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'Every breath we take: the lifelong impact of air pollution' – a call for action

Author: Stephen T Holgate[A]

ABSTRACT

Air pollution has become one of the major risks to human health because of the progressive increase in the use of vehicles powered by fossil fuels. While the risks of air pollution to health were thought to have been brought under control by the Clean Air Acts of the 1950s and 1960s, the situation of air pollution in the UK has now deteriorated to a point where it is contributing to 40,000 excess deaths each year. Here the findings of the RCP/RCPCH's 2015/16 Working Party on Air Pollution and Health are described and what actions now need to be taken. The UK needs to take a lead and introduce a new Clean Air Act that deals with the vehicle sources of pollution recognising that the toxic particles and gases emitted are effecting individuals from conception to death. This mandates urgent action by government both central and local, but also by all of us who have now become so dependent on road transport.

KEYWORDS: Air pollution, Clean Air Act, health effects, lifecourse, outdoor and indoor, traffic

By the 1990s, the pollution and mortality peaks associated with winter smogs seemed consigned to history. How wrong we were! However, rather than coal burning, this time it is pollution from transport. Between 1949 and 2012 there was a tenfold increase in the distance travelled in the UK by the average person in their cars with a marked reduction in the distance walked. The car has become an extension of the home and a right of freedom leading to a 'windscreen perspective' of transport issues. The term 'wicked problem' was used by the Royal Commission on Environmental Pollution when capturing the interacting web of problems that the car (and other forms of motorised transport and haulage) is creating for society.[1] Pre-eminent are the emissions from petrol and diesel combustion, especially particulate matter (PM), oxides of nitrogen (NOx), volatile organic chemicals (VOCs) and the secondary photochemical production of ozone (O_3). Overwhelming evidence has accumulated that breathing such a cocktail of chemicals has severe effects on human health despite being largely invisible, odourless and tasteless.

The Royal College of Physicians (RCP) established a working group with the Royal College of Paediatrics and Child Health (RCPCH) to examine the impact of air pollution on human health across all age groups, embracing indoor as well as outdoor exposure. The evidence-based report *Every breath we take: the lifelong impact of air pollution* was released in February 2016.[2] Similar to the RCP reports on tobacco smoking, its publication broke new ground:

- The evidence is now overwhelming that primary and secondary small and ultrafine particles (PM_{10}, $PM_{2.5}$ and $PM_{0.1}$) in particular, are linked to increased all-cause mortality (29,000 deaths each year in the UK) and especially deaths from cardiovascular and respiratory disease.
- Recent research shows that oxides of nitrogen (NOx, NO, NO_2 and N_2O_4) and specifically NO_2 emitted in vehicle exhaust are not as benign as previously thought, increasing the number of associated deaths by up to 40,000 each year.[3]
- Air pollution indoors is just as relevant to ambient outdoor exposures although this is rarely taken into account. As a minimum, 99,000 deaths in Europe are attributed to indoor exposures, but this is likely to be a gross underestimate. Outdoor pollutants penetrate the home, schools and workplaces; further, current trends to make buildings energy efficient by sealing them increases the accumulation of pollutants from furnishings, household products and cooking. In the developing world, the burning of biomass for heating and cooking is a particular problem for women and children.
- Air pollution has adverse effects across the life course – from conception to old age. Air pollution impairs overall fetal growth, especially lung growth; this persists across childhood, increases the risks of developing new asthma, which might not occur in its absence, and affects the heart and lungs throughout life by direct toxicity and via epigenetic mechanisms that mediate gene/environmental interactions.
- Beyond respiratory and cardiovascular disease, air pollution has adverse impacts on the development of impaired cognition, type 2 diabetes, cancers, skin aging and even acts as a risk factor for obesity. Since the report, new evidence has become known on the adverse effects of pollution on neurodevelopment.[4–6]
- Importantly, the toxic health effects of vehicle-related pollution are greater in those socioeconomically deprived, living closer to busy roads, in poor housing, with inadequate diet,

Author: [A]chair of the RCP/RCPCH Working Party on Air Pollution, special advisor on air quality to the RCP and MRC clinical professor of immunopharmacology, Faculty of Medicine, University of Southampton, Southampton, UK

accompanying tobacco smoking and in the presence of family stress.
- All of these effects are further enhanced by the influence of climate change, with atmospheric conditions increasing accumulation of pollutants and formation of ozone and secondary particles.
- The economic burden of outdoor air pollution to the UK is in the region of £20 billion annually.

More recent research has revealed that air pollution increases the risk of stroke by a factor of one third.[7] Studies in Canada – regarded by many as a clean environment in terms of air quality – showed that individuals exposed to higher levels of air pollution had nearly threefold greater odds of developing chronic airways obstruction with asthma (ACOS).[7] In Canada, ambient levels of air pollution have been linked to a wide range of different chronic diseases, with hospital outpatient visits increasing by 1–5% for every unit increase in the 10-point Air Quality Health Index (AQHI) scale[8] – an increase of about 15,000 outpatient visits on a day with poor versus good air quality (The Air Quality Health Index or 'AQHI' is a health protection tool that is designed to help the members of the public make decisions to protect their health by limiting short-term exposure to air pollution and adjusting their activity levels during increased levels of air pollution. It also provides advice on how you can improve the quality of the air you breathe). The greatest increases were for individuals with non-lung cancers and chronic obstructive pulmonary disease (COPD). Hospitalisations for diabetes and COPD increased, the impact persisting 2 days after peak AQHI levels.

In countries such as the UK, encouraging the switch to diesel powered vehicles (now 50% of the car fleet compared with 7.4% in 1994) in an attempt to reduce CO_2 emissions has created an even greater problem with much greater production of NO_2 and ultrafine PM emissions.[9] The Euro 5 diesel cars, sold as recently as 2014, perform no better in terms of NOx emissions than Euro 1 diesels sold in the 1990s. Despite this, government policies continue to promote diesel vehicles and, as a result, diesel cars have increased from 14% of the car fleet in Britain in 2001 to 36% today – comprising 50% of new car sales. While the latest Euro 6 diesel cars show some improvement over Euro 5, on average they still emit six times more NOx than the latest petrol powered vehicles. This situation has been worsened by the misplaced confidence created by the way diesel vehicles are tested for pollution emissions under highly artificial rather than real driving conditions; on average NOx emissions from Euro 6 vehicles (Euro 6 limit of 80 mg/km NOx emissions in laboratory tests was introduced for all new cars sold after September 2015) were more than six times higher than the 80 mg/km test.[10] In addition, the scandalous deliberate actions taken by Volkswagon (and possibly other car manufacturers) to deceive the public over diesel emissions further illustrates the steps manufacturers will take to run rough shod over public concerns and safety.

Dr Margaret Chan, director-general of the World Health Organization (WHO) warned that the harm caused by air pollution and exposure to hazardous chemicals was a new epidemic, overtaking major infectious diseases like AIDS, tuberculosis, and malaria.[11]

The numbers are stunning, Dr Chan said. *The WHO estimates that 12.6 million people die each year from exposure to hazards lurking in the environment. Some 7 million of these deaths are attributed to air pollution, which is now the single largest environmental risk to health.*

The case for the devastating effects of air pollution on human health and wellbeing has been further emphasised by the severe pollution present in China, India and other parts of South-East Asia.[12] While coal and biomass burning contributes to the problem in these countries, as in all other parts of the world the main contribution comes from the ever-increasing use of motor vehicles.

Using the US Institute of Health Metrics and Evaluation's Global Burden of Disease 2010 database, a recent analysis of air pollutant levels across the world[13] indicates that most people live in areas with PM concentrations far exceeding the WHO's air quality guideline of 10 $\mu g/m^3$ with a high proportion experiencing daily exposures in excess of 100 $\mu g/m^3$. While, as might be expected, this study demonstrated great potential to reduce mortality from particulates in the world's most polluted regions, one important and unexpected finding is that cleaning air in less polluted parts of the world, including in North America and Western Europe, could have as much health benefit as similar measures taken in the most polluted areas. For example, in relation to fetal development, it has been estimated that meeting the WHO's air quality guidelines could prevent up to 1.4 million premature deaths per year in polluted areas such as China and India, whereas meeting the WHO guidelines in clean regions could reduce premature deaths from outdoor pollution by more than half a million deaths per year.[13] Another important conclusion is that because of aging populations, health risks in many countries will increase even if pollution levels remain constant. Older people are more susceptible to air pollution than younger people because of health problems such as myocardial infarction and stroke. With no changes in air pollution in India and China, attributable deaths *per capita* will increase 20–30% during the next 15 years. Accounting for population growth, the increase in deaths would be even greater even if those countries experience no further changes in levels of air pollution.

The overwhelming evidence to intervene to improve air quality for our citizens and future generations can no longer be ignored, especially since it is forecast that the situation will further worsen with climate change. So what is to be done? As the RCP/RCPCH report states 'everyone has some responsibility for reducing air pollution; real change will only occur when everyone accepts this responsibility, and makes a concerted effort'. This includes the European, national and local government, business and industry, schools and the NHS, as well as individuals in society at large. A total of 14 recommendations for action and research were identified in the report; these focused on what must now be done and are listed below.

1 Act now and think long term

All too often policies relating to air pollution are directed towards acute episodes in summer or winter in the absence of a long-term strategy. The clear recognition that the damaging effects of air pollutant toxicants starts at conception and extends across the whole of life demands a long-term set of solutions involving industry, central government and local government. The problem is not seen as the responsibility of any single government body and is, therefore, easily brushed aside. The extraordinary events currently in

progress when a non-government organisation (ClientEarth) finds it necessary to raise a legal challenge against the UK government to force it to speed up and improve measures to tackle air pollution in our cities illustrates the casual disregard given by our political leaders to the problem. [14]

2 **Educate professionals and the public**
Society has become complacent about the severe effects of air pollution on our health and that of our children. Air pollution plays a role in many of the major health challenges of our day, such as asthma, COPD, cancer, heart disease, stroke, diabetes, obesity and even dementia. When the public and patients are exposed to such a clear and avoidable cause of death, illness and disability, it is clearly our duty to speak out and be properly informed on the issue in order to raise awareness among the public.

3 **Promote alternatives to cars fuelled by diesel and petrol**
Because the issue causing almost all of the outdoor air pollution relates to reliance on the motor car, then adoption of new technologies by motor manufacturers would clearly help. We should incentivise the production of vehicles that use alternative energy sources (eg electricity, hydrogen) and promote better ways of cleaning exhaust emissions. A major issue for the UK is the high proportion of the cars, trains, buses and taxis that are powered by diesel as well as total dependence upon diesel for goods transport by road haulage and small package delivery. For cars, a diesel scrappage scheme and a levy on diesel fuel would certainly help. However, for a small island nation like ours, greater use of public transport and opportunities for active travel options like walking and cycling must be the way forward. As recent events highlight, the UK's investment in improving rail transport is woefully inadequate.
We need expanded safe cycle networks, cycle training at school, safer alternatives to the 'school run', employer support schemes for alternatives to commuting by car, promotion of leisure cycling, and urban corridors and islands for safer cycling and walking. All of this is possible if the will is there as shown in other countries like Spain.[15]
The air pollution situation in the UK is made worse by having among the highest proportion of our cars powered by diesel. Since the 1990s, the influential oil industry has promoted the dieselisation of the car fleet; however, any CO_2 benefit of diesel over petrol in relation to greenhouse gas emissions is marginal, and comes at the cost of poorer air quality in towns and cities with their much greater emission of NO_2 and fine particles. The concept of 'clean diesel fuel' being low in sulphur but still high in generating NOx remains problematic. The time has now arrived to dis-incentivise the use of diesel vehicles by a scrappage scheme and a levy on diesel fuel.

4 **Put the onus on the polluters**
Polluters must be required to take responsibility for harming our health. Tougher regulations are needed to tighten up on exhaust emissions, not only in new vehicles but afterwards in MOT tests. Regulation is of little use unless it is enforced. Political leaders at an EU, national and local level must enforce pollution regulations vigorously, especially in deprived areas where pollution levels are higher and people are more vulnerable. The RCP championed the smoking in public places legislation of 2006 putting the onus on tobacco companies and smokers for the harm they do to non-smokers. The health gains resulting from this have exceeded all expectation, including unexpected benefits such as an almost 20% reduction in childhood hospital admissions for asthma in Scotland[16] and a 2.5% reduction in hospital admissions for myocardial infarction.[17] Effective interventions to reduce ambient air pollution would achieve even greater health gains.

5 **Monitor air pollution effectively**
Air pollution monitoring by central and local government must track exposure to harmful pollutants, especially in major urban areas and near schools, and proactively communicate the results to the public in a clear way that everyone understands. When levels exceed EU or WHO limits, local authorities must publish a serious incident effect. Only in this way is it possible to raise public awareness of the harmful effects of pollution. Of the UK's 43 air quality zones, 38 are not being compliant with EU limit values for NO_2 with air pollution limits being regularly exceeded in 16 zones.[18] It is the repeated and persistent breaching of the WHO limit values for outdoor air pollution (especially NO_2) that, in 2014, initiated the European Commission action against the UK for persistent air pollution problems.
In addition to fixed site monitoring, there have been considerable advances in small mobile devices that can be carried by individuals to monitor personal air pollutant exposure such as that developed by CleanSpace® that detects ambient levels of carbon monoxide or handheld particle monitors such as the Lighthouse Handheld 3016-IAQ monitor. The widespread use of such devices will serve to empower the public regarding their personal air pollution exposures.

6 **Act to protect the public health when air pollution levels are high**
When air pollution limits are exceeded, local authorities need to close or divert roads to reduce the volume of traffic, especially near schools. In many cities, such as Paris, Athens and Beijing during the Olympic Games,[12] this mitigation is part of the air quality improvement strategy but is rarely if ever enacted in the UK. Air pollution around our schools is a particularly sensitive issue. In 2010, 433 of London's 1,777 primary schools were in areas where pollution breached the EU limits for NO_2, of which 83% were considered to be deprived schools.[19] Not infrequently, schools are sited near busy roads and traffic junctions made worse by the 'school run' and idling engines as parents drop off or wait for their children.[20] It is essential that our schoolchildren are protected from pollution, with considerable health and other benefits to be gained, including educational attainment.[21] A 2015 study has shown that the introduction of a Low Emission Zone (LEZ) in London had no significant effect on respiratory health in schoolchildren;[22] more drastic interventions are needed.

7 **Tackle inequality**
Our most deprived communities are exposed to some of the worst outdoor and indoor air quality,[23] which contributes to the gap in life expectancy of almost 10 years when the most and least affluent communities are compared. Regulators, local government and the NHS organisations must prioritise improvements in air quality in our most deprived areas by setting high standards of emission control. The RCP has identified inequality as a major target for action.

8 Protect those most at risk
Children, older people and people with chronic health problems are among the most vulnerable to air pollution. Public services must take account of this disproportionate harm through local tools, such as planning policies for housing and schools, equalities impact assessments and joint strategic needs assessments. At an individual level, healthcare professionals should help vulnerable patients protect themselves from the worst effects of air pollution. The physician and other healthcare professionals have an important role to play in explaining air pollution and how to deal with it to patients.

9 Lead by example in the NHS
The NHS is one of the largest employers in Europe, contributing 9.1% of the UK's GDP. The health service must no longer be a major polluter. The Department of Health, NHS and devolved administrations must give commissioners and providers incentives to reduce their emissions and protect their patients and employees from dangerous pollutants. The RCP/RCPCH report illustrates how this can be achieved, such as through the Barts Health Cleaner Air Programme in London and their recently launched Global Action Plan.

10 Define the economic impact of air pollution
Air pollution damages not only our physical health but also our economic wellbeing; an estimated annual cost of outdoor and indoor air pollution to the UK economy of £20–54 billion.[24] Further studies are needed to determine the economic benefits to be gained by air pollution reduction strategies. Indeed, Public Health England is establishing an economic analysis that should greatly inform decision making.

11 Quantify the relationship between indoor air pollution and health
We spend 90% of our time indoors and yet this is rarely taken into account when evaluating the health burden of air pollution. While we are familiar with the devastating effects of carbon monoxide production from faulty heating appliances, there is little awareness of other pollutants. Indoor pollutants are emitted from furnishings (volatile organic chemicals), air sprays, cleaning products, and heating and cooking appliances. Particulate matter indoors may contain a different range of chemicals from that encountered outside,[25] including those from air fresheners[26] and microbial products.[27] In addition, polyaromatic hydrocarbons are emitted in large amounts during cooking and frying,[28] all made worse by the sealing of buildings for energy conservation. Indoor air is enriched in biological pollutants such as allergens from dust mites, pets and fungi, as well as microorganisms that become concentrated especially in damp conditions. [29] The combined exposures to outdoor and indoor pollutants creates an even greater health hazard than outdoor pollution alone.[30] Using volatile chemicals together less and having good ventilation (including opening windows) needs to be brought to the attention of homeowners.

12 Determine how global trends are affecting air quality
Our pollution of the environment harms the delicate global ecosystems on which we rely; many of the pollutants that cause environmental damage are the same ones that cause damage to human health. Many strategies that decrease air pollution are also beneficial in slowing down climate change. We can make this happen by using less energy; using energy more efficiently; burning less oil, gas, and coal while making more use of renewable energy sources such as hybrid and low emission vehicles; and the development and use of technologies that sequestrate carbon from industrial plants.

13 Develop new technologies to improve air pollution monitoring
There is a need for better, more accurate and wider-ranging pollution monitoring programmes so that we can track population-level exposure to air pollution.[31] Any push by central and local government to reduce air pollution monitoring should be resisted. Indeed, new smart monitoring will make air pollution monitoring much more widely available and accessible to the public.

14 Study the effects of air pollution on health
To fully appreciate the risks of air pollution to health, further research is urgently required on how pollutant mixtures impact on the body. Beyond lung and cardiovascular disease, research should accommodate systemic effects such as obesity, diabetes, and changes linked to dementia and cancer, as well as effects on the developing fetus and early childhood. The advent of multi-omics technologies (eg genomics, transcriptomics, proteomics, metabolomics, microbiomics) to analyse the complex multi-level interactions of pollution with humans is creating an exciting new science of exposomics in which exposures can be directly linked to disease causal pathways.[32,33]

The adverse health case for reducing air pollution is overwhelming. If, in the UK, there were 40,000 excess deaths from drinking polluted water, there would be a national outcry. However, major hurdles to producing the changes needed are the lack of public and political awareness of how damaging air pollution is, in part because we cannot see it, smell it or taste it, and the multiplicity of regulatory organisations. What is now required is a truly joined-up approach to tackle this major public health issue. We, as physicians, have a duty to speak out about this and raise awareness in our communities and at the same time offer solutions.[34] Since the publication of the RCP/RCPCH report, efforts are being made to achieve this with new initiatives being rolled out from Public Health England, the Mayor of London and through parliamentary process. Maybe Brexit creates an opportunity to introduce a new Clean Air Act focused on transport as recently called for by Environmental Protection UK. Let us hope these efforts maintain and increase in momentum because it is the health of our future generations that is at stake. ■

Conflicts of interest

Stephen Holgate is the RCP Special Advisor on Air Quality and was Founder Chair of the Committee on the Medical Effects of Air Pollutants (COMEAP).

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Address for correspondence: Professor ST Holgate, Clinical and Experimental Sciences, Mail Point 810, Level F, South Block, Southampton General Hospital, Southampton SO16 6YD, UK. Email: S.Holgate@soton.ac.uk