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Toxicity of airborne particles

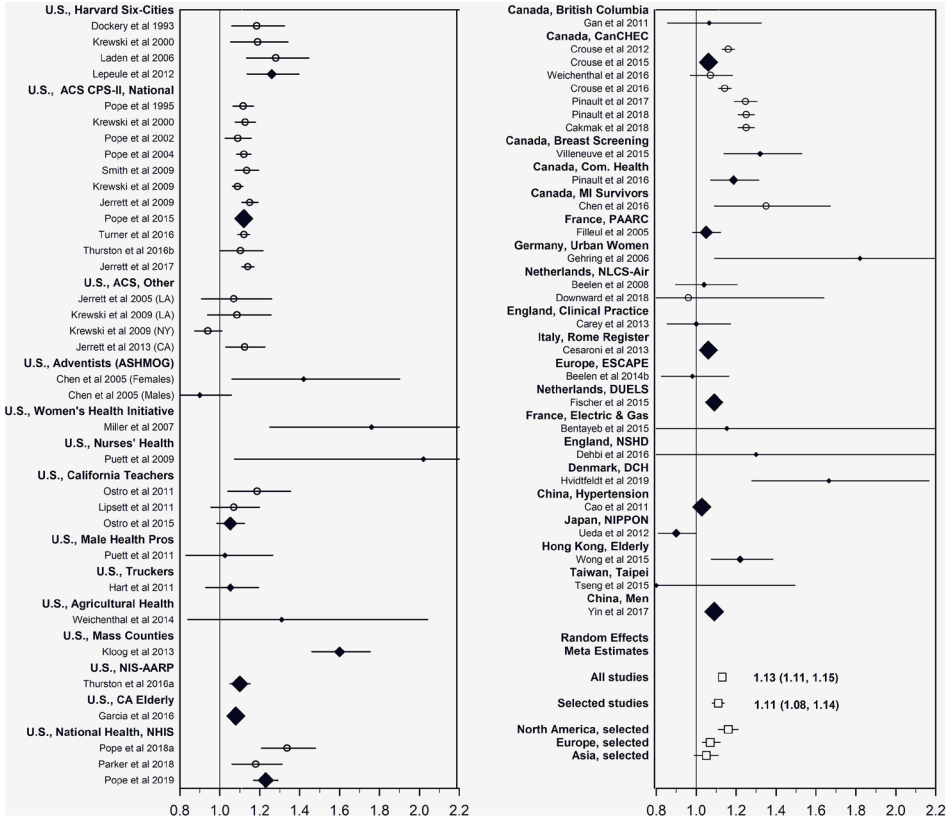
Established evidence and knowledge gaps

Frank J Kelly

Imperial College London

Cohort studies link $PM_{2.5}$ with excess cardiopulmonary mortality

RR=1.13 (1.07–1.20) per 10 μg/m^3



Pope et al 2019. Environ Res Nov 14:108924

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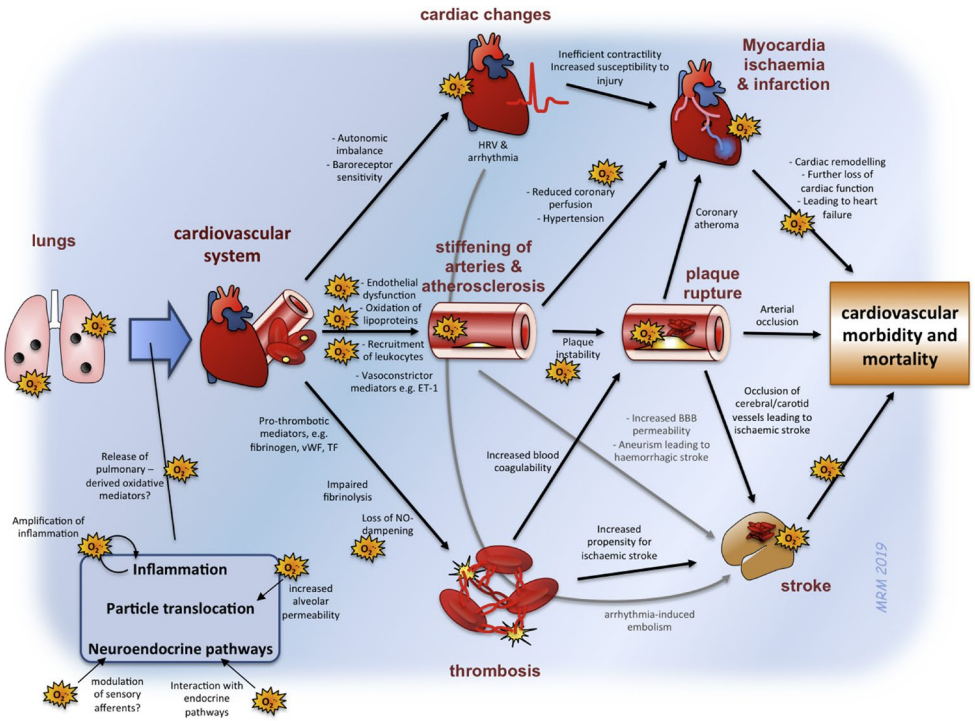
Ambient PM: toxicological evidence

- Contribution of oxidative stress to mechanisms by which inhaled PM induces CVD
- A complex series of interconnecting mechanisms underlies the effects of inhaled PM on cardiovascular morbidity & mortality



Miller 2020. Free Radic Biol Med Jan 7. pii: S0891-5849(19)32275-0

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Differential toxicity of ambient PM

- Represents one of the most challenging areas of environmental health research
- Has prompted momentous research efforts


HEI

RESEARCH REPORT

HEALTH EFFECTS INSTITUTE

Number 177
October 2013

National Particle Component Toxicity (NPACT) Initiative: Integrated Epidemiologic and Toxicologic Studies of the Health Effects of Particulate Matter Components
Morton Lippmann, Lung-Chi Chen, Terry Gordon, Kazuhiko Ito, and George D. Thurston

NPACT Study 1. Subchronic Inhalation Exposure of Mice to Concentrated Ambient $PM_{2.5}$ from Five Airsheds
Lung-Chi Chen and Morton Lippmann

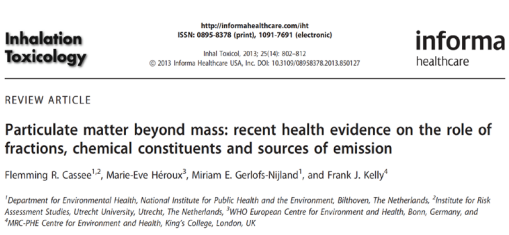
NPACT Study 2. In Vitro and in Vivo Toxicity of Exposure to Coarse, Fine, and Ultrafine PM from Five Airsheds
Terry Gordon, Morton Lippmann, Arthur Nádas, and Christina Hickey

NPACT Study 3. Time-Series Analysis of Mortality, Hospitalizations, and Ambient $PM_{2.5}$ and Its Components
Kazuhiko Ito, Zev Ross, Jiang Zhou, Arthur Nádas, Morton Lippmann, and George D. Thurston

NPACT Study 4. Mortality and Long-Term Exposure to $PM_{2.5}$ and Its Components in the American Cancer Society's Cancer Prevention Study II Cohort
George D. Thurston, Kazuhiko Ito, Ramona Lall, Richard T. Burnett, Michelle C. Turner, Daniel Krewski, Yuanli Shi, Michael Jerrett, Susan M. Gapstur, W. Ryan Diver, and C. Arden Pope III


World Health Organization
REGIONAL OFFICE FOR Europe

HEALTH EFFECTS OF
BLACK CARBON


Inhalation Toxicology

http://informahealthcare.com/iht
ISSN: 0895-8378 (print), 1091-7691 (electronic)

Inhal Toxicol, 2013; 25(14): 802–812
© 2013 Informa Healthcare USA, Inc. DOI: 10.3109/08958378.2013.850127

informa healthcare

REVIEW ARTICLE

Particulate matter beyond mass: recent health evidence on the role of fractions, chemical constituents and sources of emission

Flemming R. Cassee[1,2], Marie-Eve Héroux[3], Miriam E. Gerlofs-Nijland[1], and Frank J. Kelly[4]

[1]Department for Environmental Health, National Institute for Public Health and the Environment, Bilthoven, The Netherlands, [2]Institute for Risk Assessment Studies, Utrecht University, Utrecht, The Netherlands, [3]WHO European Centre for Environment and Health, Bonn, Germany, and [4]MRC-PHE Centre for Environment and Health, King's College, London, UK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HEALTH EFFECTS INSTITUTE

Number 184
January 2015

Advanced Collaborative Emissions Study (ACES): Lifetime Cancer and Non-Cancer Assessment in Rats Exposed to New-Technology Diesel Exhaust

The National Environmental Respiratory Center (NERC) experiment in multi-pollutant air quality health research: I. Background, experimental strategy and critique

Joe L. Mauderly

Imperial College London

Ambient PM: factors influencing toxicity

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Differential toxicity: overall consensus

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RESEARCH REPORT

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'the studies do not provide compelling evidence that any specific source, component, or size class of PM may be excluded as a possible contributor to PM toxicity'

HEI. 2013 National Particle Component Toxicity (NPACT) Initiative

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Differential toxicity: overall consensus

Short-term Exposure to Particulate Matter Constituents and Mortality in a National Study of U.S. Urban Communities

Jenna R. Krall,[1] G. Brooke Anderson,[1] Francesca Dominici,[2] Michelle L. Bell,[3] and Roger D. Peng[1]

[1]Department of Biostatistics, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA; [2]Department of B Harvard School of Public Health, Boston, Massachusetts, USA; [3]Yale School of Forestry and Environmental Studies, Yale Univ New Haven, Connecticut, USA

BACKGROUND: Although the association between $PM_{2.5}$ mass and mortality has been extensively studied, few national-level analyses have estimated mortality effects of $PM_{2.5}$ chemical constituents. Epidemiologic studies have reported that estimated effects of $PM_{2.5}$ on mortality vary spatially and seasonally. We hypothesized that associations between $PM_{2.5}$ constituents and mortality would not vary spatially or seasonally if variation in chemical composition contributes to variation in estimated $PM_{2.5}$ mortality effects.

OBJECTIVES: We aimed to provide the first national, season-specific, and region-specific associations between mortality and $PM_{2.5}$ constituents.

METHODS: We estimated short-term associations between nonaccidental mortality and $PM_{2.5}$ constituents across 72 urban U.S. communities from 2000 to 2005. Using U.S. Environmental Protection Agency (EPA) Chemical Speciation Network data, we analyzed seven constituents that together compose 79–85% of $PM_{2.5}$ mass: organic carbon matter (OCM), elemental carbon (EC), silicon, sodium ion, nitrate, ammonium, and sulfate. We applied Poisson time-series regression models, controlling for time and weather, to estimate mortality effects.

RESULTS: Interquartile range increases in OCM, EC, silicon, and sodium ion were associated with estimated increases in mortality of 0.39% [95% posterior interval (PI): 0.08, 0.70%], 0.22% (95% PI: 0.00, 0.44), 0.17% (95% PI: 0.03, 0.30), and 0.16% (95% PI: 0.00, 0.32), respectively, based on single-pollutant models. We did not find evidence that associations between mortality and $PM_{2.5}$ or $PM_{2.5}$ constituents differed by season or region.

CONCLUSIONS: Our findings indicate that some constituents of $PM_{2.5}$ may be more toxic than others and, therefore, regulating PM total mass alone may not be sufficient to protect human health.

CITATION: Krall JR, Anderson GB, Dominici F, Bell ML, Peng RD. 2013. Short-term exposure to particulate matter constituents and mortality in a national study of U.S. urban communities. Environ Health Perspect 121:1148–1153; http://dx.doi.org/10.1289/ehp.1206185

and California (Ostro et al. 2007 outside the United States (Cal 2009; Cao et al. 2012). Although all estimated associations betwee and individual $PM_{2.5}$ constituents, constituents that were associated tality varied among the studies (carbon (Cakmak et al. 2009; Cao Ito et al. 2011), EC (Cakmak et al et al. 2012; Ito et al. 2011; Ostro Zhou et al. 2011), silicon (Ito Zhou et al. 2011), sulfate (Cao Ito et al. 2011), nitrate (Cao Ostro et al. 2007), ammonium 2012). Thus, there is uncertaint contributions of specific $PM_{2.5}$ co $PM_{2.5}$-related mortality.

A national study of mortality constituents could provide impo mation about the toxicity of PM tribute to the scientific evidence b to develop more targeted regulati ent PM. Different chemical con $PM_{2.5}$ are generated by differen sources. For example, EC and

'Associations with a given $PM_{2.5}$ chemical component should be considered as potentially indicative of associations with another component or set of components with similar sources'

Krall et al 2013. Environ Health Perspect 121:1148-1153

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Global pressures & challenges

Non-exhaust PM at the roadside

Likely shift in composition of PM & emergence of novel components

Microplastics

Domestic wood burning

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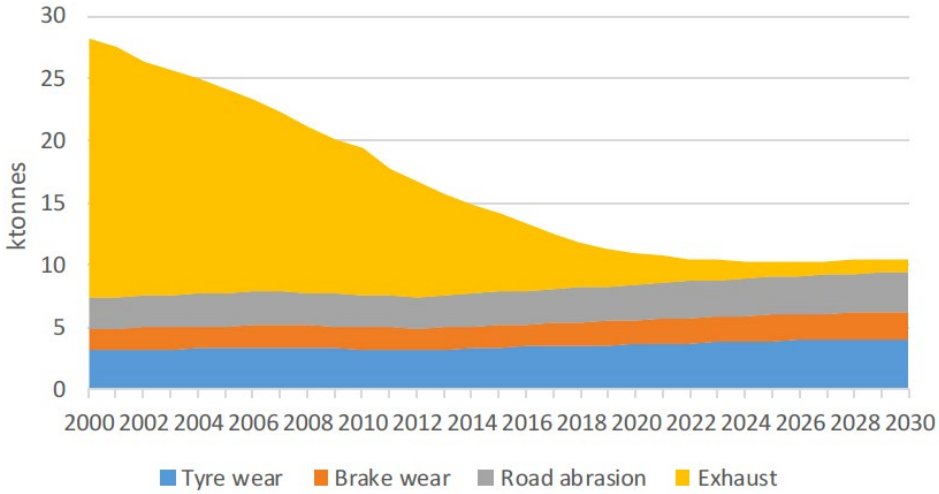
UK emissions of $PM_{2.5}$ from road transport

Particles from brake, tyre & road surface wear constitute (by mass):

- 60% of primary $PM_{2.5}$
- 73% of primary PM_{10}

emissions from road transport



UK Air Quality Expert Group 2019. Non-exhaust Emissions from Road Traffic. http://uk-air.defra.gov.uk

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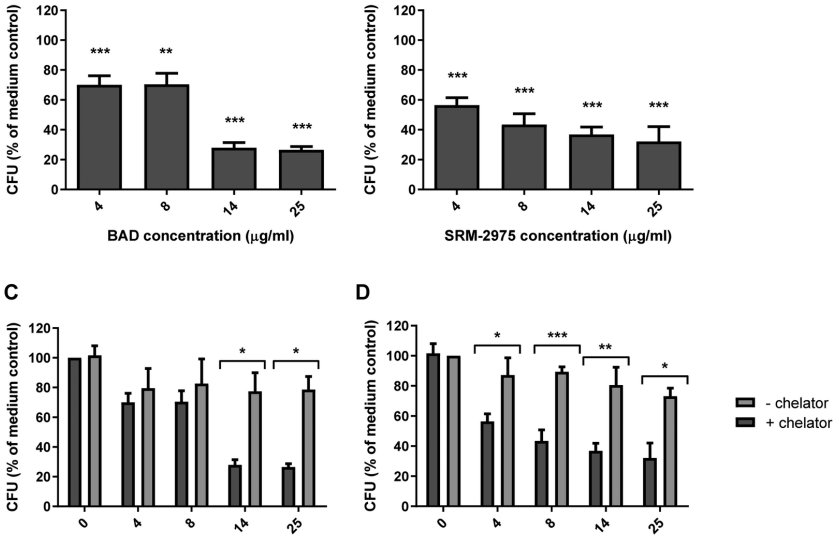
Brake abrasion dust (BAD)

- At minimally cytotoxic doses DEP & BAD perturbed bacterial clearance & promoted inflammatory responses with similar potency
- Highlights requirement to consider contributions of abrasion particles to traffic-related clinical health effects



Selley et al 2020. Metallomics 12:371-386

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Microplastics

≤ 5 μm particles & fibres produced from breakdown of larger items eg clothing, car tyres & mismanaged urban waste

Concern stems from:

- Global mass production (> 320 Mt/y)
- Persistence in the environment & synthetic physiological fluids

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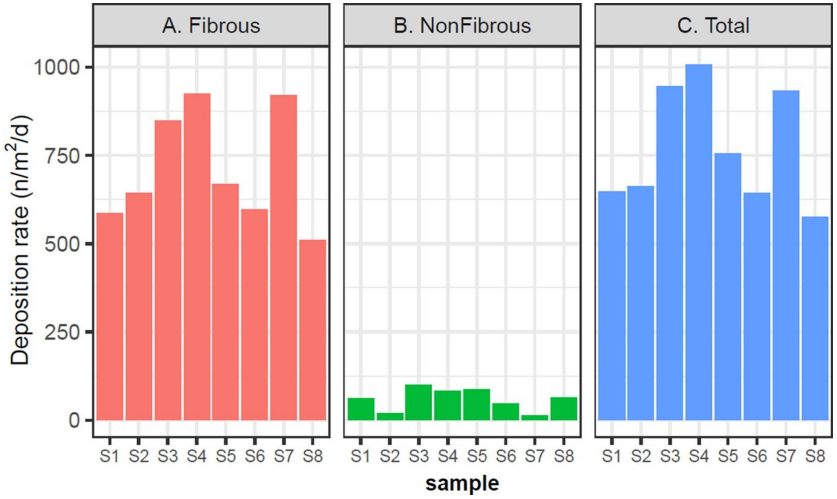
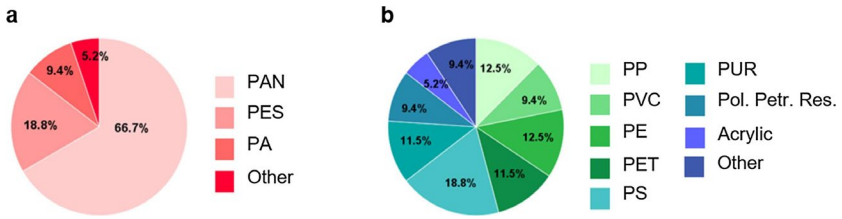
Airborne microplastics in an urban environment



Deposition rates: 575 - 1008 per m^2/d



15 different petrochemical-based polymers identified

Wright et al 2020. Environ Int 136: 105411

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Are inhalable microplastics affecting our health?

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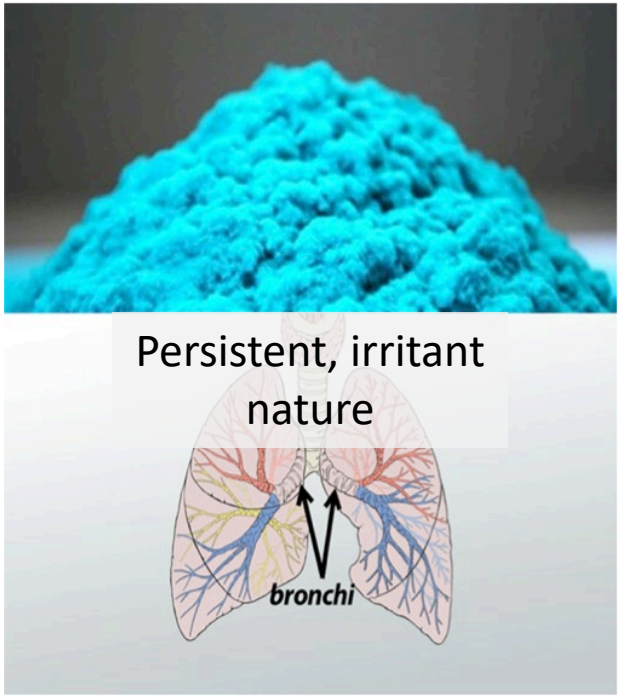
Flocker Worker's Lung

- Persistent dry cough, shortness-of-breath, chest pain
- Infection in the airway
- Inflammation of tissues surrounding bronchi
- '**Health hazard exists from occupational exposures to flock–associated dust**' (National Institute for Occupational Safety & Health)



Kern et al 1998, 2000, 2003

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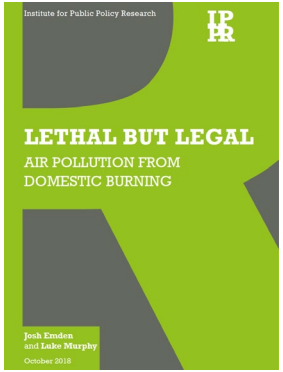
Domestic wood burning

- Commonplace for residential heating in mid- & high-latitude climates
- Throughout N America, wood stoves remain most commonly used type of residential heaters
- Europe is experiencing a return to home heating with solid fuels owing to aesthetic appeal & quest to reduce fossil fuel combustion



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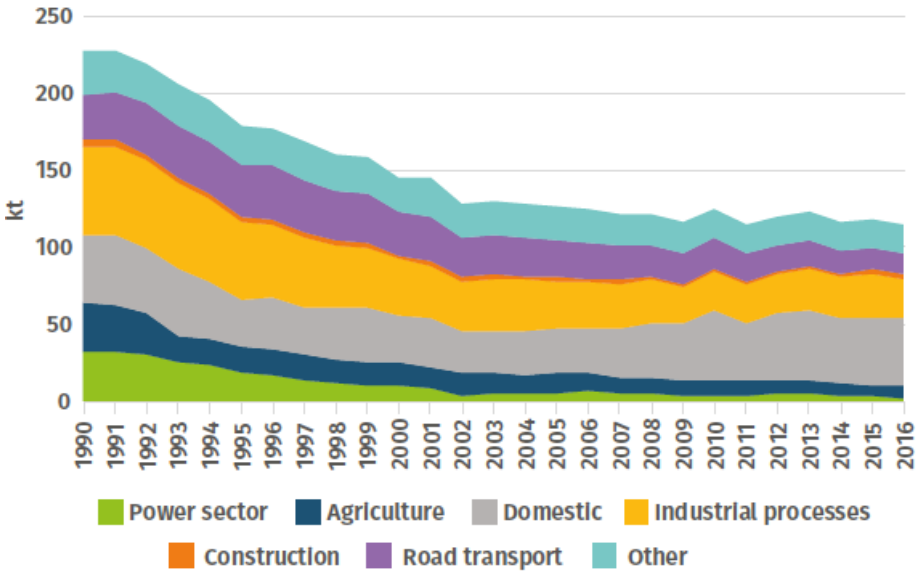
$PM_{2.5}$ from domestic combustion in the UK

- Domestic sector produces 40% of the UK's $PM_{2.5}$
- Over 3 times more than road transport
- Burning of wood is largest contributor to PM emissions in domestic sector
- Emission factors for PM in wet wood substantially higher than dry wood



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Inextricable link with climate change

Increased temperatures
Extended drought
High winds
Changes in vegetation

↓

Increased risk from natural events

Wildfires

Desert dust storms

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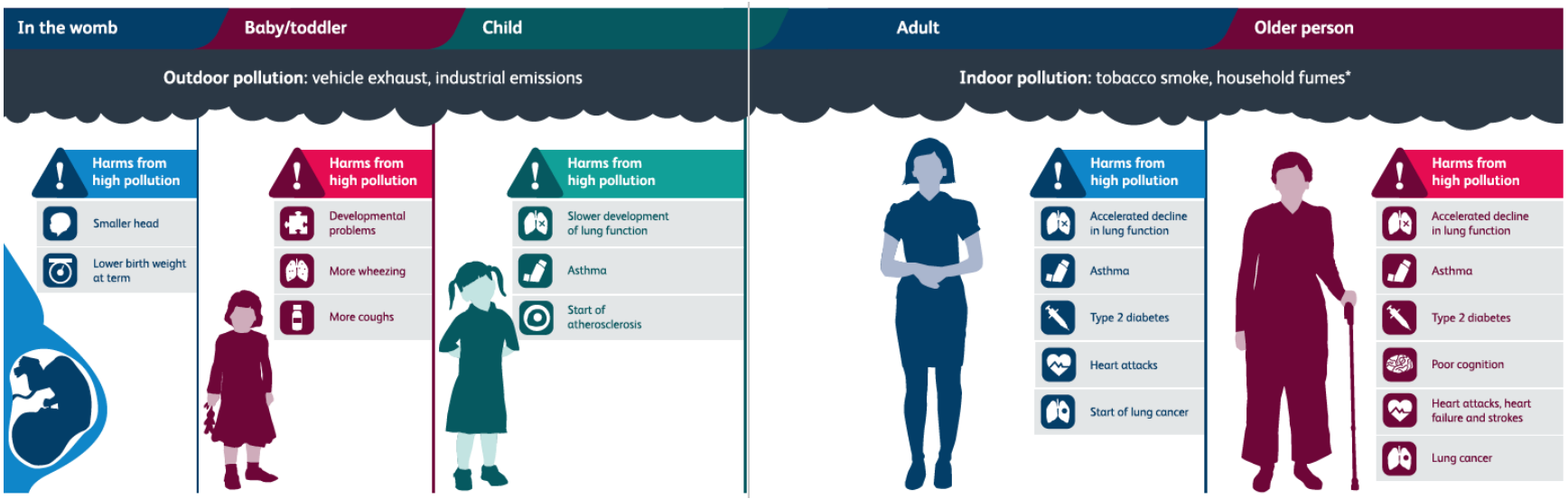
The wider threat to human health



Royal College of Physicians & Royal College of Paediatrics & Child Health. 2016

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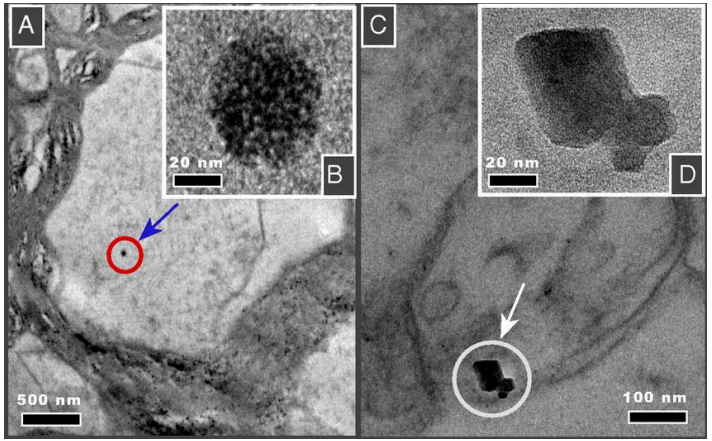
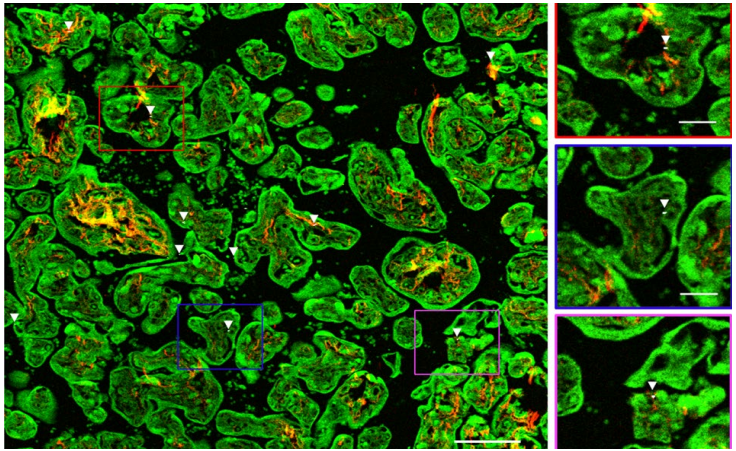
Possible causal pathways

Magnetite pollution nanoparticles in human brain



Maher et al 2016. PNAS 113: 10797-10801

Ambient BC particles on fetal side of human placenta



Bove et al 2019. Nat Commun 10:3866

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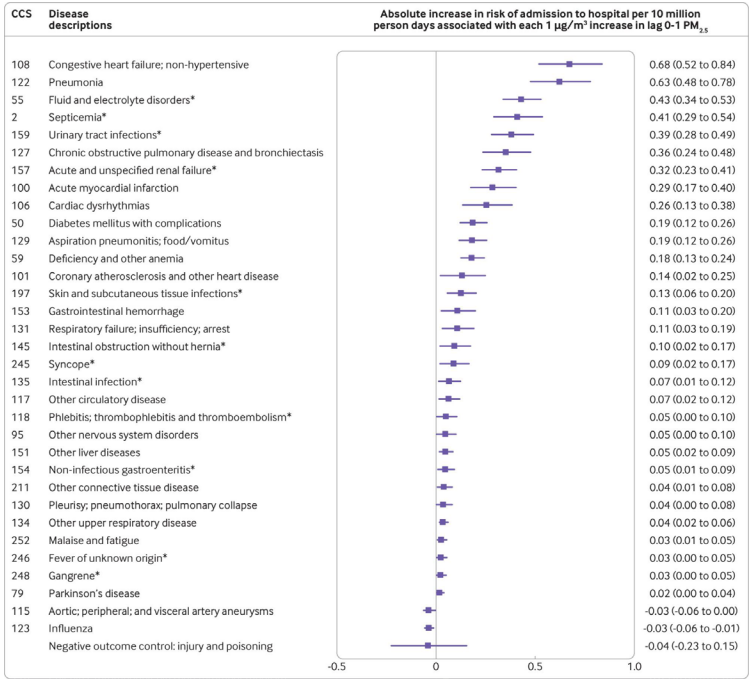
Health effects of $PM_{2.5}$ ... harder we look the more we find

- Hypothesis free analysis of large dataset
- Discovered new causes of hospital admissions
- Even at daily $PM_{2.5}$ concentrations below current WHO guideline



Wei et al 2019. BMJ 367:l6258

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Ambient PM: factors influencing toxicity

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+ too many other great researchers to name.