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Air Pollution: The Public Health Challenge of our Time

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Introduction

Air Pollution is a global problem. 90% of the urban population worldwide are exposed to levels above the WHO guideline limit for small particulates (PM2.5) of 10 micrograms per cubic metre of air (μg/m3)[1] Recent studies estimate that air pollution causes 8.8 million premature deaths globally, which represents 15.7% of all deaths.[2] This makes ambient air pollution the greatest preventable cause of death globally, bigger even than smoking at 7.2 million deaths. The new estimate for mortality in the UK is 64,000 premature deaths annually which means that the average UK newborn loses on average 2.2 years of life due to a health hazard that is beyond their control. It should be noted however that the "official" figure for the number of premature deaths annually from PM2.5, according to the Department of Health's advisory Committee, COMEAP, (Committee on the Medical Effects of Air Pollution) remains between 28-36,000 pa.

The higher estimate of 64,000 is based on 41 studies linking air pollution with mortality in 16 different countries.[3] However excess mortality is only a small part of the total picture. A joint Royal Colleges report from 2016, based on 40,000 deaths annually, estimated that air pollution in the UK carries social and health costs of £20 billion per annum, with mortality contributing only 8% of the total.[4] The rest relates to morbidity - in other words the chronic effects of air pollution which begin before birth and persist throughout life. This review will examine some of these other effects.

Fine particulate matter (PM2.5) is deemed the pollutant most detrimental to human health. The particulates arising from processes that burn carbon such as coal-fired power stations, wood-heaters and combustion engine emissions are small enough to translocate from the lungs into

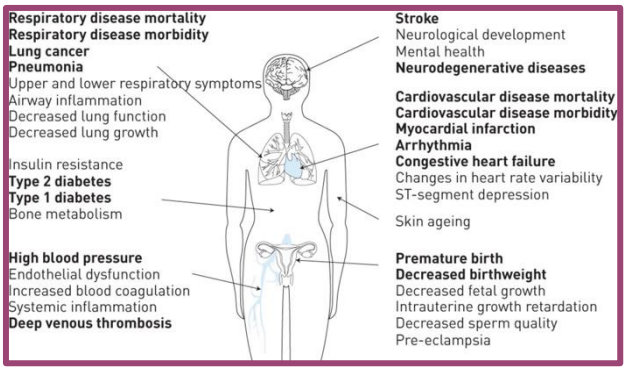

Figure 1. Overview of diseases, conditions and biomarkers affected by outdoor air pollution. [5]
Bold type indicates conditions currently included in the Global Burden of Disease categories, 2016.

Birth weight

Birthweight is a critical measure. An analysis of 32 studies linking pregnancy outcomes with the level of small particulates (PM2.5) concluded that each increase of 10 μg/m3 in PM2.5 lowers birthweight by 16 grams.[6] It is well known that smoking during pregnancy also lowers birth weight, but mothers have the option of stopping, and most do. But living in urban areas does not give pregnant women this option. In city centres all over the world, pregnant women are exposed to levels of air pollution that will lower the birthweight of their babies and lay the seeds of problems in childhood and later life. In cities in India and China, where little attention has been devoted to air quality, the pollution problem is severe enough to render those cities unfit for human habitation in general, and dangerous for pregnant women in particular. In Central London pregnant women are exposed to a level of small particulates (15 μg/m3) that will lower the birth weight of their baby by around 24 grams. In Delhi

the average annual level for small particulates is 143 microg/m3, and in other cities in Northern India it is even higher (200 microg/m3). One cannot extrapolate directly from London to Delhi on the basis of PM2.5 measurements as we don't know the shape of the dose-response curve; nor the chemical constituents of the locally generated particulates; although it is known that much of the pollution in Delhi is from biomass burning and construction. As discussed later, this is likely to be less toxic than exhaust emissions from traffic. A better way to compare levels of "traffic" pollution in Delhi and London is by measuring NO_2.

Levels of $PM_{2.5}$ in the London are below the annual EU standard of 25 μg/m3, but the health effects of small particulates are without threshold. Even in low pollution countries such as Australia, where the legal limit for $PM_{2.5}$ is 8 μg/m3, air pollution makes a significant contribution to illness and premature death.[7]

The EU commission are currently reviewing the Ambient Air Quality Directive and are likely to lower the annual limit. In the US, the legal limit is 12 μg/m3. The EU commission already include a measure of particle number as well as particle mass in vehicle emission tests, as ultrafine particulates ($PM_{0.1}$), generated mainly from traffic exhausts, are more dangerous biologically than larger particulates. This is important as electric vehicles will still generate particles through wear and tear on tyres and brakes. However, in 2017, researchers from Kings College London showed that reductions in birth weight are tied more closely to exhaust emissions than to friction particulates, and not at all to noise pollution.[8] During the Olympic Games in 2008, the Chinese Government made every effort to reduce pollution levels in Beijing, notably by restricting vehicle access, and birth weight increased.[9] The maximum benefit (23 grams) was for women who were in the last trimester of their pregnancy during the Olympic Games: in other words, the stage of pregnancy associated with maximum foetal growth.

Exposure in utero

Low birth weight is linked to a host of adverse outcomes in later life, including lower IQ. Evidence also exists for a direct impact of pollution during pregnancy. Polycyclic Aromatic Hydrocarbons (PAHs) are generated by any combustion process, so members of the public are exposed from activities such as smoking, cooking, domestic fires, and of course traffic, particularly diesel. Researchers in New York have reported that exposure to PAHs during pregnancy in non-smoking mothers is linked to developmental delay at 3 years,[10] an IQ reduction of 4-5 points at 5 years,[11] increased anxiety, depression and inattention at 6-7 years,[12] reduced surface white matter in the brain at 8 years,[13] and delayed self-regulatory behaviour that was most significant at 11 years.[14] These observations have not yet been replicated in the UK or elsewhere. Even so, the situation may be worse in other countries where diesel vehicles represent a much larger proportion of the car market than in the US. Since 2000 the proportion of new vehicles in the UK which run on diesel has increased from 14% of the new car market to almost 50%. Levels of Benzo-a-pyrene, the only PAH monitored in the EU, have increased by 52% at traffic monitoring sites since 2000.[15] While some European countries are now taking action to reduce diesel emissions, others such as Australia remain on an increasing trajectory of diesel vehicle uptake. For instance, diesel vehicles increased to 25.6 per cent of the national fleet, up from 19.7 per cent in 2015.[16]

In the UK, diesel sales are going in the opposite direction. In September 2020, sales of hybrid and electric vehicles exceeded the sales of new diesel vehicles for the first time (JATO Press Release Oct 29, 2020).

Effect on IQ

These observations have profound implications for public health and educational attainment. UK children and teenagers are currently suffering a mini epidemic of mental health problems, which the medical profession is struggling to explain. Commentators have targeted social media, but the toxic impact of air pollution on developing brains is equally worthy of attention, and a vital area for further research. Thus, air pollution has also been linked with IQ deficits in teenagers,[17] and a recent London-based study showed higher rates of depression amongst teenagers exposed to higher levels of air pollution.[18] It could be argued that these associations are not causal, but intervention studies are more compelling and cannot be dismissed so easily. We already know that efforts to reduce air pollution during the Olympic games in Beijing led to an increase in birthweight (see endnote 7). This is an intervention study. Equally a recent US study demonstrated an increase in the cognitive performance of school children when air filters were fitted to schools in Los Angeles.[19]. Perhaps most remarkable is that depression and anxiety in the UK has fallen by 43

and 48% respectively since lockdown, and self harm by almost 38% (20). This was actually predicted by RRJ in emails to the editor of the Guardian in March 2020 (Personal Communication)

Dementia

There are data showing that air pollution also impacts cognitive function in later life. A systematic review in 2016 identified 31 studies linking air pollution with cognitive decline: 15 in the Americas, 5 in Asia and 11 in Europe.[21] In 2017 a study of 2.2 million older adults living in Ontario showed that their chances of developing dementia increased the closer they lived to a major highway, indicating a dose-response relationship for traffic-derived pollution and dementia.[22] In 2018 a study of 75 GP practices in Greater London showed that the chances of developing dementia were linked to ambient levels of both $PM_{2.5}$ and NO_2.[23] The authors concluded that 14% of dementia cases in the UK are attributable to air pollution. A compelling case for causality comes from a study in New York showing that individuals with apolipoprotein E genotype E4 allele (one of the strongest genetic risk factors for Alzheimer's) have an accelerated decline in cognition in proportion to ambient air pollution exposure.[24]

The UK situation

We are constantly being told by Government Ministers that air quality in the UK is improving. This is certainly true for pollutants such as Sulphur dioxide, which has largely been eliminated by the use of low Sulphur fuels and desulphurisation equipment. It is also true if emissions of particulates and nitrogen oxides are viewed as a national total, as the UK, along with most other countries in the EU, has been closing coal-fired power stations. In urban areas however, where traffic is the major pollution source, better air quality has proven much more difficult to achieve. At the same time evidence as to the harmful effects of air pollution has been rapidly increasing, particularly in relation to small particulates and ultra-fines.

Indeed, there is also considerable concern that ultrafine particles ($PM_{0.1}$ or nanoparticles), are even more dangerous biologically due to their enhanced ability to bypass the lung barrier, thereby accessing the blood stream and penetrating tissues, including the brain and the placenta. [25-27] These particles are coated with metals, cancer-causing compounds such as benzo-a-pyrene, and other organic substances. Once deposited in tissues they induce "oxidative stress" and inflammation, causing cells to die more quickly. Virtually any organ is susceptible to their damaging effects and it is for this reason that air pollution is the public health challenge of our time.

In February 2016, a joint report by the Royal College of Physicians and the Royal College of Pediatrics and Child Health entitled "Every breath we take: the lifelong impact of air pollution", estimated an extra 40,000 premature deaths annually in the UK as a result of pollution from $PM_{2.5}$ and nitrogen dioxide (NO_2). There is an on-going debate as to the relative contribution of these two pollutants to mortality, but it is generally agreed that $PM_{2.5}$ is the main problem

It is also agreed that NO_2 aggravates asthma, and peak levels relate to increased hospital admissions. [28, 29] The ACHAPS study of 2630 Australian school children across 12 cities found a 4ppb increase in nitrogen dioxide exposure was significantly associated with asthma and reduced lung function despite the low median annual concentration of only 9ppb,[30] well below the current standards of any country.

Current UK Inquest

Ella Kissi-Debrah, the nine- year old girl from Lewisham who suffered a fatal asthma attack in 2013.

In July 2018, the BBC reported the tragic case of Ella Kissi-Debrah, a nine-year-old girl living close to the South Circular Road in London, who was admitted to hospital 27 times over a 3-year period before suffering a fatal asthma attack in February 2013. In December 2020, she became the first person in the UK to officially have air pollution listed as a cause of death in a coroner's report. A "striking association" was found by the senior author of this document between her admissions to hospital and pollution levels near her home, including NO_2. In London and other major cities, up to eighty per cent of NO_2 is derived from diesel vehicles. 38 out of 43 areas in the UK have been in breach of EU air quality standards for NO_2 since 2010. New vehicles with tighter emission standards have not produced the expected improvements in air quality due to gaming of the emissions tests by car manufacturers and cheating in the case of the Volkswagen who fitted NO_2 reduction technology that only operated under laboratory conditions. Under real driving conditions, these "cheat" devices turned off NO_2 controls resulting in emissions from diesel vehicles that were 30 to 40 times higher than in the laboratory. The government subsidies for diesel vehicles have helped to lead to a significant increase in the proportion of highly polluting diesel vehicles on our roads in recent years. It should also be remembered that NO_2 is a marker pollutant for vehicle emissions (especially diesel emissions) and is accompanied by many thousands of other chemicals that are emitted during combustion that are not measured but may well contribute to the adverse health linked to NO_2; of which PAHs are probably the most toxic, whether in gaseous or particulate form.

EU Disease Burden

At the time of the RCP report, mortality data was strongest for heart disease, stroke, pulmonary diseases and lung cancer. Since then, further medical studies have confirmed a relationship between $PM_{2.5}$ and other non-communicable diseases such as diabetes, obesity and dementia. A recent study in the European Heart Journal includes these diseases in their mortality figures and estimate an extra 790,000 deaths annually from ambient air pollution in Europe including 64,000 deaths in the UK (see endnote 2). Forty per cent of deaths were from heart disease, 8% from strokes, 7% from pneumonia, 6% from asthma and bronchitis, and another 32% from "other non-communicable diseases."

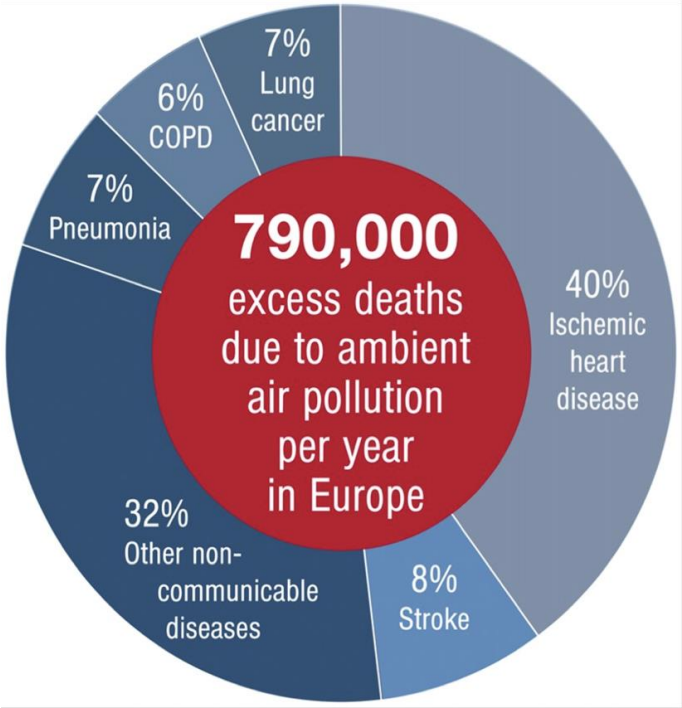

FIGURE 2. Disease Burden from Ambient Air Pollution in Europe

Air Quality standards are set by the EU and then translated into domestic law. Medicare data from the United States involving more than 60 million subjects demonstrate that there is no safe limit for $PM_{2.5}$.[31] Even so the current annual limit for $PM_{2.5}$ set by the EU is very weak. As a result, only 10% of the EU population is exposed to levels above 25 $\mu g/m^3$. However, the WHO guidelines are much stricter, as they are based on medical studies rather than being set politically at a level which most countries can meet. Currently the WHO annual guideline limit for $PM_{2.5}$ is set at 10 $\mu g/m3$, a level to which 90% of the EU urban population is exposed, including all of Central London. The expectation is that the EU will progressively tighten air quality standards in line with WHO recommendations. There is no guarantee that the UK will follow suite now that it has withdrawn from the EU: but equally there is no reason why the UK cannot use this unique post-Brexit opportunity to introduce stricter standards ahead of the EU.

Stringent standards alone are ineffectual unless accompanied with explicit enforcement measures and communication strategies.[32] Given the emerging evidence of significant impacts at low concentrations, any reduction will be associated with health gains regardless of the concentration. This is

analogous to the situation with lead exposures. Forty years ago the blood lead level deemed "safe" by the then Department of Health and Social Security (DHSS) was 35 μg/dl (33). With emerging medical data the American Pediatric Association now regard a level above 5 μg/dl as a "cause for concern". An ambitious continual population exposure reduction framework should also be established for PM2.5, particularly where nanoparticles are being generated in close proximity to the public.

In 2016 a cross-party select committee of MPs described air pollution in the UK as a "public health emergency."[34] It is time for Governments everywhere to respond to that challenge by fulfilling their obligation to protect the health of current and and future generations. The best way to achieve this ambition is by recognising through legal instruments that every person on the planet has a "Right to Breath Clean Air."[35]

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References

1. Landrigan, Philip J., et al. "The Lancet Commission on pollution and health." *The Lancet,* 39, 110119 (October 2018), 464-512. doi: 10.1016/S0140-6736(17)32345-0.
2. Lelieveld et al. "Cardiovascular disease burden from ambient air pollution in Europe reassessed using novel hazard ratio functions." *European Heart Journal*, ehz135, https://doi.org/10.1093/eurheartj/ehz135.
3. Burnett, R., et al. "Global estimates of mortality associated with long-term exposure to outdoor fine particulate matter." *Proceedings of the National Academy of Sciences of the United States of America* 115, 38 (September 2018), 9592-9597. At URL https://doi.org/10.1073/pnas.1803222115
4. Joint Report by the Royal College of Physicians and the Royal College of Paediatrics and Child Health. "Every Breath We Take: The Lifelong Impact of Air Pollution." (February 2016).
5. Thurston, G. D., Kipen, H., Annesi-Maesano, I., Balmes, J., Brook, R. D., Cromar, K., ... & Grigg, J. (2017). "A joint ERS/ATS policy statement: what constitutes an adverse health effect of air pollution? An analytical framework." *European Respiratory Journal*, *49*(1). Also, Rückerl R, Schneider A, Breitner S, et al. "Health effects of particulate air pollution: a review of epidemiological evidence." *Inhal Toxicol* 23, 10 (2011), 555–592. doi: 10.3109/08958378.2011.593587.
6. Sun X et al. The association between birth weight and exposure to fine particulate matter (PM2.5) and its chemical constituents during pregnancy: a meta-analysis. Environ pollution 2016; 211: 38-47
7. Australian Institute of Health and Welfare. (2019). *Australian burden of disease study: impact and causes of illness and death in Australia*, (2015). Australian Institute of Health and Welfare.
8. Smith, Rachel B., et al. "Impact of London's road traffic air and noise pollution on birth weight: retrospective population-based cohort study." *BMJ Clinical research ed.*, 359, j5299 (2017), https://doi.org/10.1136/bmj.j5299
9. Rich, David Q., et al. "Differences in birth weight associated with the 2008 Beijing Olympics air pollution reduction: results from a natural experiment." *Environ Health Perspective* 123, 9 (2015), 880-88. doi:10.1289/ehp.1408795
10. Perera, F., et al. "Effect of prenatal exposure to airborne polycyclic aromatic hydrocarbons on neurodevelopment in the first 3 years of life among inner-city children." *Environ Health Perspective*, 2006, 114: 1287-1293
11. Perera, F., et al. "Prenatal airborne polycyclic aromatic hydrocarbon exposure and child IQ at age 5 years." *Pediatrics* 124 (2009), 195-202.
12. Perera, F., et al. "Prenatal polycyclic aromatic hydrocarbon (PAH) exposure and child behaviour at age 6-7 years." *Environ Health Perspective* 120 (2012), 921-926.
13. Peterson, B., et al. "Effects of prenatal exposure to air pollutants (Polycyclic Aromatic Hydrocarbons) on the development of brain white matter, cognition, and behavior in later childhood." *JAMA Psychiatry* 72 (2015), 531-40.
14. Margolis. A., et al. "Longitudinal effects of prenatal exposure to air pollutants on self-regulatory capacities and social competence." *Journal of Child Psychology and Psychiatry* 57 (2016), 851-60.
15. European Environment Agency Report No. 28, (2016).
16. https://www.abs.gov.au/statistics/industry/tourism-and-transport/motor-vehicle-census-australia/latest-releas
17. Wang, P., et al. "Socioeconomic disparities and sexual dimorphism in neurotoxic effects of ambient fine particles on youth IQ: A longitudinal analysis." PLoS ONE 2017; 12(12): e0188731.
18. Roberts, S., et al. "Exploration of NO2 and PM2.5 air pollution and mental health problems

using high-resolution data in London-based children from a UK longitudinal cohort study." *Psychiatric Research*, 272 (2019), 8-17.
19. Gilraine, M., et al. "Air Filters, Pollution and Student Achievement." *Education Working Paper No. 20*-188. (Jan, 2020.)
20. Carr M et al. Effects of the COVID-19 pandemic on primary care-recorded mental illness and self-harm episodes in the UK: a population-based cohort study - The Lancet Public Health. https://www.thelancet.com/journals/lanpub/article/PIIS2468-2667(20)30288-7/fulltext
21. Clifford A et al. Exposure to air pollution and cognitive functioning across the life course- A systematic literature review. Environ Research 2016; 147: 383-398.
22. Chen H et al. Living near major roads and the incidence of dementia, Parkinson's disease, and multiple sclerosis: a population-based cohort study. The Lancet 2017; 389:718-726.
23. Carey I et al. Are noise and air pollution related to the incidence of dementia? A cohort study in London England. *British Medical Journal*, Open 2018;8:e022404.doi:10.1136/bmjopen-2018-022404
24. Kulick, Erin R., et al. "Long-term exposure to ambient air pollution, APOE-4 status, and cognitive decline in a cohort of older adults in northern Manhattan." *Environment International*, Vol. 136 (March 2020), 105440. Available at https://www.sciencedirect.com/science/article/pii/S0160412019337511
25. Miller, M., et al: "Inhaled nanoparticles accumulate at sites of vascular disease." *ACS Nano* (2017). DOI: 10.1021/acsnano.6b08551.
26. Liu, N., et al. "Do inhaled carbonaceous particles translocate from the lung to the placenta? Abstract No PA 360." *Occupational and environmental lung diseases: asthma and the airways*, (September, 2018).
27. Cacciotollo et al. Particulate air pollutants, APOE alleles and their contributions to cognitive impairment in older women and to amyloidogenesis in experimental models. *Translational Psychiatry*, 2017; 7:1022-29.
28. Mills, I. Quantitative systematic review for the associations between short-term exposure to nitrogen dioxide and mortality and hospital admissions. *British Medical Journal*, Open 2015;5e006946.
29. Collard P. "Short-term effects of nitrogen dioxide on hospital admissions for cardiovascular disease in Wallonia, Belgium." *International Journal of Cardiology*,(2018), 255: 231-236, 2018.ehz135,https://doi.org/10.1093/eurheartj/ehz135.
30. Knibbs L. D., Coorey C. P., Bechle M. J., Cowie C. T., Dirgawati M., Heyworth J. S., et al. "Independent validation of national satellite-based land-use regression models for nitrogen dioxide using passive samplers." *Environment Science Technology* 50(22) (2016), 12331-8.
31. Di Q, et al. "Air Pollution and Mortality in the Medicare Population." *New England Journal of Medicine*, 376: 2513-2322. 2017.
32. World Health Organization. (2018). Occupational and Environmental Health Team.(2006). WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide: global update 2005: summary of risk assessment. *World Health Organization, Geneva. http://www. who. int/iris/handle/10665/69477 (accessed 14th September, 2020).*
33. Lead Versus Health. The biological effects of low level lead exposure. Eds Dr Robin Russell-Jones and Professor Michael Rutter FRS Publishers John Wiley 1983.
34. House of Commons. Environment, Food and Rural Affairs Committee. Air Quality, 2016.
35. UK Clean Air Strategy, Ref PB14554. Published Jan 14. 2019. https://www.gov.uk/government/publications/clean-air-strategy-2019

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