Fossil Fuels: Their Impact on Climate Change and Air Pollution

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Health Effects of Air Pollution
Risk factors for exposures that contribute to chronic-disease mortality. The chart was compiled from World Health Organization estimates of exposures affecting 50 million global deaths in 2010.
Pollutants that trigger air pollution - Two types of pollutant – primary and secondary
Air pollutant particles (PM$_{2.5}$ and PM$_{0.1}$) become systemically bioavailable.
Air Pollution and Mortality in the Medicare Population

• In the entire Medicare population, there was significant evidence of adverse effects related to exposure to PM$_{2.5}$ and ozone at concentrations below current national standards.

• This effect was most pronounced among self-identified racial minorities and...
Size, source and chemical composition as determinants of toxicity attributable to ambient particulate matter

Pathways of particle induced toxicity at the air–lung interface. **Particles elicit oxidative stress through five inter-related mechanisms.**

RTF= Respiratory Tract Lining Fluid

Fussell JC, Kelly JF. Atmospheric Environment. 2012; 60: 504-26
If Oxidative Potential is found to be related to major health impacts this could imply that controlling its specific sources might be more effective.

crustal material (crustal), SIA (comprising NH4\(^+\) + NO_3\(^-\) + SO_4^{2-}\), vehicular wear, anthropogenic SOA (aSOA), biogenic SOA (bioSOA), vehicular exhaust POA (HOA).

SOA = secondary organic aerosol

\[
DTT_{PM10}^v = \text{Antioxidant of PM10}
\]
Ambient Particulate Air Pollution and Daily Mortality in 652 Cities

Pooled concentration–response curves for the associations of 2-day moving average concentrations of PM$_{10}$ and PM$_{2.5}$ with daily all-cause mortality.

Annualised average Daily PM$_{10}$ and PM$_{2.5}$

World Health Organization Air Quality Guidelines (WHO AQG), WHO Interim Target 1 (IT-1), WHO Interim Target 2 (IT-2), WHO Interim Target 3 (IT-3), European Union Air Quality Directive (EU AQD), U.S. National Ambient Air Quality Standard (NAAQS), and China Air Quality Standard (AQS).

Previous risk assessments have examined the health response to total PM$_{2.5}$, not just PM$_{2.5}$ from fossil fuel combustion, and have used a concentration-response function with limited support from the literature and data at both high and low concentrations.

This assessment examines mortality associated with PM$_{2.5}$ from only fossil fuel combustion, making use of a recent meta-analysis of newer studies with a wider range of exposure.

This study demonstrates that the fossil fuel component of PM$_{2.5}$ contributes a large mortality burden. The steeper concentration-response function slope at lower concentrations leads to larger estimates than previously found in Europe and North America, and the slower drop-off in slope at higher concentrations results in larger estimates in Asia.
120 million children live in areas where outdoor air pollution exceeds international limits.

20 million children live in areas where outdoor air pollution exceeds 2 times international limits.
Air pollution affects people throughout their lifetime

**Pregnancy**
- low birth weight

**Children**
- asthma
- slower development of lung function
- development problems
- more wheezing and coughs
- start of atherosclerosis

**Adults**
- asthma
- coronary heart disease
- stroke
- lung cancer
- chronic obstructive pulmonary disease (as chronic bronchitis)
- diabetes

**Elderly**
- asthma
- accelerated decline
- lung function
- lung cancer
- diabetes
- dementia
- heart attack, heart failure and strokes
Overview of diseases, conditions, and biomarkers affected by outdoor air pollution. Conditions currently included in the Global Burden of Disease categories are shown in **bold**

What Constitutes an Adverse Health Effect of Air Pollution? An analytical framework


![Diagram of diseases, conditions, and biomarkers affected by outdoor air pollution]
Evidence for the presence of air pollution nanoparticles in placental tissue cells.

Liu NM et al. Science of The Total Environment, 2021; 751: 142235

- Human placentas were used to investigate translocation of inhaled nanoparticles.
- Carbon and metal-bearing nanoparticles were found in tissue phagocytes in vivo.
- Size, shape and elemental composition of these exogenous particles were identified.
- Tissue phagocytes uptake of diesel exhaust particles was demonstrated in vitro.

Translocated PM (red arrows) interacting with tissue phagocytes in distant

Elemental mapping shows elongate nanoparticle clusters containing calcium and iron (figure B and C).
Ambient black carbon particles reach the fetal side of human placenta.

Using femtosecond pulsed laser illumination, Black Carbon identified in all screened placentae, with an average particle count of $0.95 \times 10^4$ and $2.09 \times 10^4$ particles/mm$^3$ for low and high exposed mothers, respectively.
Placental BC load is positively associated with mothers’ residential BC exposure during pregnancy (0.63-2.42 µg/m$^3$).

**BC particles accumulate on the fetal side of the placenta** suggests that ambient particulates could be transported towards the fetus and represents a potential mechanism explaining the detrimental health effects of pollution from early life onwards.
Effect of air pollution in modifying gene expression – epigenetics – CpG methylation


Principle stages of lung development in humans

Pollution effects on the brain – dementia and cognitive decline
High-resolution analytical imaging and electron holography of magnetite particles in amyloid cores of Alzheimer’s disease

Electron energy loss spectroscopy of high-contrast individual particles indicating presence of characteristic oxygen and iron peaks
Combustion- and friction-derived magnetic air pollution nanoparticles in human hearts.

• 27 clinically healthy subjects ~age 23yrs in Mexico City who died suddenly in RTAs, without chest or head trauma
• Heart magnetic content - 2G RAPID cryogenic and JR6 magnetometers and saturation magnetic remanence (SIRM) of freeze-dried left ventricle samples.
• After tissue digestion papain, heart magnetic particles examined directly by high resolution TEM analyses of magnetically-extracted particles,
• Iron-rich, strongly magnetic combustion- and friction-derived nanoparticles are present in abundance in young urbanites' hearts.
• Mexico City residents have up to ~22 billion magnetic NPs/g of ventricular tissue.
• Oxidative and endoplasmic reticulum (ER) stress are significant in human ventricular tissues.
• Exposure to abundant, highly oxidative, iron-rich pollution nanoparticles is a plausible route into CVD pathogenesis.
The particle size distribution of metal-bearing NPs samples in Mexico City air; inset transmission electron micrograph shows the typical rounded shape of these pollution ‘nanospheres’, rich in Fe and other associated transition metals.
Combustion- and friction-derived magnetic air pollution nanoparticles in human hearts.


HRTEM micrographs of (A) magnetic NPs ~80 nm diameter with fused interlocking nanocrystallites (note the varying orientations of the individual crystallite faces) extracted from left ventricle sample in a 48 yr old male.

(B) for comparison, airborne pollution particle collected by air sampling near a power generating plant (Didcot, U.K.)

(D–F) Aggregated heart nano-magnetite (hkl plane = 311) or nano-maghemite (hkl plane = 312) particles, with lattice spacing of 2.5 Å
The average person in Britain spends just 8 per cent of their time outside on a week day, meaning less than two hours a day out of doors.

Most of this time is spent walking to the shops or the car, but men are slightly better at getting out than women, at 28 minutes more per weekday.

Brits also admit to spending 1 hour 37 minutes per day less outside during winter in comparison to summer.

- Taking pets for a walk (17%)
- Walking to the shop at lunchtime (16%)
- Walking to and from the car (15%)
- Walking to work from my bus/train (14%)
- Going for a run (6%)
- Walking the kids to school (5%)
- Smoking (4%)
- Cycling to work (2%)

‘The Indoor Generation'
Improve indoor air quality

Actions for local authorities
- Checking people’s homes and giving advice
  - Use inspections and home visits to identify poor indoor air quality.
  - Staff who visit people’s homes should:
    - Know about sources of indoor air pollutants and their effects on health.
    - Give advice on avoiding activities that increase pollutants and improving ventilation (see below).
    - Ensure that advice can help with repairs and necessary improvements.
    - Give advice on requesting a housing assessment if poor indoor air quality is suspected.
    - Advise private and social tenants to contact their landlord if ventilation is inadequate.
    - Repairs are needed to prevent water from entering the home.
    - Improvements are needed to heating or insulation to prevent condensation.
    - Advise tenants to contact their local authority if no action is taken to improve ventilation or carry out repairs.

Advice on reducing damp and condensation
- Use background ventilation (trickles vents or whole house mechanical ventilation)
- Use extractor fans and open windows of portable and fixed appliances
- Avoid moisture-producing activities (such as air-drying clothes or, if unavoidable, improving ventilation)
- Repair sources of water damage and remove residual moisture

Advice on increasing ventilation
- Use extractor fans in bathrooms and kitchens, or open windows if possible and safe when using.
- Using extractors, using open solid fuel stove or free-standing gas heaters
- Using candles, using cleaning products, household sprays or aerosols and paints
- Having a bath or shower
- Air-drying clothes

Other advice
- Do not use solid fuel or paraffin heaters.
- Follow product instructions if using, for example, paint, glue and solvents.
- Choose low-emitting materials if replacing furniture or flooring.
- Ensure adequate ventilation when installing a new cooker.
- Do not use gas cookers to heat a room.
- Avoid smoking in the home.

Actions for healthcare professionals
- Advice for people with breathing or heart problems
  - Explain that indoor air pollutants can trigger or exacerbate asthma, other respiratory conditions and cardiovascular conditions.
  - Help the patient to avoid exposure to indoor dust mites, including use of second-hand mattresses if possible.
  - Help the patient to avoid exposure to indoor dust mites, including use of allergen barriers such as mattress and pillow covers and avoiding bedding regularly.

Advice for people allergic to house dust mites
- Advise on how to reduce exposure to indoor dust mites, including the use of second-hand mattresses if possible.
- Help the patient to avoid exposure to indoor dust mites, including use of allergen barriers such as mattress and pillow covers and avoiding bedding regularly.

Advice for pregnant women and babies under 12 months
- Advise on the increased risks from poor indoor air quality.
- Explain the risks of tobacco smoke.
- Help the patient to avoid exposure to indoor dust mites, including the use of second-hand mattresses if possible.
- Help the patient to avoid exposure to indoor dust mites, including the use of allergen barriers such as mattress and pillow covers and avoiding bedding regularly.

Advice on avoiding or reducing the use of open solid fuel stoves or candles
- Advise on avoiding smoking in the home or around the women and baby.

January 2020
Wave 2 - Clean Air: Addressing the Challenge of the Indoor/Outdoor Continuum

BACKGROUND

- The scientific, technical, behavioural and policy approaches used to assess and manage exposure to air pollution need radical change to reflect the indoor/outdoor continuum of exposure.

- Human exposure to air pollution occurs in the home, at school and in workplaces, whilst travelling, and during leisure activities.
An indoor chemical cocktail: The chemistry that determines human exposure to indoor pollutants is incompletely understood - Gligorovski S, Abbatt JPD. Science 2018: 359; 632-3

- Recent work has highlighted the wealth of chemical transformations that occur indoors to generate Secondary Organic Aerosol (SOA).

- This chemistry is associated with 3 of the top 10 risk factors for negative health outcomes globally: household air pollution from solid fuels, tobacco smoking, and ambient particulate matter pollution.

- Highly oxidised organic compounds arise via auto-oxidation mechanisms initiated by either ozone or radical attack.

- Reaction with a single oxidant molecule can form multiple oxygenated functional groups on an organic reactant within seconds, changing it from a volatile gas to a molecule that will condense to form secondary organic aerosol (SOA) particles.
Third-hand smoke is residual - or leftover - nicotine and other chemicals that remain on clothing and surfaces after someone smokes in the area. Dangerous residue from tobacco smoke sticks to carpets, walls and other surfaces after the smoke clears.

1. Third-hand smoke may be a culprit in more cancer cases
2. Third-hand smoke may damage DNA
3. Residue may react with airborne chemicals to form carcinogens
4. Children are most at risk
5. Removing the residue is very difficult
SPF Clean Air – Two Waves

Wave 1 - Clean Air: Analysis & Solutions
Developing solutions to air pollution to help policymakers and businesses protect health and work towards a cleaner economy. (£20.5m)

Wave 2 - Clean Air: Addressing the Challenge of the Indoor/Outdoor Continuum
The programme aims to equip the UK to proactively tackle new air quality challenges related to changing emissions and exposure patterns, in order to protect human health and support clean growth. (£22m)
Air quality dependencies and basis for Clean Air systems analysis framework

Failure of engagement and ownership of the health problems by medical community

Communication barriers between physical and biological/health scientists

Lack of public understanding

Little motivation for behaviour change

Lack of interfaces to promote innovations

Capability/Linkages limited, fragmented and not aligned: Street ⇐ Global a particular challenge
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https://www.ukcleanair.org/
People will change their behaviour only if they see the new behaviour as easy, rewarding, empowering and normal.