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 (PM$_{2.5}$) of 10 micrograms per cubic metre of air (µg/m$^3$).[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 PM$_{2.5}$, 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 (PM$_{2.5}$) 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...
the average annual level for small particulates is 143 microg/m^3, and in other cities in Northern India it is even higher (200 microg/m^3). 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 NOX.

Levels of PM2.5 in the London are below the annual EU standard of 25 µg/m^3, but the health effects of small particulates are without threshold. Even in low pollution countries such as Australia, where the legal limit for PM2.5 is 8 µg/m^3, 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/m^3. The EU commission already include a measure of particle number as well as particle mass in vehicle emission tests, as ultrafine particulates (PM0.1), 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 deet, 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 PM2.5 and NO2.[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 E4 genotype 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 (PM0.1 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 PM2.5 and nitrogen dioxide (NO2). There is an on-going debate as to the relative contribution of these two pollutants to mortality, but it is generally agreed that PM2.5 is the main problem.

It is also agreed that NO2 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 NO₂. In London and other major cities, up to eighty per cent of NO₂ is derived from diesel vehicles. 38 out of 43 areas in the UK have been in breach of EU air quality standards for NO₂ 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 NO₂ reduction technology that only operated under laboratory conditions. Under real driving conditions, these “cheat” devices turned off NO₂ 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 NO₂ 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 NO₂; 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 PM2.5 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.”

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 PM2.5. Even so the current annual limit for PM2.5 set by the EU is very weak. As a result, only 10% of the EU population is exposed to levels above 25 μg/m³. 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 PM2.5 is set at 10 μg/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 suit 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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using high-resolution data in London-based children from a UK longitudinal cohort study.”