Air Quality and Health: Beyond the Lungs and Heart

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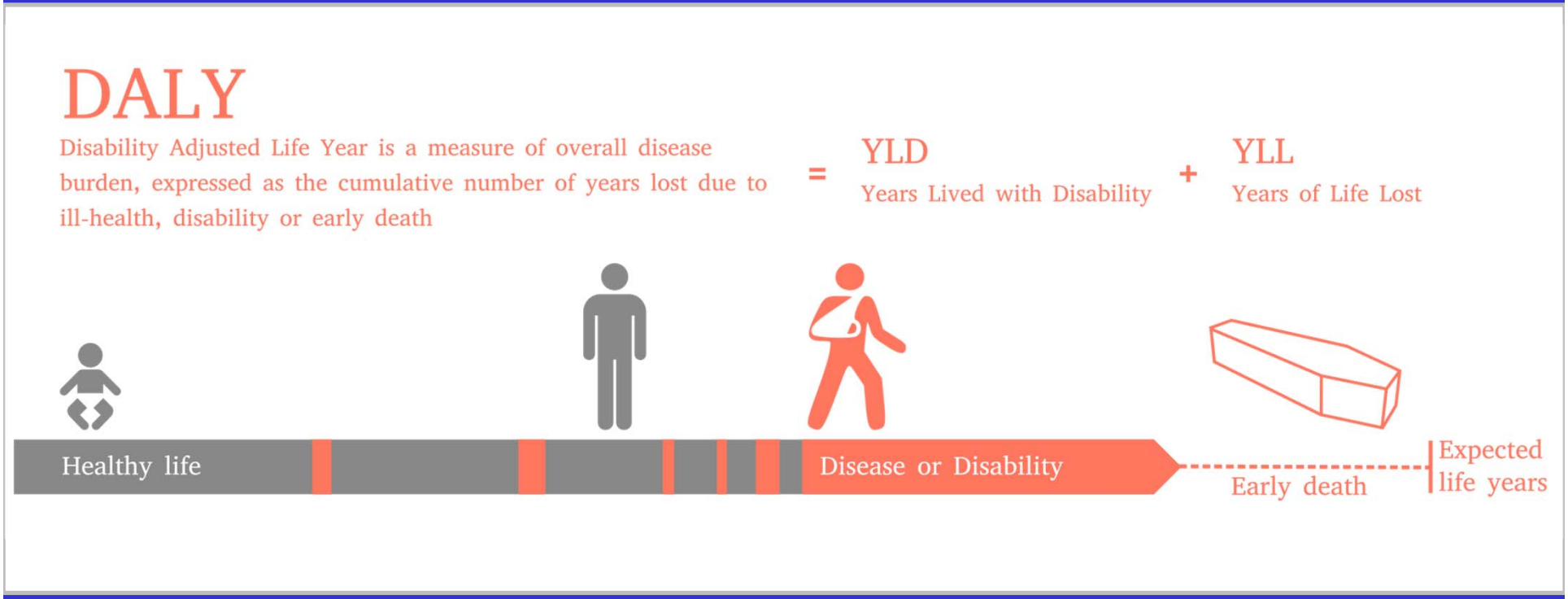
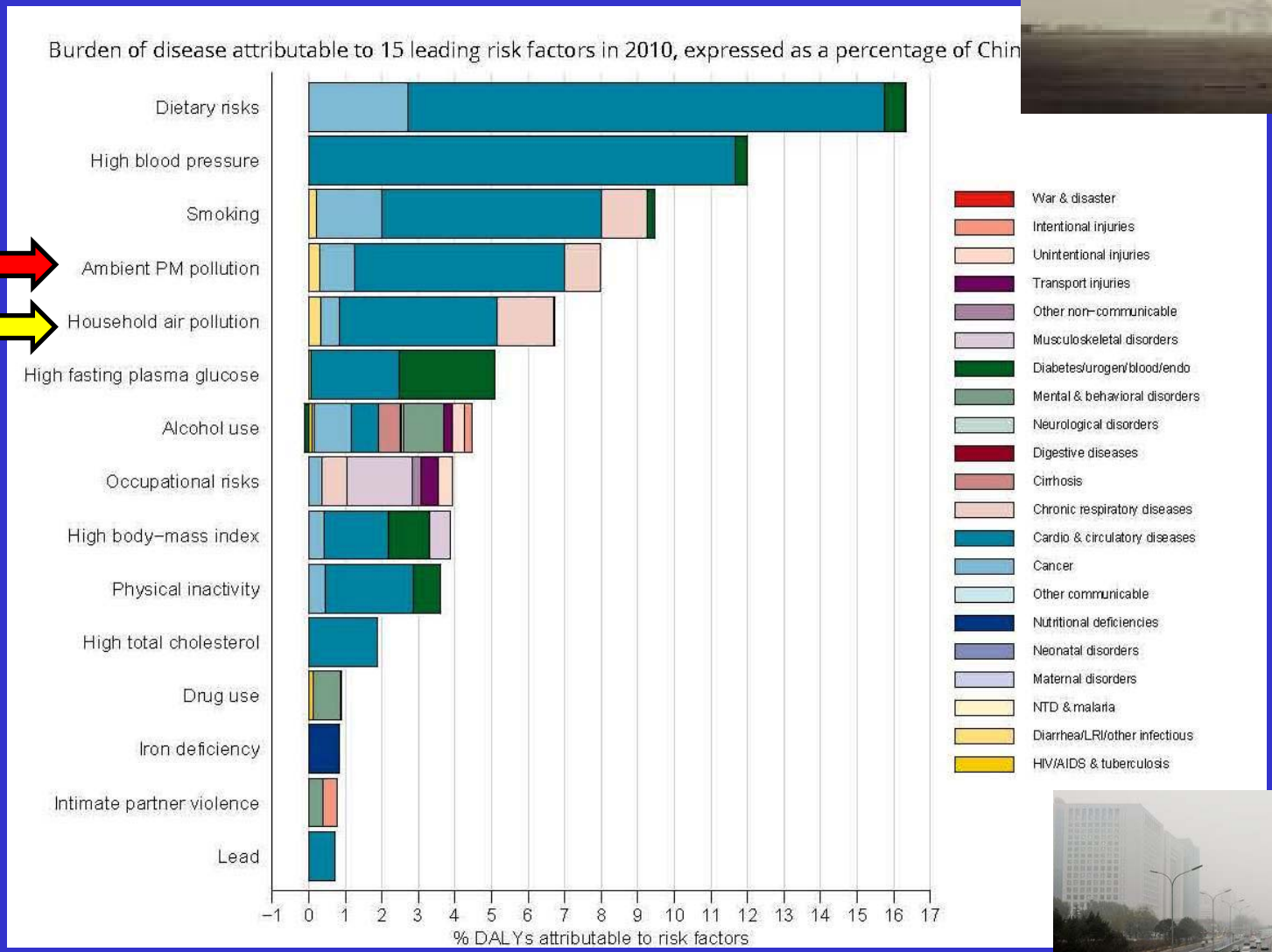
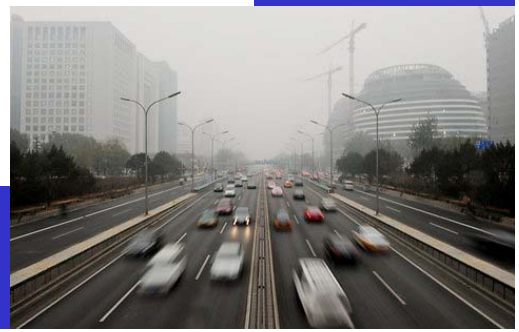
Image: power plant stacks and plumes as seen from aloft, wintertime in Ulaanbaatar, Mongolia

Quantifying Burden of Disease
Disability Adjusted Life Year (DALY)



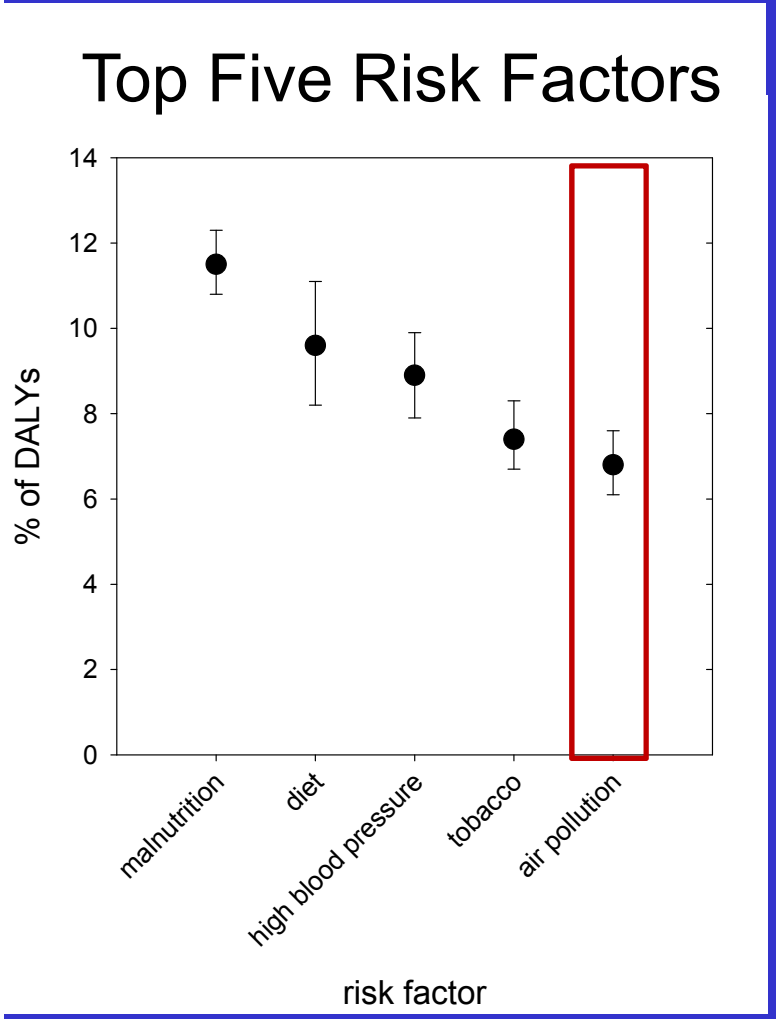
Air Quality in Context - China





Source: IHME (2012): 2010 GBD Report – China

Global Risk-Attributable Burden of Disease



DALY = disability adjusted life years

84 risk factors, 481 risk-outcome pairs

Top five risk factors account for 44% of total burden

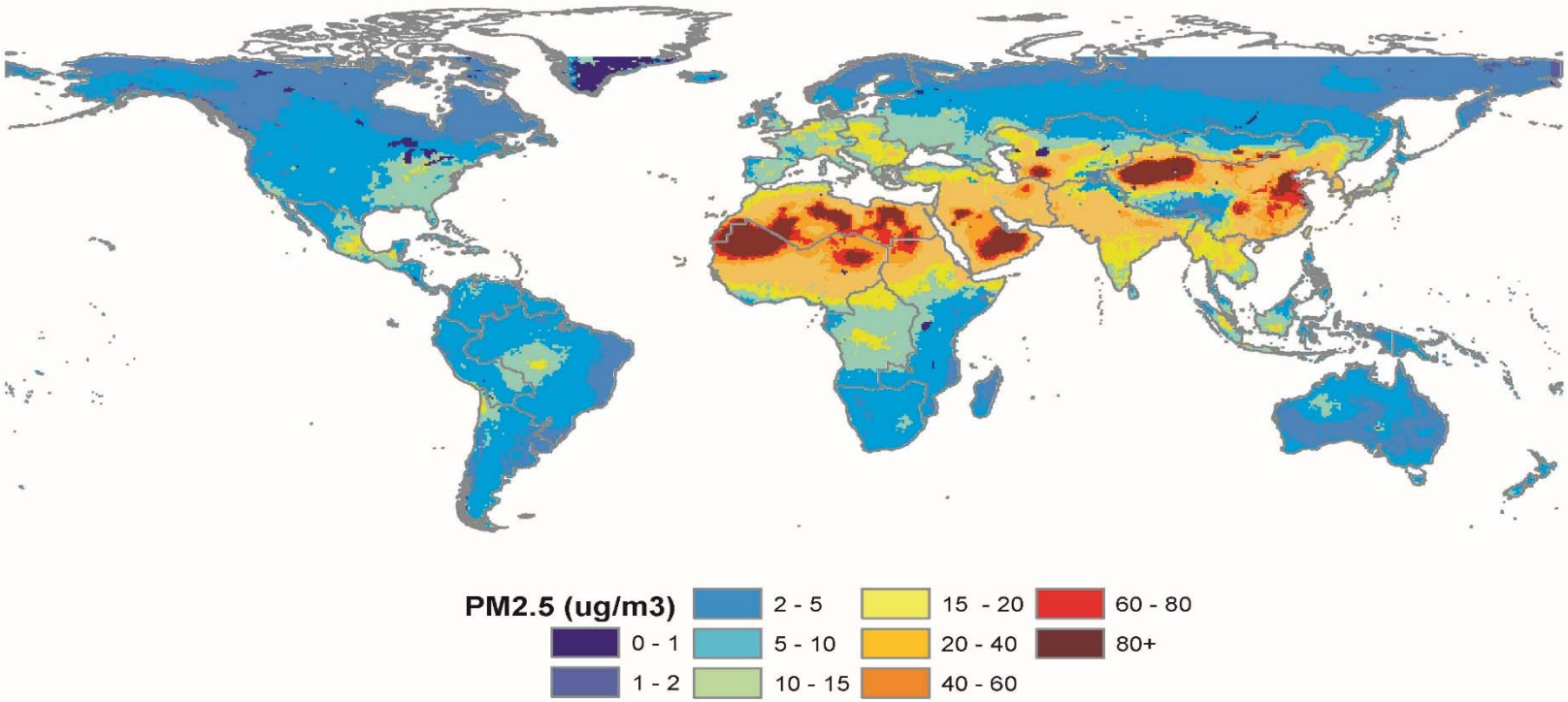
Air pollution (ambient and household combined) ranks 5th with ~7% of DALYs

After stratifying by socio-demographic index (SDI), air pollution ranks are:

- High SDI – 10th
- Middle SDI – 6th
- Low SDI – 2nd

Data from E. Gakidou et al. (2017) Lancet 390: 1345-1422

Fine Particulate Matter Air Pollution Annual Average (2005)



Brauer et al. (2015) *Environmental Science and Technology*, 46, 652-660

Spectrum of Particulate Matter (PM) Health Effects

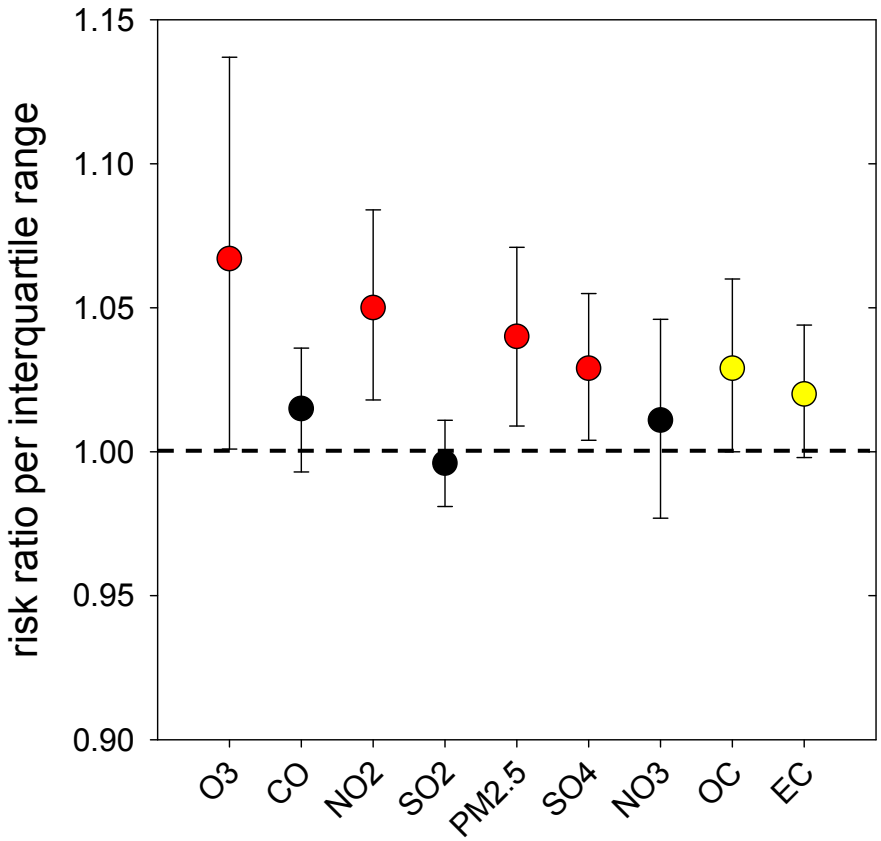
Historical focus…

- Pulmonary
- Cardiovascular
- Cardiopulmonary

- exposures: short term (acute) versus long term
- endpoints: mortality [death] vs. morbidity [disease]

Respiratory Emergency Department Visits and Ambient Air Pollutants in St. Louis

Asthma/Wheeze



June 2001 – April 2003

Gases

O3 = ozone (8-hr max)

CO = carbon monoxide (1-hr max)

NO2 = nitrogen dioxide (1-hr max)

SO2 = sulfur dioxide (1-hr max)

Fine Particles (PM2.5) (24-hr avg)

PM2.5 = total mass

SO4 = sulfate ion

NO3 = nitrate ion

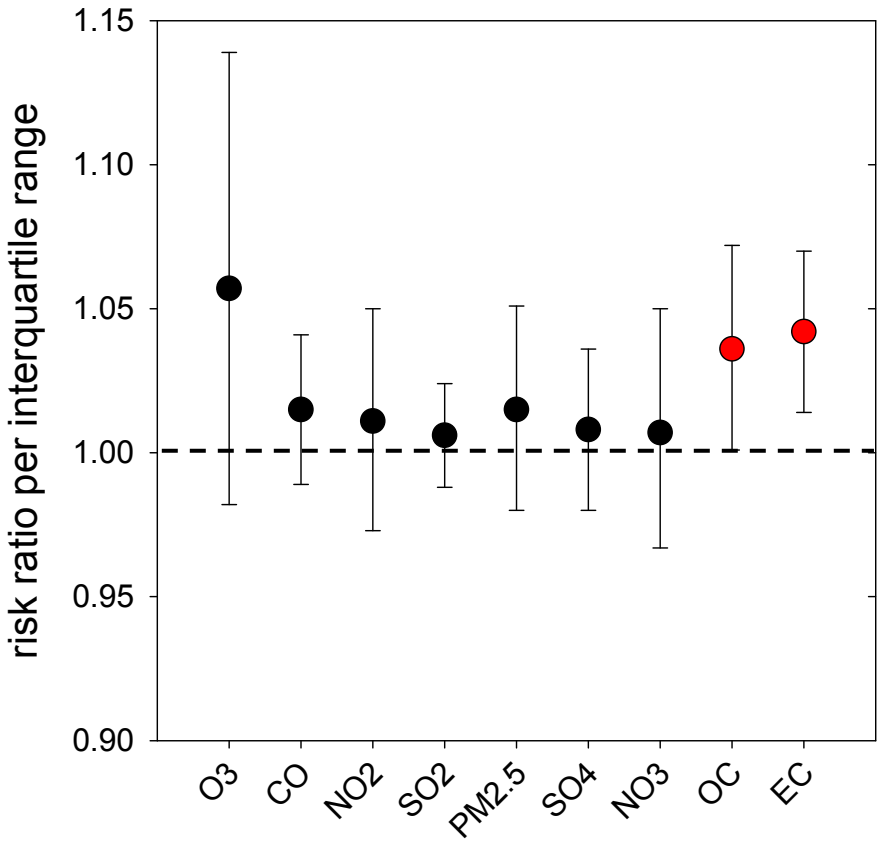
OC = organic carbon

EC = elemental carbon

Data from S. Sarnat et al. (2015) Environ. Health Perspec. 123: 437-444

Cardiovascular Emergency Department Visits and Ambient Air Pollutants in St. Louis

Congestive Heart Failure



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<u>Fine Particles (PM2.5) (24-hr avg)</u>
PM2.5 = total mass
SO4 = sulfate ion
NO3 = nitrate ion
OC = organic carbon
EC = elemental carbon ("soot")

Data from S. Sarnat et al. (2015) Environ. Health Perspec. 123: 437-444

Ambient PM and Cardiovascular Effects

Numerous mechanisms, e.g.

- Proinflammatory responses, e.g. plasma fibrinogen formation
- Reactive oxidant species (ROS) causing oxidative stress

Leading to numerous impacts, e.g.

- Chronic: systemic inflammation $\rightarrow$ atherosclerosis
- Acute: systemic inflammation $\rightarrow$ blood clots

Long-term exposure to $PM_{2.5}$ increases the risk of nonaccidental mortality by 6% per a 10 $\mu g/m^3$ increase, independent of age, gender, and geographic region
(Chen *et al.*, 2008)

Air Pollution and Neurodegenerative Effects: Dementia (including Alzheimer's Dementia)

Epidemiology Studies

- Cognitive level
- Neuroimaging marker status
- Cognitive change
- Incident dementia or poor cognition
- Time series and hospital admissions

Biological Plausibility

- PM can reach the brain via circulation (bypass blood-brain-barrier) or by direct translocation through the olfactory bulb
- Cardiovascular and cerebrovascular disease appear to promote cognitive decline and dementia

Review by Power *et al.* (2016)

Air Pollution and Neurodegenerative Effects: Dementia (including Alzheimer's Dementia)

Example…

Cognitive decline in older women (70-81 years old) in the Nurses' Health Study Cognitive Cohort

Conclusion: "a 10-µg/m3 increment in long-term PM exposure is cognitively equivalent to aging by approximately 2 years"

Weuve *et al.* (2012)

Airborne Manganese and Motor/Cognitive Impacts

oxides of manganese particles

Dr. Brad Racette, Washington University School of Medicine, Project Principal Investigator

Air Pollution and Neurodevelopmental Effects: Autism Spectrum Disorder (ASD)

- Evidence of toxicity scale

evidence of lack of toxicity	inadequate evidence of toxicity	limited evidence of toxicity	sufficient evidence of toxicity

- Currently "limited evidence" for early life exposure to air pollution as a whole and diagnosis of ASD
- The strongest evidence between prenatal exposure to particulate matter and ASD (PM_{10}, n=6; $PM_{2.5}$, n=3)

Review and meta-analysis by Lam *et al.* (2016)

More Broadly: Air Pollution and Birth Outcomes

Associations between maternal $PM_{2.5}$ exposures and:

- Pre-term birth
- Term low birth weight

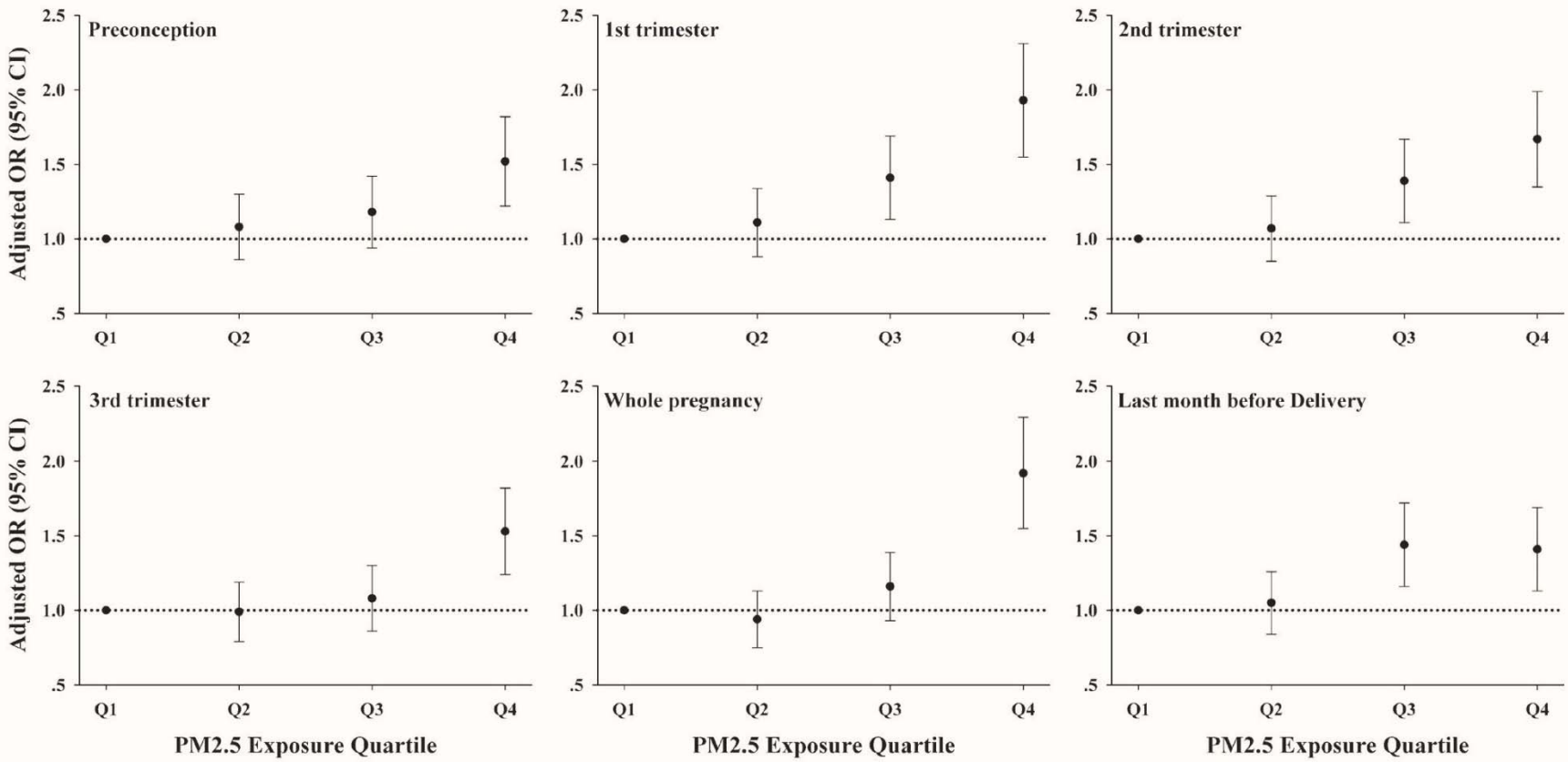
Example

- Prenatal $PM_{2.5}$ exposure and intrauterine inflammation, a risk factor for preterm birth and neurodevelopmental outcomes (for example, affecting development of the placenta)

Nachman *et al.* (2016)

Air Pollution and Intrauterine Inflammation (Boston Birth Cohort)

Odds ratios by $PM_{2.5}$ exposure quartile



Nachman *et al.* (2016)

Air Pollution and Kidney Disease

Dr. Ziyad Al-Aly group, Washington University School of Medicine (among other affiliations)

Particulate Matter Air Pollution and the Risk of Incident CKD and Progression to ESRD

METHODS

Observational cohort of 2,482,737 US Veterans followed for 8.52 years

Fine particulate matter <2.5 µm in aerodynamic diameter ($PM_{2.5}$) exposure data:

EPA ground-based air monitoring stations

NASA satellites spaceborne sensors

OUTCOMES

Increase in Risk of Kidney Outcomes for Every 10 Increase in $PM_{2.5}$ (µg/m³)

National Burden of Incident CKD Attributable to $PM_{2.5}$ Exposure Above the EPA recommended level of 12 µg/m³

CONCLUSION Our findings demonstrate a significant association between exposure to ambient $PM_{2.5}$ and risk of incident CKD, eGFR decline, and ESRD.

doi.org/10.1681/ASN.2017030253

JASN

B. Bowe et al. (2017) Journal of the American Society of Nephrology, 28 (preprint)

In the Recent Press…

Does Eating Right Protect You From Air Pollution?

Moises Velasquez-Manoff

New York Times

October 19, 2017

Credit: Kelsey Wroten for the New York Times