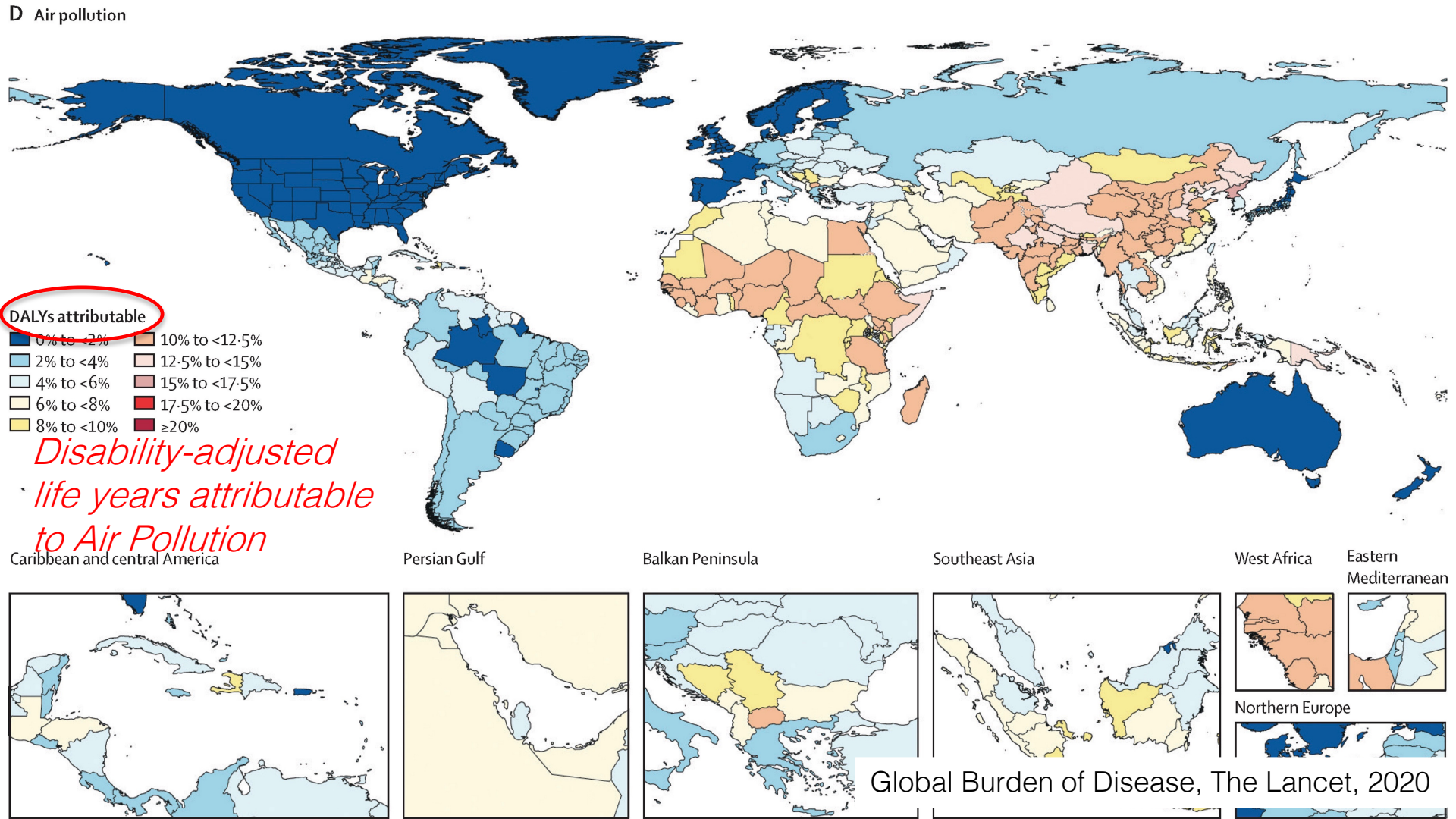
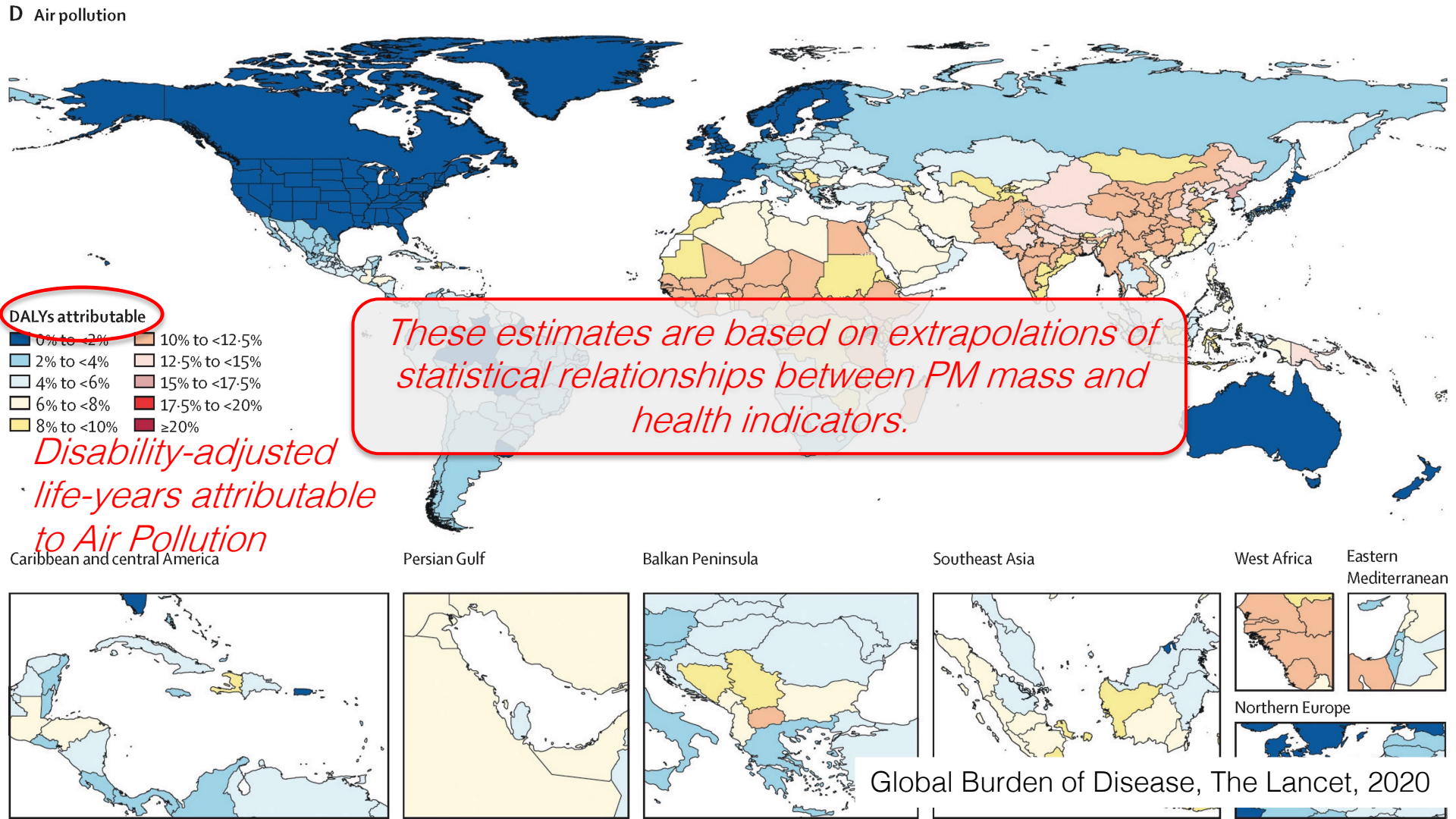
Chemical Markers for Potential Health Actors in African Megacities

James M. Roberts, NOAA Chemical Sciences Laboratory, Boulder, Colorado

REUTERS/TISKAN EGERI


D Air pollution
DALYs attributable
0% to <2%
2% to <4%
4% to <6%
6% to <8%
8% to <10%
10% to <12·5%
12·5% to <15%
15% to <17·5%
17·5% to <20%
≥20%
Disability-adjusted life years attributable to Air Pollution
Caribbean and central America
Persian Gulf
Balkan Peninsula
Southeast Asia
West Africa
Eastern Mediterranean
Northern Europe
Global Burden of Disease, The Lancet, 2020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These estimates are based on extrapolations of statistical relationships between PM mass and health indicators.
Disability-adjusted life-years attributable to Air Pollution
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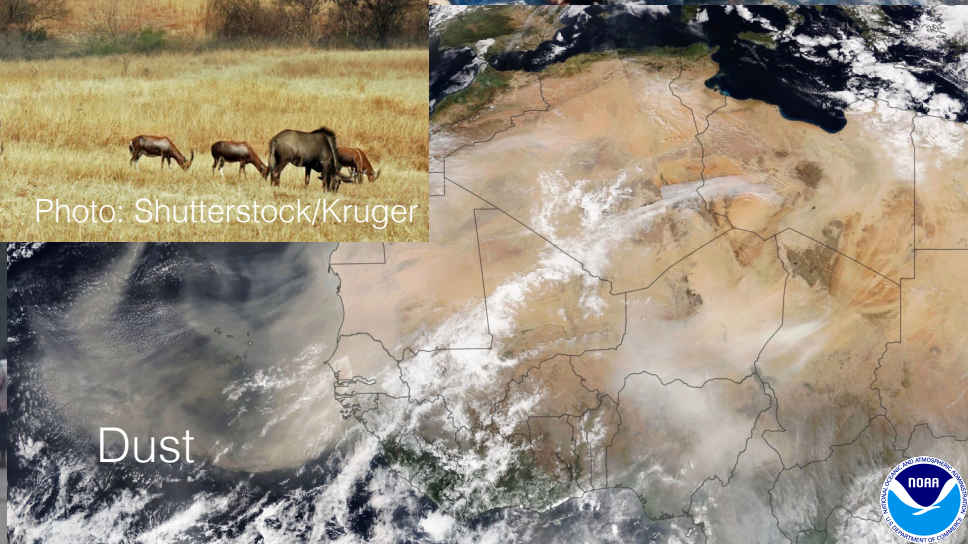
Global Burden of Disease, The Lancet, 2020


Biomass burning
Wikimedia


Trash Burning

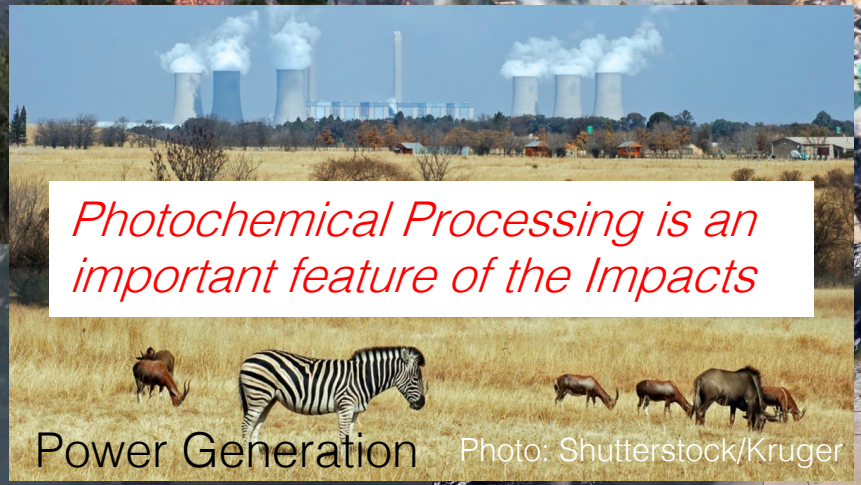

Power Generation
Photo: Shutterstock/Kruger


BUS
MOTREX LTD
Vehicle Exhaust
© Max Ahman/ UN Environment

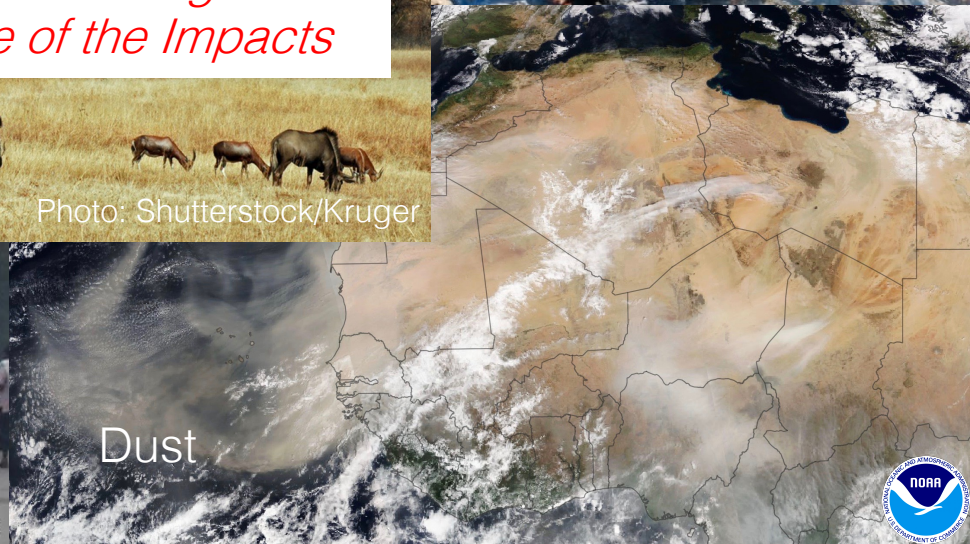

Dust
NOAA


Biomass burning
Wikimedia


Trash Burning
Gorich/Shutterstock.com


Photochemical Processing is an important feature of the Impacts
Power Generation
Photo: Shutterstock/Kruger


BUS
MOTREX LTD
Vehicle Exhaust
© Max Ahman/ UN Environment


Dust
NOAA

Biomass Burning

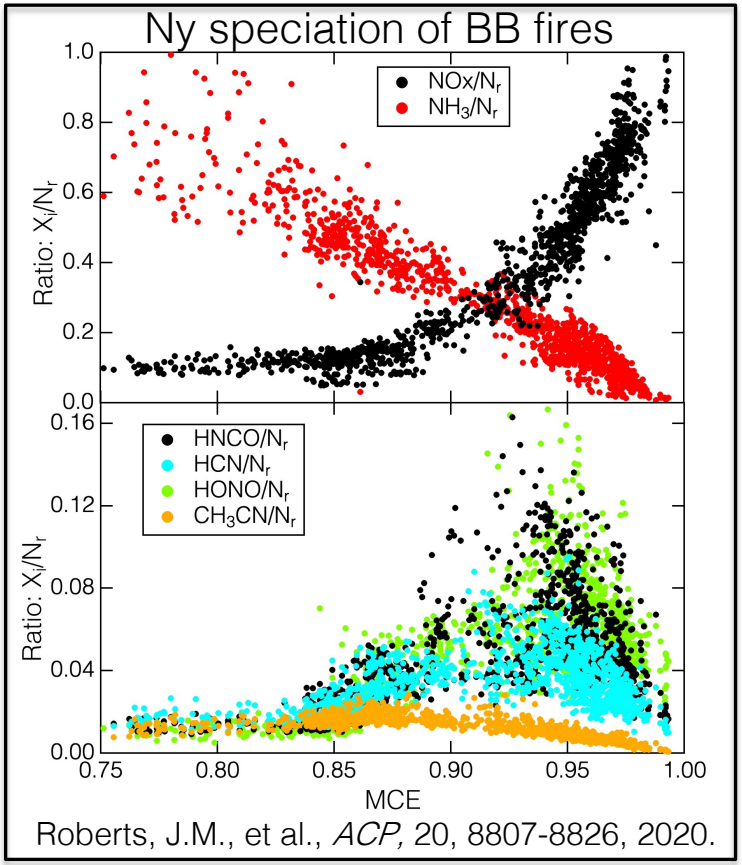
Markers;

- CO
- Black Carbon
- Furans
- Phenols
- (HCN, N compounds depend on fuel N)

Wikimedia

Health Actors:

- Acrolein (α,β-unsaturated carbonyls)
- Benzene — carcinogens
- Formaldehyde — carcinogens
- Isocyanic Acid (HNCO) protein modification
- Nitro-phenols mutagens
- Particle Reactive Oxygen Species (ROS)



Refs.

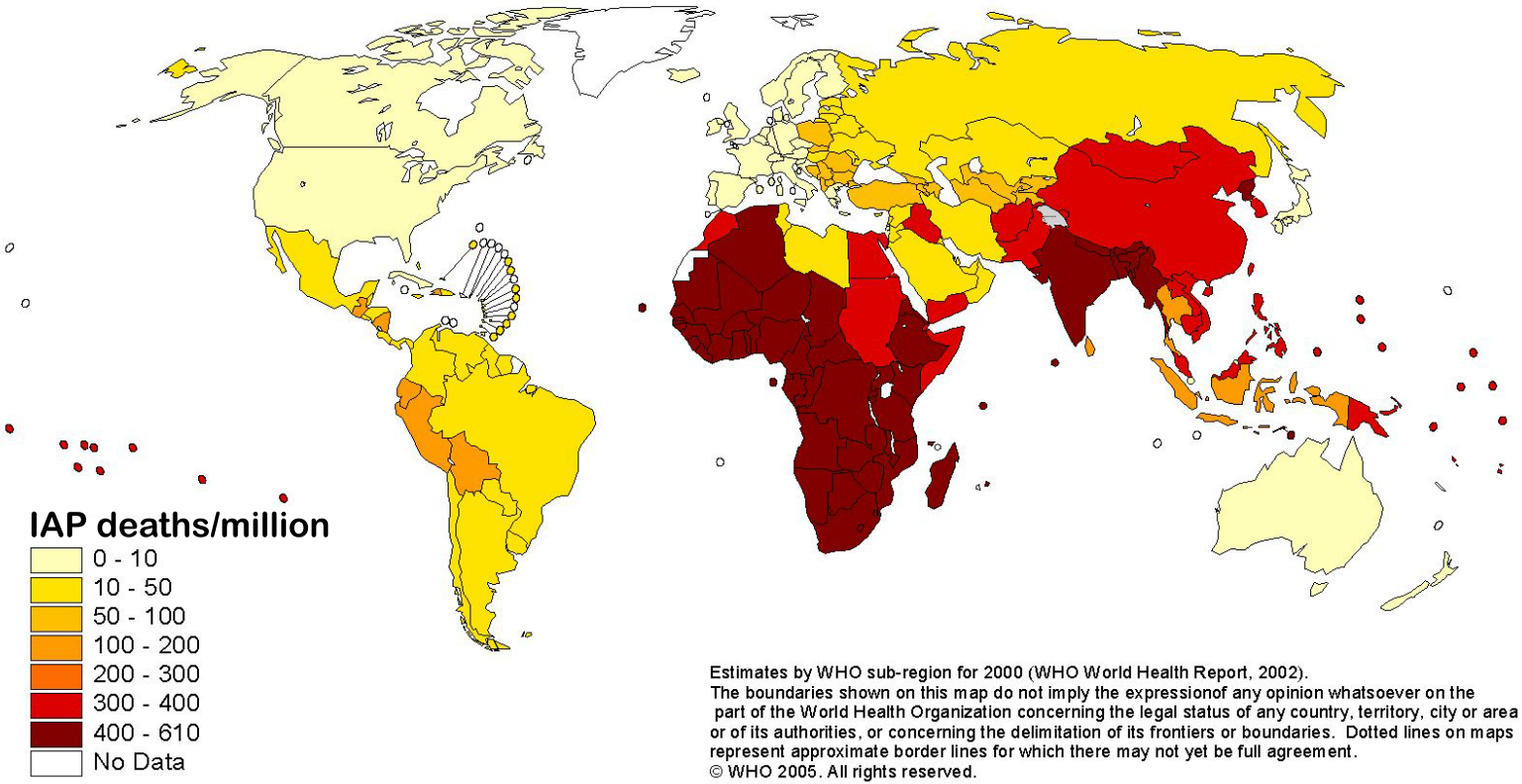
O'Dell, K., et al., *Environ.Sci.Technol.,* 54, 11838, 2020.

Roberts, J.M., et al., *PNAS,* 108, 8966, 2011.

Koss, et al., *ACP,* 18, 3299-3319, 2018.

Sekimoto et al., *ACP,* 18, 9263-9281, 2018

Deaths from indoor smoke from solid fuels



Estimates by WHO sub-region for 2000 (WHO World Health Report, 2002).
The boundaries shown on this map do not imply the expressionof any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

WHO World Health Report, 2002

Trash Burning

Markers;
- HCl
- Particle Chloride
- Metals (Sb, Pb…)

Health Actors
- Dioxins, PAHs, PCBs
- Vinyl Chloride
- Heavy Metals

More than half of all garbage is burned (globally)

Many urban areas have Landfill fires.

Some “unofficial” processes involve release of heavy metals and other toxics (e.g electronics burning, metals recovery).

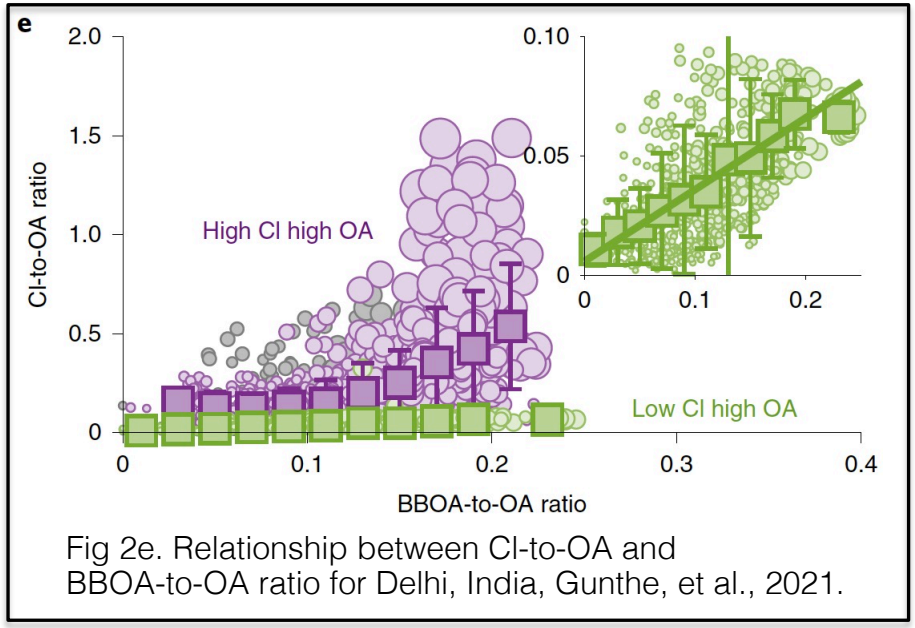


Fig 2e. Relationship between Cl-to-OA and BBOA-to-OA ratio for Delhi, India, Gunthe, et al., 2021.

Refs.
Gunthe, et al., *Nat. Geosci.,* 14, 77-84, 2021.
Christian, et al., *ACP,* 10, 565-584, 2010.

Vehicle Exhaust

Markers;

- CO
- Black Carbon
- n-Alkanes
- Nano-particles
- PAH (Diesel)

Health Actors:

- NOx
- PAHs
- Particles

Primary vehicle emissions are health actors, but also contribute to Photochemical Air Pollution

Traffic-derived nano-particles can be significant health actors

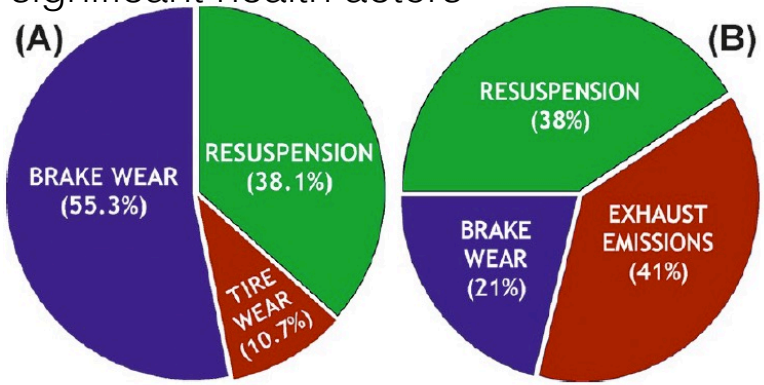


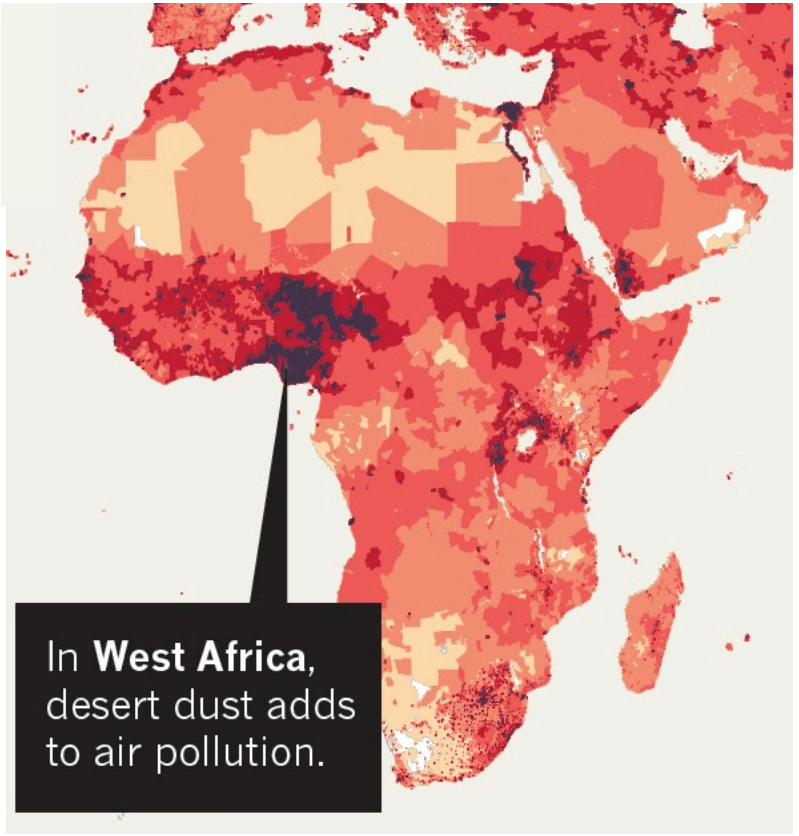
Figure 9. Source apportionment of (A) nonexhaust PM emissions (adapted from Harrison et al.[292]) and (B) total traffic-derived PM (adapted from Bukowiecki et al.[191]).

Gonet and Maher, *ES&T,* 53, 9970-9991, 2019.

Health Actors:

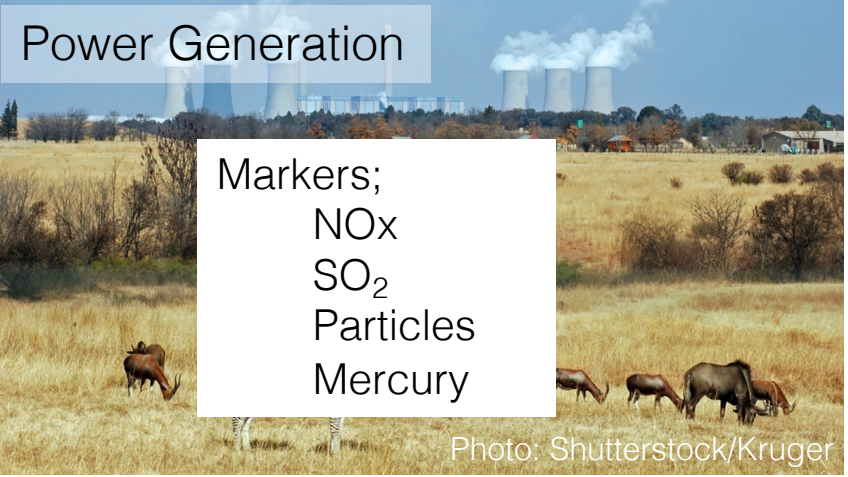
- Transition metals
- Pathogens
- Particle Reactive Oxygen Species (ROS)

Some studies have identified dust as a significant contributors to health effects

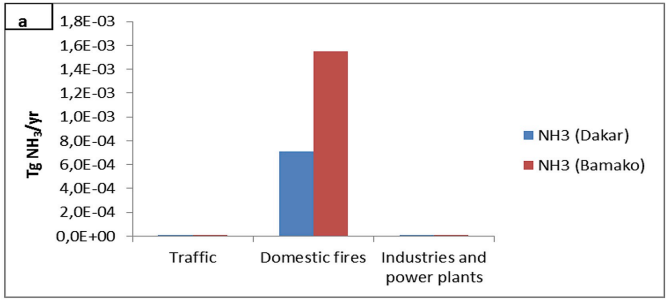


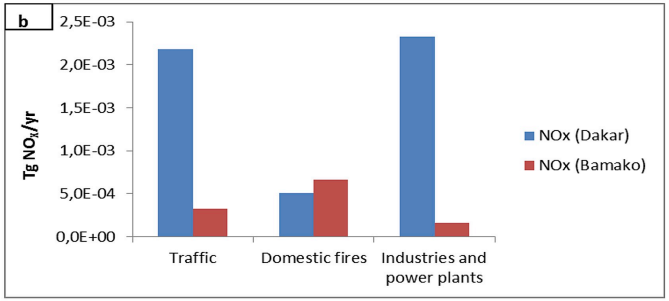
Lelieveld and Poschl, *Nature,* 551, 291-293, 2017

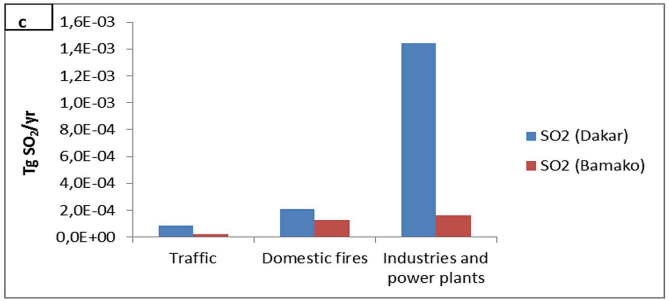
Power Generation



Much of the central power generation in Africa relies on Coal and Oil.





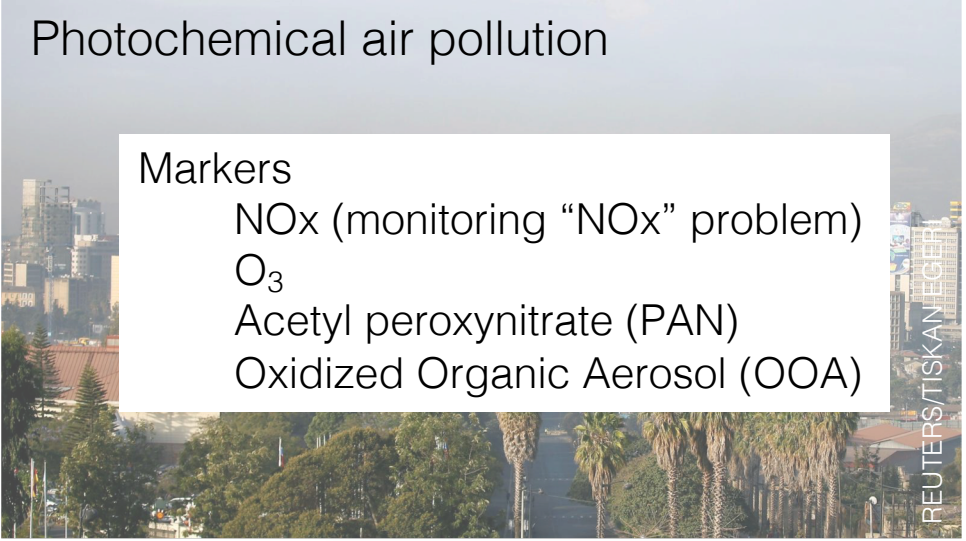


Health Actors:

- NOx, Nitrate
- Sulfate
- Heavy Metals
- Particles

Adon, et al., *Atmos Environ.,* 135, 31-40, 2016

Photochemical air pollution



Markers
- NOx (monitoring "NOx" problem)
- O_3
- Acetyl peroxynitrate (PAN)
- Oxidized Organic Aerosol (OOA)

Health Actors
- O_3
- NOx
- SOA
- Oxidants
- Long-lived radicals
  - Metals
  - Quinones

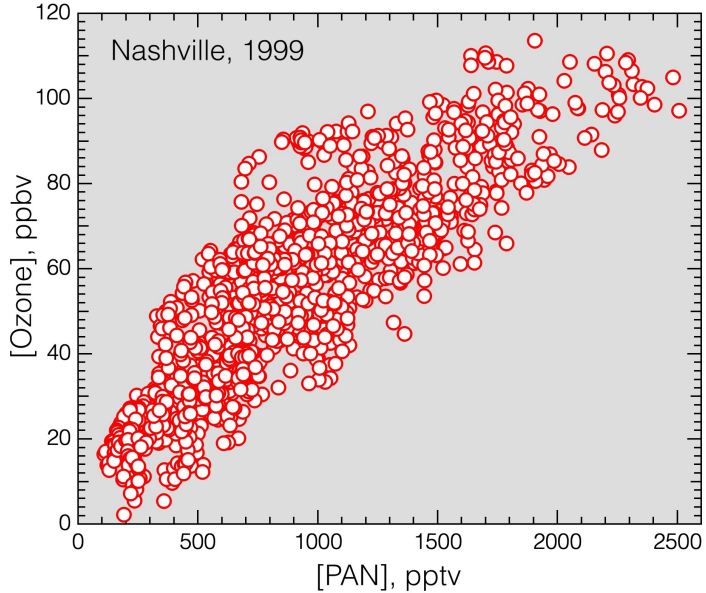
These might be best treated as a pair
e.g. $O_3 + NO_2 \equiv$ Odd Oxygen
because: $O_3 + NO_{(exhaust)} \Rightarrow NO_2 + O_2$
NO_2 is a health actor
Many low-cost sensors really measure both

Ozone is the hallmark of photochemical Air Pollution: O_3 doesn't tell you where it came from, e.g. what VOC sources where involved

<u>PAN compounds serve as indicators</u>

VOC + NOx + hν => RC(O)OONO2

Most VOCs => $CH_3C(O)OONO_2$ PAN
Isoprene => $CH_2=C(CH_3)C(O)OONO_2$ MPAN
BB VOC => $CH_2=CHC(O)OONO_2$ APAN



Summary/Conclusions

The connection between Air Pollution and Health impacts is well established

Details of the actual mechanisms and causative agents are lacking.

Better knowledge could allow us to :

- Address the most important causes first
- Design effective preventative or therapeutic measures

Sources and Chemical Actors important to African Megacities include;

- Biomass burning (Indoor and Outdoor): Toxics, Furans, Phenols, Particle ROS
- Trash burning: HCl, Dioxins, Vinyl chloride, Heavy metals.
- Vehicle Traffic: NOx, Black carbon, Nanoparticles
- Dust: Transition metals, Silica, Pathogens
- Photochemical Air Pollution: O_x (O_3 + NO_2), Particle ROS.