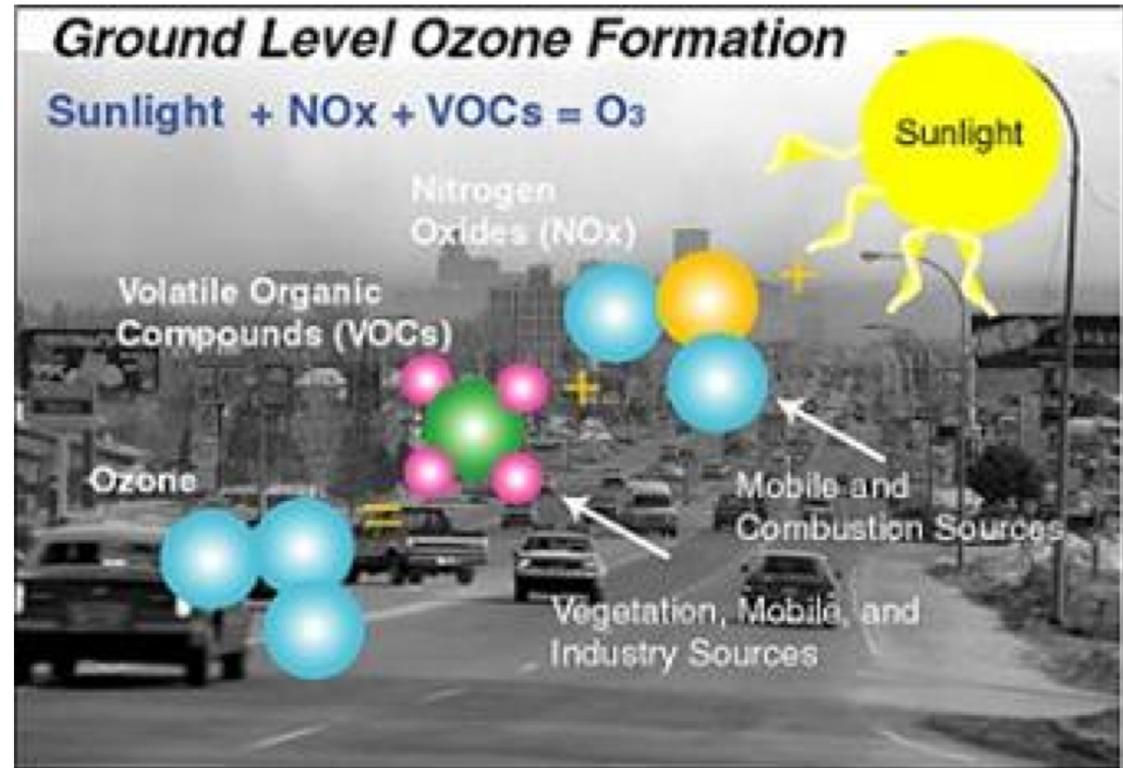
- Multiple sources
- Mixture of gases and particulate matter
- Traffic-related air pollution



Ozone

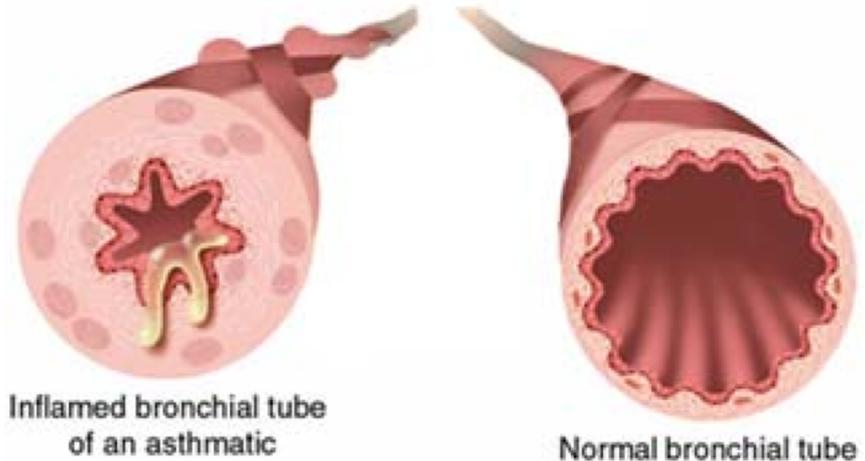


- Prototypic oxidant pollutant
- Major source: motor vehicle emissions
- Photochemistry during sunny afternoons



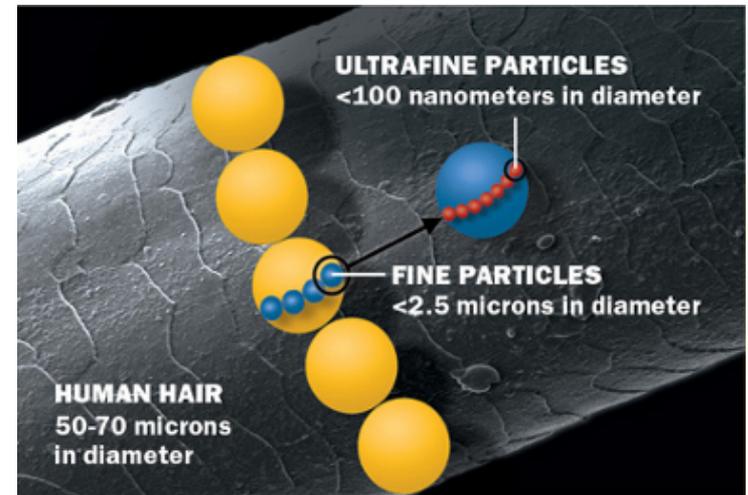
Ozone: Health Effects

- Respiratory symptoms, lower lung function, airway inflammation in healthy people
- Asthma
 - Exacerbations
 - New onset
- Mortality



Ambient Particulate Matter (PM)

- PM is a mixture, including particles of differing origin (combustion, crustal, biological) and varying size.
- Regulated by particle size in the developed world
- Multiple sources
 - Ultrafines ($PM_{<0.1}$): Fuel (including biomass) combustion
 - $PM_{2.5}$: Fuel (including biomass) combustion
 - $PM_{10-2.5}$: Road dust, crustal, and biological material



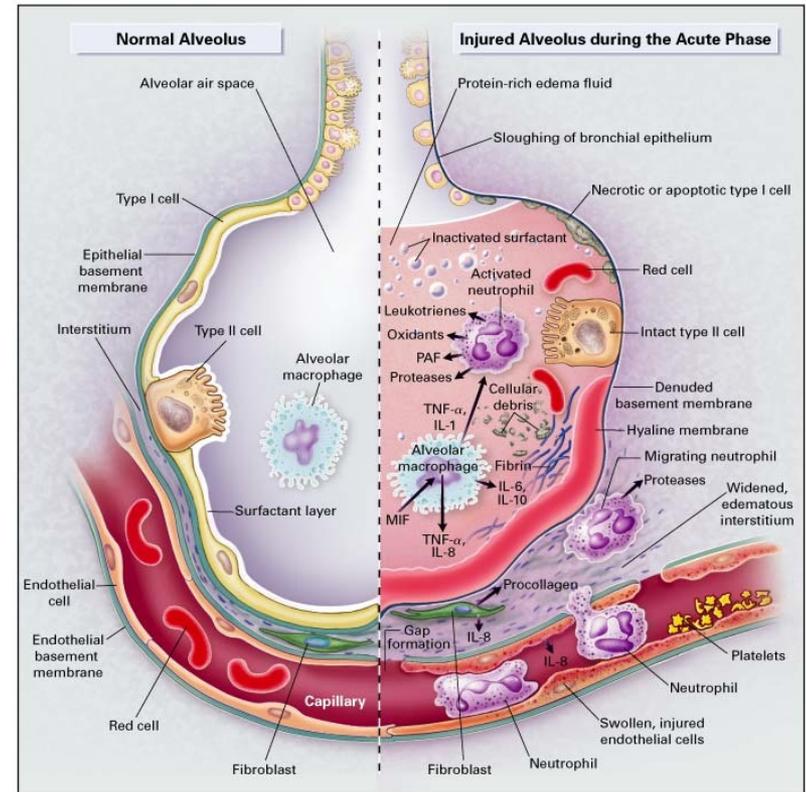
Particulate Matter: Health Effects

- Asthma
 - Exacerbation
 - New-onset
- Decreased lung function growth
- Mortality
 - Ischemic heart disease
- Lung cancer



Acute Respiratory Distress Syndrome (ARDS)

- Acute respiratory distress syndrome (ARDS) can occur in those who are critically ill or who have significant injuries. It is often fatal, the risk increasing with age and severity of illness.
- Fluid fills the alveoli (air sacs)
- Berlin definition
 - Bilateral opacities on chest imaging
 - Respiratory failure not fully explained by cardiac failure or fluid overload
 - Low $\text{PaO}_2/\text{FIO}_2$ ratio (hypoxemia)



Acute Respiratory Distress Syndrome (ARDS)

- Patients with ARDS typically require mechanical ventilation to maintain adequate oxygenation of their blood
- This requires intubation with an endotracheal tube
- Because positive pressure ventilation can injure the lungs (barotrauma), lung protective strategies are used
- Compliance of the lung is monitored with modern ventilators as well as PaO₂ and end-tidal CO₂
- Prone position can improve oxygenation



Patient on ventilator and prone

Air Pollution and ARDS

Long-Term Ozone Exposure Increases the Risk of Developing the Acute Respiratory Distress Syndrome

Lorraine B. Ware^{1,2}, Zhiguo Zhao³, Tatsuki Koyama³, Addison K. May⁴, Michael A. Matthay^{5,6}, Fred W. Lurmann⁷, John R. Balmes^{5,8}, and Carolyn S. Calfee^{5,6}

Long-term ozone exposure is associated with development of ARDS in at-risk critically ill patients, particularly in trauma patients and current smokers.

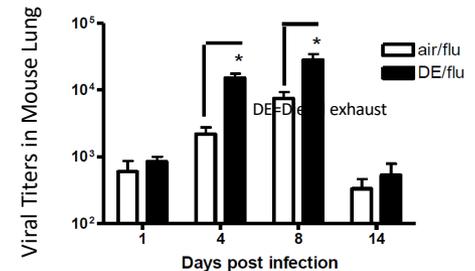
Low to Moderate Air Pollutant Exposure and Acute Respiratory Distress Syndrome after Severe Trauma

John P. Reilly^{1,2}, Zhiguo Zhao³, Michael G. S. Shashaty^{1,2}, Tatsuki Koyama³, Jason D. Christie^{1,2,4,5*}, Paul N. Lanken¹, Chunxue Wang⁶, John R. Balmes^{5,7,8*}, Michael A. Matthay^{8,9}, Carolyn S. Calfee^{8,9}, and Lorraine B. Ware^{6,10}

Long-term low- to moderate-level exposure to PM_{2.5} is associated with a greater risk of developing ARDS after severe trauma.

Acute Effects of Pollution on Respiratory Infection

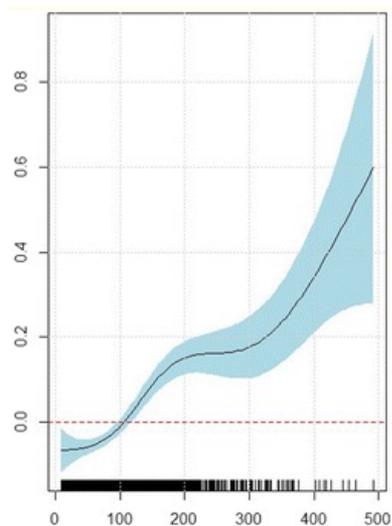
- Controlled exposure¹ to NO₂, O₃ and/or PM_{2.5} worsens viral proliferation and severity of infection by other viruses:
 - Influenza
 - Rhinovirus
 - RSV
- Mechanisms of increased severity of viral infection:
 - Impaired ciliary function (first line defense of upper airways)²
 - Oxidative stress and production of free radicals, causing local damage¹
 - Reduced ability of macrophages to phagocytose¹



Gowdy et al. *Particle and Fibre Toxicol* 2010

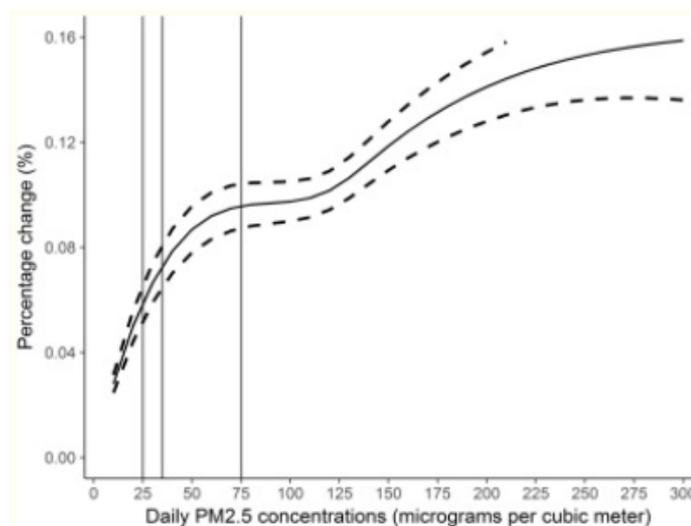
1. Ciencewicki J., Jaspers I. *Inhal Toxicol.* 2007.
2. Cao et al. *Thorac. Cancer.*, 11 (2020),

PM_{2.5} Link to Flu and Pneumonia Hospitalization



Lag 0–1 concentrations of PM_{2.5} and hospital admissions for flu-like illness during flu season in Beijing, 2008–2014

Feng et al. *Environ Health*. 2016

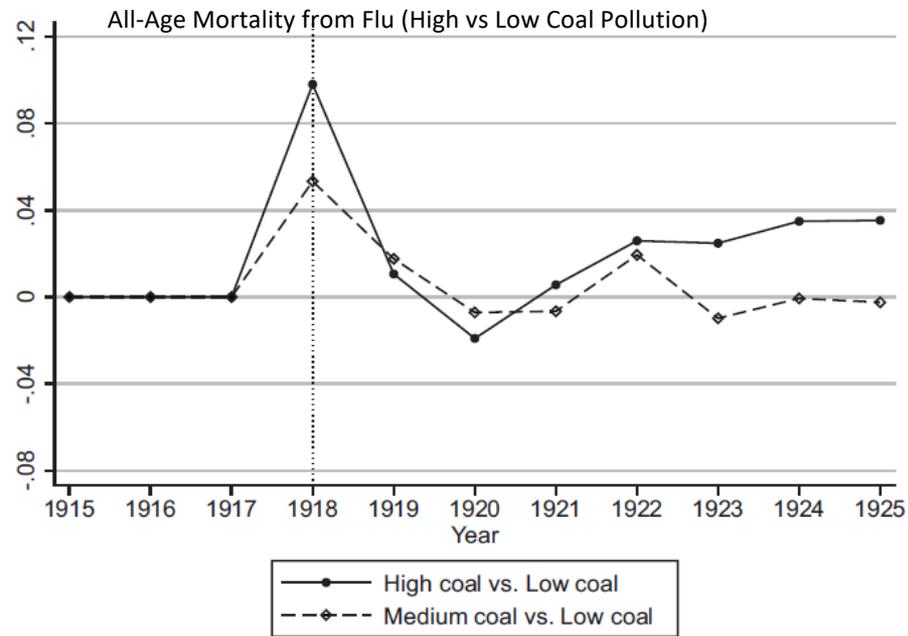


3-day moving average (lag 0–2) concentrations of PM_{2.5} and hospital admissions for pneumonia in 184 cities in China, 2014–2017

Tian et al. *PLoS Med*. 2019



Coal Pollution and the 1918 Flu Pandemic



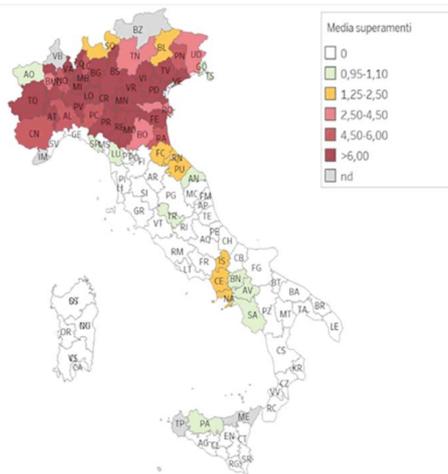
Clay K. *Economics and Human Biology*. 2019



Suspended Particles May Spread Virus

- Particulate matter pollution may be platforms for viruses to spend more time in the air and travel longer distances
- In Italy¹ and China², COVID-19 mortality greatest in most polluted areas
- SARS-COV-2 RNA has been found on outdoor particulate matter in Bergamo³

Media n° superamenti limite PM10/n° centraline Prov (10-29 Feb 2020)



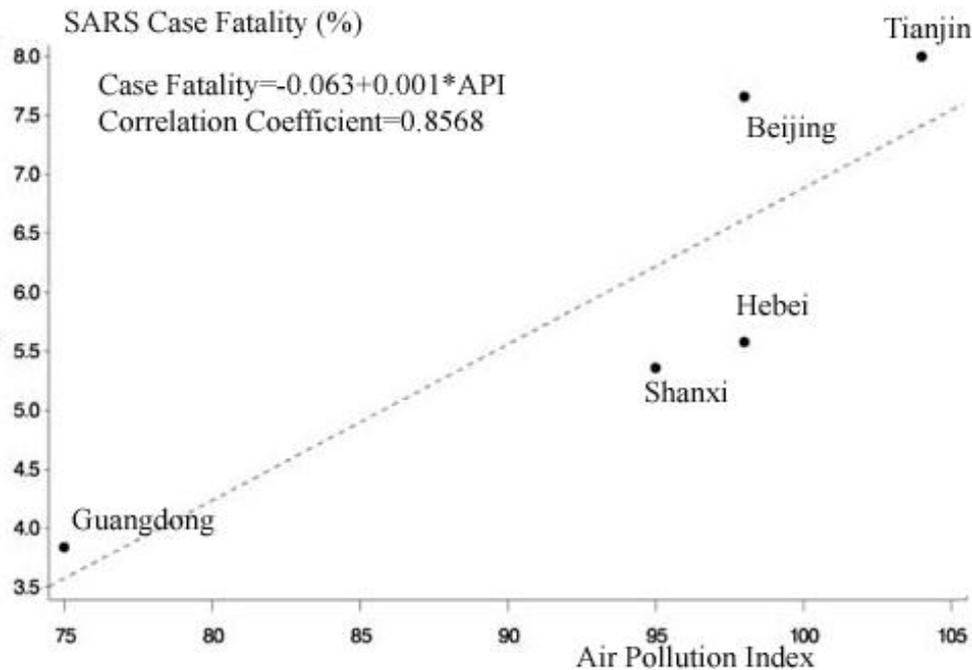
PM₁₀ Levels Feb 10-29, 2020



Covid-19 Fatalities Feb 10-29, 2020

1. Martelletti et al. *Comprehensive Clin Med* 2020
2. Frontera et al. *J Infect.* 2020
3. Setti et al. *MedRxiv* (preprint). 2020.

Outdoor Pollution and Mortality from the original SARS in China



Cui et al. *Environ Health*.
2003.

Thank you