Sixty years since the 1956 Clean Air Act: are we really doing enough to reduce air pollution?

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In the year that the UK's Clean Air Act turns sixty, the head of public health at the World Health Organisation (WHO) declared air pollution as a global health emergency [1]. Globally, air pollution is responsible for 7 million premature deaths per year [2], equivalent to 1 in 8 of all recorded deaths. Across Europe, 400,000 deaths were attributed to air pollution in 2012, whilst in the UK over 50,000 deaths per year are due to a combination of gaseous (nitrogen dioxide and ozone) and particulate matter (PM) air pollution [3]. On a local authority scale, approximately 5% of all deaths in England and Wales are linked to air pollution, although, based purely on PM, this is recognised as an underestimate [4]. Air pollution is the greatest environmental health risk facing mankind [5] but in the sixty years since the seminal Clean Air Act 1956 have we really done enough to address this challenge?

Air pollution, a catch-all term for airborne substances that are not naturally present, are harmful, or out of natural proportions, has been of concern for thousands of years [6]. The source material responsible for air pollution has also changed over time. Reference to soot-stained buildings in Ancient Rome was made by Horace, likely as a result of wood burning for domestic use and industrial processes. In England, coal, was first widely used in the 9th Century. By the 13th Century air pollution as a result of coal smoke forced Queen Eleanor to leave Nottingham and in the early 14th Century the burning of sea-coal by craftsmen became prohibited in London.

The principles of air pollution management were set out by John Evelyn in the 17th Century. In Fumifugium, 1661 [7], Evelyn proposed three tenets of air quality management that still apply to this day: the introduction of smokeless fuels, the substitution of 'dirty' fuels for cleaner ones and the removal of polluting sources away from receptors.

During the industrial revolution air pollution was considered an inescapable and often welcome sign of economic virility. In 18th century Manchester, the first industrialised city, a committee was set up to report on nuisance cases, regulate chimney height and enforce the control of smoke from steam engines.

The impact on health was first quantified in the 20th Century following the Manchester and Salford Smog of 1931. However, it wasn't until 1952, when over 4,000 deaths were attributed to the London Smog, that parliament finally took action. The smog of December '52 was the combination of a lingering anticyclone during a period of cold weather and domestic and industrial coal burning. In response, the first UK Clean Air Act of 1956 was established in which Smokeless Zones were introduced and a transition to smokeless fuels was encouraged [8]. Historically, pollution found in cities was from domestic and industrial burning of fossil fuels.

Thanks, in part, to the Clean Air Act, significant improvements have been made in this regard. The Act and its subsequent iteration in 1968 were thought by many to be the solution to the blight of air pollution in towns and cities. What wasn't appreciated by most was that the nature of air pollution was changing and would go on to affect the health of hundreds of millions of people globally in the near future. This change, and the subsequent threat to public health, was brought about primarily by vehicle emissions, particularly the impact of PM and NO2 [9].

Health Impacts of Air Pollution

The International Agency for Research on Cancer (IARC) classified ambient air pollution as carcinogenic to humans (Group 1) [10]. According to the WHO, the deaths caused by outdoor air pollution in 2012 can be broken down by disease into: ischaemic heart disease (40%), stroke (40%), chronic obstructive pulmonary disease (11%), lung cancer (6%) and acute lower respiratory infections in children (3%) [11]. However, air pollution does not affect everyone equally, disproportionately affecting both children and the elderly, as well as those with existing health conditions. It contributes to low birth weight [12] and impedes lung growth in children [13]. Mechanisms by which this can occur include the narrowing of the airways through irritation and inflammation [14]. Additionally, high level prenatal exposure to air pollution may also increase the risk of autism spectrum disorder [15]. In the elderly, air pollution contributes to a more rapid decrease in lung function than would otherwise be the case [16]. In the UK, air pollution affects the poorest in society disproportionately more [17], primarily because those dwellings are often in areas with high traffic volumes and noise and are considered least pleasant to live in (and so consequently cheaper).

National Air Quality Management

In 1987, the World Health Organisation set health based guidelines for particulate matter, nitrogen dioxide, ozone and sulphur dioxide, amongst others [18]. These guidelines provide absolute thresholds for health exposure. Based on the WHO health based guidelines, the EU Air Quality Framework Directive (96/62/EC) and subsequent daughter Directives were developed which Member States were required to transpose by 1998.

As a comparison between the EU limit values and the WHO guidelines, 88% of European citizens were exposed to PM10 levels deemed by the WHO to be hazardous to health whilst only 33% of citizens were in areas exposed to PM10 above national limit values. It could crudely be considered therefore that 55% of the EU population are in an air pollution 'no-man's land', i.e. levels of air pollution are deemed harmful by the WHO but national strategies are not designed to protect them from the harmful effects of air pollution.

In the UK, the government established national air quality objectives in parallel to the EU limit values to be achieved by a combination of national measures supplemented with local action (a selection of the national objectives are set out in Table 1). Fine particulate matter (PM2.5) was not included in national air quality objectives until the 2007 National Air Quality Strategy, and is only now being considered for introduction as a voluntary target for local authorities.

Table 1: UK National Air Quality Objectives

Pollutant	*Objective*	*Measured as*
Nitrogen Dioxide	200µg/m^3	1-hr mean not be exceeded more than 18 times per annum
Nitrogen Dioxide	40µg/m^3	Annual mean
Particulates (PM_{10})	50µg/m^3	24-hr mean not be exceeded more than 35 times per annum
Particulates (PM_{10})	40µg/m^3	Annual Mean
Sulphur Dioxide	266µg/m^3	15-min mean not be exceeded more than 35 times per annum
Sulphur Dioxide	350µg/m^3	1-hr mean not be exceeded more than 24 times per annum
Sulphur Dioxide	125µg/m^3	24-hr mean not be exceeded more than 3 times per annum

Local Air Quality Management

Under Part IV of the Environment Act, 1995 (itself over 20 years old), local authorities have a statutory duty to undertake periodic reviews of ambient (outdoor) air quality within their respective boundaries. Specifically, Section 84 of the Environment Act imposes duties on a local authority with respect to Air Quality Management Areas. An AQMA is a spatially designated zone where a Local Authority Review and Assessment of air quality has shown that one or more Air Quality Objectives set by Defra and the Devolved Administrations in Air Quality Regulations have not, or will not, be met by the date specified in the Regulations. The local authority must draw up an Air Quality Action Plan specifying the measures to be carried out and the time scale to bring air quality in the area back within limits. Section 85 gives reserve powers for assessments to be made in any area and for instructions to be given to a local authority to take specified actions. Authorities have a duty to comply with these instructions. Section 87 provides the Secretary of State with wide ranging powers to make regulations concerning air quality. These include standards and objectives, the conferring of powers and duties, the prohibition and restriction of certain activities or vehicles, the obtaining of information, the levying of fines and penalties, the hearing of appeals and other criteria. The regulations must be approved by affirmative resolution of both Houses of Parliament [19].

Monitoring these pollutants across the UK is challenging, primarily because the instruments required to conform to the EU Ambient Air Quality Directive (2008/50/EC) are very expensive and their mass deployment is not feasible. A series of Standard Methods [20] for measuring nitrogen oxides, sulphur dioxide, ozone, carbon monoxide and PM2.5 were introduced in 2005. These Standard Methods are used to calculate the performance of monitors and provide approval of monitors used in national monitoring networks.

In order to account for the lack of coverage of real-time monitoring devices, passive samplers can be deployed to assess gaseous pollutants. For example, NO2 diffusion tubes (essentially a tube with triethanolamine (TEA) coated membrane in which NO2 is absorbed) are used widely throughout the UK to obtain readings from multiple locations, albeit with a greater standard error than active samplers. They also provide a wide coverage of samples which may identify previously unknown hotspots of pollution. In this

regard, the use of passive samplers has contributed to the declaration of over 350 AQMAs, (predominantly as a result of exceedances of the annual mean NO2 objective) most of which unfortunately are still in place as pollution levels have not dropped below the required thresholds. Our means of identifying air quality problems within the UK is very good, however our ability to address them is lacking.

The national NO2 objectives were due to be met by 31st December 2005, however by this deadline exceedences of the NO2 annual mean objective were still widespread and growing. The equivalent EU limit value for NO2 was to be achieved by 1st January 2010. At present, the UK remains non-compliant in 38 out of 43 zones and agglomerations for the NO2 limit value.

In April 2015, the UK government was ordered by the Supreme Court to draw up new air quality plans to address air pollution in the UK. The Supreme Court emphasised the need for 'immediate action' [21]. The air quality plans were submitted to the European Commission in December 2015, however the consensus across the air quality profession was that these plans are not sufficient to address the public health challenge in as short a time as possible [22].

The Air Quality Plan

It has been exactly 60 years since the introduction of the Clean Air Act, introduced to address the growing public health crisis that industrial and domestic coal burning was imposing on the citizens of towns and cities throughout the UK. Today, the challenge lies primarily with vehicle emissions and if we are to address them we will require steps that are equally as bold as those of the 1950s. The Air Quality Plan is meant to do just that. A key part of the plan, and one which is considered to be critical to achieving compliance in the shortest time possible, is the introduction of a network of Clean Air Zones across the UK, although none of those proposed include restrictions on private cars. Crucially, evidence from a Europe-wide study has shown that unless cars are included, CAZs are not likely to address air pollution problems [23]. Notwithstanding many other assumptions within the plan, the UK is at considerable risk of maintaining, and not addressing, poor air quality for the foreseeable future.

Vehicle Emissions

One reason why NO2 concentrations have not decreased as expected may be as a result of an inaccurate assessment of real-world vehicle emissions. Since 1992 Euro emissions standards have been applied to vehicles sold in the EU. These standards define an acceptable amount of emissions from those vehicles sold and all new vehicles must pass type-approval tests that have been agreed on by the European Parliament. Recently, real-world vehicle emissions have been identified as being higher than those allowed in type approval testing [24]. In late 2015, Volkswagen was identified as using defeat devices to pass emissions tests in the USA [25] and investigations are ongoing both there and in Europe to determine its extent.

Future Challenges

A number of pollutants, most notably NO2 and PM have been identified as being harmful to health, but many more are present in ambient air pollution and our understanding of them and their health impact is less advanced. The future understanding of air pollution, analysis and source apportionment will, as ever, fall at the door of environmental chemists, statisticians and other academic researchers. As an air quality community, with reference to PM in particular, we are yet to determine whether it is simply particle size which is to blame for the health

impact of particulate matter, or whether it is also as a result of its organic or inorganic composition or the adherence of other substances to the particles' surfaces. These are challenging questions to answer and will likely require the development of new in-situ sampling and analysis techniques before effective interpretation and quantification of the health effects of each component can be made, and management mechanisms developed.

Conclusions

The 60th anniversary of the seminal Clean Air Act has so far been marred by disappointment. Air pollution is the biggest environmental health threat we face globally yet the political will to address it decisively is lacking, both in the UK and in many places globally. Evidence currently identifies vehicle emissions as a key contributor to air pollution within cities and as such any solution to the air pollution crisis will have to address this head-on.

In answer to the question 'Are we doing enough?', in some sense yes. The global scientific community is making significant progress in characterising air pollution, identifying its health impacts and developing strategies for its measurement and management. However, in the UK, political and societal will is lacking to make any meaningful attempt at addressing the air pollution challenge and the health crisis that goes hand in hand with it. We can, and must, do a whole lot more.

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References

1. Vidal, H. Helm, T (2016) Shock figures to reveal deadly toll of global air pollution. Available from: http://www.theguardian.com/environment/2016/jan/16/world-heslth-organisation-figures-deadly-pollution-levels-world-biggest-cities [accessed 18th January, 2016]

2. World Health Organisation Executive Board (2014) Health and the environment: addressing the health impact of air pollution. Available from: http://apps.who.int/gb/ebwha/pdf_files/EB136/B136_15-en.pdf

3. European Environment Agency (2015) Air quality in Europe — 2015 report. Publications Office of the European Union. Luxembourg

4. Gowers, A.M, Miller, B.G, Stedman, J.R. (2014) Estimating Local Mortality Burdens associated with Particulate Air Pollution. Public Health England, Oxfordshire.

5. World Health Organisation (2015). World Health Assembly closes, passing resolutions on air pollution and epilepsy. Available from: (http://www.who.int/mediacentre/news/releases/2015/wha-26-may-2015/en/ [accessed on 14th January, 2016]

6. Brimblecombe, P (1988) The Big Smoke: A History of Air Pollution in London since Medieval Times. Routledge, London.

7. Evelyn, J (1661) Fumifugium: or The Inconveniencie of the aer and smoak of London dissipated. Together with some remedies humbly proposed. Godbid, Bedel and Collins, London.

8. Clean Air Acts 1956 and 1968, HMSO, London

9. Walton, H. Dajnak, D. Beevers, S. Williams, M. Watkiss, P. Hunt A. (2015) Understanding the

health impacts of air pollution in London. Kong's College, London.

10. International Agency for Research on Cancer (IARC), 2013. Outdoor air pollution a leading environmental cause of cancer deaths.

11. World Health Organisation (2012) Burden of disease from household air pollution.

12. Yorifuji, T. Kashima, Doi, H (2015). Outdoor air pollution and term low birth weight in Japan. *Environment International*. **74**: 106-111.

13. He, Q-Q. Wong, T. W. Du, L. Jiang, Z-Q. Gao, Y. Qiu, H. Liu, W-J, Wu, J-G, Wong, A. Yu, T, S, I. (2010). Effects of ambient air pollution on lung function growth in Chinese schoolchildren. *Respiratory Medicine*. **104 (10)**: 1512-1520.

14. Liu, L. Zhang, J. (2009) Ambient air pollution and children's lung function in China. *Environment International*. **35**: 178-186.

15. Volk, H.E. McConnell, R. Herz-Picciotto, I. Lurmann, F. Kerin, T. Kalkbrenner, A. Lee, N. Windham, G. (2015) Prenatal air pollution exposure effects on autism spectrum disorder and neurodevelopment. *Neurotoxicology and Teratology*. **49**: 100-101

16. Guo, Y. Zeng, H. Zheng, R. Li, S. Barnett, A.G. Zhang, S. Zou, X, Huxley, R. Chen, W. Williams, G (2016). The association between lung cancer incidence and ambient air pollution in China: A spatiotemporal analysis. *Environmental Research*. **144 (Part A)**: 60-65.

17. Pye, S, King, K. Sturman, J. (2006). Air Quality and Social Deprivation in the UK: an environmental inequalities analysis – Final Report to Defra, Contract RMP/2035. AEA Technology, Oxfordshire.