



# Joint select committee inquiry: improving air quality

## Royal College of Physicians' submission

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### Introduction

The Royal College of Physicians (RCP) welcomes the opportunity to respond to the Environment, Food and Rural Affairs, Environmental Audit, Health, and Transport Committees' inquiry on improving air quality.

There is a growing body of evidence demonstrating the impact air pollution has on many aspects of our health, across our lifetime. Air pollution causes and exacerbates many chronic conditions, increasing the likelihood of strokes and heart attacks in susceptible individuals. Air pollution also adversely affects the development of the foetus. There is compelling evidence that air pollution is associated with new onset asthma in children and adults as well as contributing to diabetes, neurodegenerative diseases and is a risk factor for lung cancer. These findings were highlighted in the RCP and Royal College of Paediatrics and Child Health's (RCPCH) report 'Every breath we take: the lifelong impact of air pollution'<sup>i</sup>.

Although successive governments have introduced legislation to control air pollution since the Clean Air Act of 1956, around 40,000 deaths a year are linked to outdoor air pollution. As the RCP and RCPCH report highlights, the harm from air pollution is not just linked to poor health over short periods but is a long term problem with lifelong implications. The issue has clearly not been resolved and much more needs to be done to ensure people are protected from the harms associated with air pollution.

### Summary of evidence

- The negative health impacts of air pollution occur across the life course and can begin at conception.
- Both long-term exposure and acute air pollution episodes are linked to poor health.
- Exposure to air pollution in infancy can damage the lungs, and increase the risk of lung infections that may be fatal.
- Air pollution is linked to reduced lung function in children and adults, lung cancer in adulthood and the development of new onset asthma as well as exacerbating asthma in those who already live with the condition.
- Air pollution is also an issue of health inequality. The most vulnerable groups – namely people living in deprived areas, children, older people living with chronic long-term conditions such as Chronic Obstructive Pulmonary Disease (COPD) and cardiovascular diseases – suffer the most harm.
- There is no level of exposure to air pollution that is safe with multiple organs being affected.
- Whilst a number of sectors contribute to the UK's poor air quality, road transport (and especially diesel combustion from older vehicles) is responsible for a high proportion of the burden of disease.

## Recommendations

- There needs to be more collaboration across government departments to ensure air quality targets are achieved.
- National policies need to go further to protect people from the harms associated with air pollution.
- Brexit must not be used as an opportunity to weaken laws and regulations relating to air pollution.
- The UK government must work closely with local authorities to ensure they have the right powers and adequate funding to implement the changes needed to protect people from air pollution.
- There is a wealth of evidence to show that air pollution is harmful, even below current limits, and there is no safe level of exposure to individual pollutants. Therefore, government policies should seek to decrease pollution exposure, even where limits are met.
- Air pollution monitoring by central and local government must track exposure to harmful pollutants in urban areas and near schools. These results should be communicated proactively to the public, in a clear way that everyone can understand so people can take adequate precautions to protect themselves.
- National government, local authorities and health professionals should do more to improve the public's understanding of the health impacts of air pollution and communicate the ways in which people can reduce their own exposure to protect themselves from the harms of air pollution.

## Questions

### **How effectively do Government policies take into account the health and environmental impacts of poor air quality?**

The RCP's joint report with the Royal College of Paediatrics and Child Health (RCPCH) found that annually an estimated 40,000 deaths are linked to air pollution in the UK<sup>ii</sup>. According to the Lancet Commission on pollution and health, pollution is the largest environmental cause of disease and premature death in the world today. Diseases caused by pollution were responsible for an estimated 9 million premature deaths globally in 2015<sup>iii</sup>. (Please see appendix for more information on the health impacts of air pollution).

The government's latest plan to tackle nitrogen dioxide emissions acknowledges the adverse health impacts of exposure to outdoor air pollution. The plan notes that 'poor air quality is the largest environmental risk to public health in the UK'<sup>iv</sup>. There is a consistent emphasis throughout the plan on achieving improvements to public health. However, the plan as it stands, does not far enough to cut pollution, not only to meet legal limits but to deliver maximum health and environmental benefits.

### **Do these plans set out effective and proportionate measures to achieve necessary emissions reductions as quickly as possible?**

The Government has taken some positive steps to address air pollution, such as the planned phase-out of coal power stations. However, the latest national plan to tackle NO<sub>2</sub> emissions is inadequate<sup>v</sup>. Banning the

sales of diesel and petrol cars by 2040 will eventually deliver important public health benefits, in the long-term. However, this is only one part of the response required to protect people from pollution and help meet the UK's climate change commitments.

There needs to be properly implemented and joined up Clean Air Zones that local authorities can implement with support from the national government. This is the fastest way of dealing with unsafe and illegal air pollution. The government's own technical report accompanying the draft plan shows that charging for entry to Clean Air Zones is the most effective intervention for the reduction of nitrogen dioxide levels, with an average reported 18.3% reduction in mean NO<sub>2</sub> concentrations in the first year<sup>vi</sup>. This contrasts with other measures such as retrofitting and scrappage schemes, which while still helpful, are estimated to reduce outdoor NO<sub>2</sub> concentrations by only 0.19% and 0.02% respectively.

The Plan rightly focuses on local action as part of the solution to tackling air pollution. Local authorities have a central role in achieving improvements in air quality. However, an £11 million air quality grant to support the delivery of this activity across urban areas of England and Wales grossly underestimates what is needed to deliver local programmes at a time when local authorities are having severe difficulties meeting their current commitments. Unlike the Clean Air Act of 1956, when central government recognised the national nature of this problem and enacted ground-breaking legislation, the current crisis is being delegated to under-resourced local authorities to tackle. National government must work closely with local authorities to empower them both politically and financially to implement the changes needed to protect people from the harms associated with air pollution.

Given the magnitude of the multiple health problems caused by air pollution across the life-course, the government's response is clearly insufficient, particularly in light of Supreme Court's ruling to tackle the UK's illegal levels of air pollution 'in the shortest possible time'<sup>vii</sup>. New figures show the number of local authority areas in the UK that are breaching their air quality targets reached a seven-year high in 2016. Government statistics show a total of 28 of the 39 local authorities (71%) missed their air quality targets last year, up from 25 in 2010<sup>viii</sup>.

In order to adequately address the wide ranging and severe health impacts of poor air quality, the RCP is calling on the government to include the following measures in its forthcoming Clean Air Strategy due for publication in 2018.

- Collaborate effectively across government departments to ensure air quality targets are achieved.
- Ensure government works closely with local authorities so they have the right powers and adequate funding to implement the changes needed to protect people from air pollution.
- Decrease pollution exposure, even where limits are met.
- Monitor exposure to harmful pollutants in major urban areas and near schools. These results should be communicated proactively to the public, in a clear way that everyone can understand so people can take adequate precautions to protect themselves.

- Improve public understanding of the health impacts of air pollution and communicate the ways in which people can control their own pollution contributions as well as protect themselves from the harms of air pollution.
- Ensure Brexit is not be used as an opportunity to weaken laws and regulations relating to air pollution. The government should:
  - consolidate the complex and disparate body of domestic, EU and international air pollution laws into one coherent and effective piece of legislation
  - adopt revised objectives based on World Health Organisation (WHO) guidelines<sup>ix</sup>
  - continue to work with EU institutions in responding to the challenge of tackling air pollution. Without such cooperation, the UK may be unable to meet the WHO's air pollution standards through local action alone.

### **Is there enough cross-government collaboration to set in place the right fiscal and policy incentives?**

Cross-government collaboration, as well as coordination across the devolved nations, is essential for ensuring that action on air pollution protects health. This is because the causes and effects of air pollution cut across the mandates for Defra, the Departments for Transport, Communities and Local Government, Health, Business, Energy and Industrial Strategy (BEIS) as well as their associated non-departmental public bodies such as the Environment Agency, Highways Agency, and Public Health England.

The allocation of responsibility for tackling air pollution at present is unclear and does not take into account the interdependencies of the potential policy solutions. Furthermore, there is no incentive or framework for different departments to work together to devise a long-term strategy to tackle air pollution. Better cross-departmental co-ordination would allow for a more integrated and effective policy response. For example, longer term solutions to air pollution depend upon reducing car use and developing better infrastructure for public transport, cycling and walking. There is currently a gap in the responsibility for the health impacts of road transport. This gap is best filled by ensuring a joined-up approach, involving all the government departments outlined above. Advice and support from the Treasury is also required to consider the broader fiscal aspects of decarbonising the transport system.

### **Are other nations or cities taking more effective action that the UK can learn from?**

**London** – The Mayor of London's transport<sup>x</sup> and environment strategies<sup>xi</sup> have set out a number of ambitious and bold solutions to tackling London's illegal levels of air pollution. Changing the way people travel so that, by 2041, 80% of all Londoners' trips will be made on foot, by cycle or by public transport will reduce air pollution levels and unlock health benefits resulting from improved air quality such as reducing rates of stroke, heart disease and chronic lung disease. The RCP also welcomes the recent toxicity-charge and the eventual introduction of the ultra-low emission zone (ULEZ) in 2019. Phasing out pure diesel buses from 2018 and ensuring all newly licensed taxis are zero emissions capable will also go some way to tackling London's air pollution. Transport for London's decision to invest in cost-effective measures that deliver

improvements in public health will set an example for local authorities across the UK considering such interventions.

**Paris, France** – The city imposes odd-even bans on vehicles<sup>xii</sup>, makes public transport free during major pollution events and encourages car and bike sharing programmes. A long section of the right bank of the Seine is now car-free and a monthly ban on cars has come into force along the Champs-Élysées<sup>xiii</sup>. Paris also plans to ban diesel vehicles from the city centre within the next decade<sup>xiv</sup>.

**The Netherlands** – The Dutch government has recently outlined plans to make all new cars emission-free by 2030<sup>xv</sup>.

**Helsinki, Finland** - The Finnish capital [plans to reduce drastically the number of cars on its streets](#) by investing heavily in better public transport, imposing higher parking fees, encouraging bikes and walking and converting inner city ring roads into residential and walking areas. The idea is to make the city's public transport so good that no one will want to own a car by 2050.

## Conclusion

The negative health impacts of air pollution can and must be mitigated. Closer working between different government departments to deliver strict enforcement of air quality limits, and transition to clean fuels and renewable energy sources will go some way to reducing our exposure to air pollution. Limiting the use of diesel and other polluting fuels in urban centres, improving access to public transport and mandating fuel efficiency standards for private vehicles, buses, and vans are some of the other policy solutions available to the government.

Planning initiatives that encourage walking and cycling through construction of cycle paths, and walkways represent an additional strategy for reducing exposure to outdoor air pollution. An added benefit of these approaches is that they increase exercise and thus reduce the risk of obesity, diabetes, and cardiovascular disease and improve mental health and well-being. The RCP strongly encourages the government to adopt a combination of these strategies to tackle air pollution in its upcoming Clean Air Strategy due for publication in 2018.

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## About the RCP

The RCP plays a leading role in the delivery of high quality patient care by setting standards of medical practice and promoting clinical excellence. We provide physicians in the United Kingdom and overseas with education, training and support throughout their careers. As an independent body representing almost 34,000 fellows and members worldwide, we advise and work with government, the public, patients and other professions to improve health and healthcare. Our primary interest is in building a health system that delivers high quality care for patients

## Appendix

The most prevalent chemical pollutants in our outdoor air are:

- Particulate matter (PM) – small specks of matter such as soot, which can be natural but are primarily from traffic (especially diesel engines)
- nitrogen oxides (NO<sub>x</sub> and especially NO<sub>2</sub>) – gases generated by vehicles, or by chemical reactions in the atmosphere
- sulphur dioxide (SO<sub>2</sub>) - In the UK, this gas is largely emitted from industrial sources including power stations. The contribution from motor vehicle exhausts has been much reduced in recent years, owing to the use of low-sulphur fuels.
- Ozone (O<sub>3</sub>) – this gas is formed when other pollutants react in the atmosphere.
- Volatile organic chemicals (VOCs, such as polycyclic aromatic hydrocarbons - PAHs)

### Health effects of air pollution across a lifetime

Long-term exposure to outdoor air pollution is associated with:

- Premature birth<sup>xvi</sup>
- Reduction in foetal growth and low birth weight
- Increased risk of death during the first year of life, particularly from respiratory illnesses
- Exacerbating the effects of respiratory infections in young children
- Affecting the normal growth of lung function during childhood<sup>xvii xviii</sup>
- Cardiovascular diseases (heart attacks, hypertension and stroke)
- Chronic Obstructive Pulmonary Disease (COPD), pneumonia, accelerated decline in lung function and lung cancer in adulthood
- Development of new onset asthma as well as exacerbating asthma in those who already live with the condition
- Impaired cognition, dementia and other neurodegenerative disorders
- Type II diabetes, obesity and metabolic syndrome

The damage that air pollution causes to health occurs across a lifetime, from the baby's first weeks in the womb through early years, adolescence, adulthood and old age. The heart, brain, hormone systems and immunity can all be harmed by air pollution<sup>xix</sup>. Research is also pointing towards effects on growth, intelligence, and development of the brain and coordination.

### Pregnancy and the developing foetus

Exposure of the mother to harmful substances, such as air pollution, can result in slowing of foetal growth. This can affect the growth of different organs and, if growth is hampered at a critical time of development, can lead to permanent damage. The foetus undergoes a coordinated process of organ development which follows a time-dependent course. Even seemingly minor interferences during critical periods can

irrevocably harm organs and tissues (the foetal brain and nervous system are particularly sensitive to these effects) or change their developmental trajectory so that their function becomes permanently impaired.

### **Early years**

Infants have a relatively high metabolic rate, so they breathe a greater volume of air per minute than an adult relative to their size. This is a double jeopardy: they become exposed to relatively higher doses of toxic pollutants, as well as being more vulnerable to their harmful effects. Furthermore, infants are dependent on their parents to protect them or move them from sources of pollution, yet their main mode of outdoor transport (e.g. pushchairs) seems designed to put them at precisely the level of motor vehicle exhaust emissions. Schools are also often built in urban settings, close to roads and intersections, thereby increasing children's exposure to vehicle-related pollutants<sup>xx</sup>.

### **The link between air pollution and cognitive development**

Because the central nervous system is still developing rapidly after birth, children remain susceptible to harmful effects of air pollution on their neurodevelopment and long-term cognitive health. Several types of air pollution have been associated with harmful effects on neurocognitive development. As with prenatal effects, exposure of young children to heavy metals, even at very low levels, impairs cognitive development and lowers IQ.

### **Effects in adulthood and older age**

The damage caused by chronic exposure as well as repeated high pollution episodes is sometimes gradual, and may not be apparent for many years. For example, lung function naturally develops throughout childhood, and there is clear evidence that long-term exposure to outdoor air pollution suppresses this process. In addition, it may speed up the decline of lung function through adulthood and into older age. There is also good evidence that outdoor air pollution is an important risk factor for lung cancer, with both ambient particulates and diesel emissions considered by International Agency for Research on Cancer (IARC) as a Class 1 carcinogen (i.e. a substance that causes cancer in humans).

We still need more research, but it is possible that exposure to air pollution could be associated with the appearance of diabetes, and may also damage the brain's thinking abilities (cognition) in subtle ways that build up over time. As explained below, large studies have shown a strong link between air pollution and cardiovascular disease (heart disease and strokes) and asthma.

### **The link between exposure to air pollution and asthma**

It is very likely that long-term exposure to air pollution is linked to the development of asthma and associated respiratory allergy. For people who already have asthma, there is strong evidence that air pollution can make it worse. A 3-year longitudinal study that recruited both preschool and early school age children in different communities in southern California, USA, found that increased risk of developing early school-age asthma was associated both with markers of traffic-associated outdoor air pollution near the home and with exposure to background NO<sub>2</sub><sup>xxi</sup>. The study also found that exposure to higher local concentrations of NO<sub>2</sub> was associated with new-onset asthma<sup>xxii</sup>. A study of women in the USA reported an

association between exposure to PM<sub>2.5</sub> and new-onset asthma<sup>xxiii</sup>. A number of recent studies have also investigated perinatal<sup>1</sup> and childhood exposure to air pollution<sup>xxiv xxv xxvi xxvii</sup>.

### **The link between exposure to air pollution and cardiovascular disease**

Epidemiological studies have shown significant associations between air pollution and a range of cardiovascular effects in adults. Both short- and long-term exposure to air pollution can increase the risk of myocardial infarction (heart attacks), heart failure, arrhythmias (abnormal rhythms of the heart) and stroke in susceptible individuals, such as older people or those with pre-existing medical conditions, including cardiovascular disease, high blood pressure, obesity, metabolic syndrome and Type II diabetes.<sup>xxviii xxix xxx</sup>

### **The link between air pollution and impaired cognition**

There is emerging evidence that air pollution adversely affects both the developing and the ageing brain. A cross-sectional analysis of data from the US Health and Retirement Study found reduced cognitive function in older adults living in areas with higher PM<sub>2.5</sub> concentrations<sup>xxxi</sup>. More recent studies have demonstrated increasing evidence for air pollution being a causative factor for impaired cognition<sup>xxxii xxxiii</sup>

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### **The most vulnerable suffer the most harm**

Air pollution is harmful to everyone. However, some people suffer more because they are:

- More likely to live in polluted areas.
- Exposed to higher levels of air pollution.
- More vulnerable to health problems caused by air pollution due to a pre-existing conditions.

A combination of factors such as age, presence of respiratory disease, heart disease and environmental factors such as proximity of one's home to an external source of pollution make some people particularly vulnerable to the harmful effects of air pollution<sup>xxxviii</sup>.

**Age:** There is consistent evidence that older people are particularly vulnerable to the adverse effects of air pollution. A systematic review of studies that examined deaths in association with exposure to PM<sup>xxxix</sup> for example, indicated a risk in older people of about twice that observed in younger persons with similar findings for hospitalisations<sup>xl xli</sup>.

**Disease:** There are a number of studies that have compared the impact of air pollution on individuals who do or do not have pre-existing diseases. Most frequently, these include respiratory and cardiovascular disease, and more recently, Type II diabetes. These conditions are very common in the general population, and understanding whether their presence makes people more vulnerable to the harms associated with air

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<sup>1</sup> Relating to the time, usually a number of weeks, immediately before and after birth.

pollution is an important issue. Although the evidence for adverse health effects of air pollution is stronger for some diseases than it is for others, it is possible to draw the following conclusions:

- Individuals with asthma report more symptoms from pollution than those without asthma and are more likely to have an 'attack' of asthma (exacerbation) when outdoor air pollution levels are high than when they are not<sup>xlii</sup>. As might be expected, those individuals with more severe asthma and those whose asthma is undertreated are especially vulnerable.
- Patients with Chronic Obstructive Pulmonary Disease (COPD; chronic bronchitis and emphysema) have a diminished capacity to clear inhaled material from their lungs and as a result may incur a higher-than-normal 'dose' at any level of air pollution<sup>xliii</sup>. In response to elevated levels of pollution, individuals with COPD experience a greater fall in lung function and a higher risk of admission to hospital than do healthy persons of the same age. Air Pollution also increases older people's risk of contracting pneumonia.
- The presence of coronary artery disease increases the risk of adverse events from traffic-related pollutants and, in particular, those emitted from diesel engines. These events include heart attacks, but also more subtle effects such as abnormalities in heart rhythm or rate, hypertension, accelerated heart failure and type II diabetes<sup>xliv xlv</sup>.

**Deprivation:** Deprived communities live in environments that experience higher levels of air pollution<sup>xlvi</sup>. Deprivation has been identified as increasing susceptibility to PM in a number of separate studies. A European review reported that poorer communities were more vulnerable to the effects of PM<sub>10</sub> exposure, including morbidity and mortality<sup>xlvii</sup>. Other factors closely associated with deprivation, such as obesity and pre-existing cardiovascular and respiratory diseases, also increase vulnerability. Deprivation modifies the impacts of both PM on preterm birth and black smoke exposure on respiratory mortality. Adverse effects on cardiorespiratory disease and gestational hypertension continue to be reported.

The inequities described above affect people across the life course from the prenatal stage through to old age. They are compounded by the limited opportunities available for deprived communities to improve or escape their environments<sup>xlviii</sup>.

## References

- <sup>i</sup> Royal College of Physicians. Every breath we take: the lifelong impact of air pollution. Report of a working party. London: RCP, 2016
- <sup>ii</sup> Royal College of Physicians. Every breath we take: the lifelong impact of air pollution. Report of a working party. London: RCP, 2016
- <sup>iii</sup> [The Lancet Commission on pollution and public health](#). [19 October 2017]
- <sup>iv</sup> [Air quality plan for nitrogen dioxide \(NO<sub>2</sub>\) in UK \(2017\)](#)
- <sup>v</sup> [Air quality plan for nitrogen dioxide \(NO<sub>2</sub>\) in UK \(2017\)](#)
- <sup>vi</sup> [Amended technical report: Improving air quality: national plan for tackling nitrogen dioxide in our towns and cities](#)
- <sup>vii</sup> <https://www.theguardian.com/environment/2016/nov/02/high-court-rules-uk-government-plans-to-tackle-air-pollution-are-illegal>
- <sup>viii</sup> [https://uk-air.defra.gov.uk/assets/documents/annualreport/air\\_pollution\\_uk\\_2016\\_issue\\_1.pdf](https://uk-air.defra.gov.uk/assets/documents/annualreport/air_pollution_uk_2016_issue_1.pdf)
- <sup>ix</sup> WHO Ambient (outdoor) air quality and health: <http://www.who.int/mediacentre/factsheets/fs313/en/>
- <sup>x</sup> <https://www.london.gov.uk/what-we-do/transport/our-vision-transport/draft-mayors-transport-strategy-2017>
- <sup>xi</sup> <https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/draft-london-environment-strategy-have-your-say>
- <sup>xii</sup> <https://www.theguardian.com/world/2016/dec/07/paris-bans-cars-for-second-day-running-as-pollution-strikes>
- <sup>xiii</sup> <https://www.theguardian.com/cities/2016/sep/26/paris-council-approves-ban-vehicles-right-bank-seine-road>
- <sup>xiv</sup> <https://www.theguardian.com/environment/2016/dec/02/four-of-worlds-biggest-cities-to-ban-diesel-cars-from-their-centres>
- <sup>xv</sup> <https://electrek.co/2017/10/10/netherlands-dutch-ban-petrol-diesel-cars-2030-electric-cars/>
- <sup>xvi</sup> Ha S, Hu H, Roussos-Ross D et al. The effects of air pollution on adverse birth outcomes. *Environ Res* 2014; 134:198–204.
- <sup>xvii</sup> NHS Choices. *Type 2 diabetes*. [www.nhs.uk/Conditions/Diabetes-type2/Pages/Introduction.aspx](http://www.nhs.uk/Conditions/Diabetes-type2/Pages/Introduction.aspx) [Accessed 31 March 2015].
- <sup>xviii</sup> Thiering E, Cyrys J, Kratzsch J et al. Long-term exposure to traffic-related air pollution and insulin resistance in children: results from the GINIplus and LISAPLUS birth cohorts. *Diabetologia* 2013; 56: 1696–704.
- <sup>xix</sup> Royal College of Physicians. Every breath we take: the lifelong impact of air pollution. Report of a working party. London: RCP, 2016
- <sup>xx</sup> City-Specific Spatiotemporal Infant and Neonatal Mortality Clusters: Links with Socioeconomic and Air Pollution Spatial Patterns in France. Padilla CM, Kihal-Talantikit W, Vieira VM, Deguen S. *Int J Environ Res Public Health*. 2016 Jun 22; 13(6).
- <sup>xxi</sup> McConnell R, Islam T, Shankardass K et al. Childhood incident asthma and traffic-related air pollution at home and school. *Environ Health Perspect* 2010; 118:1021–6.
- <sup>xxii</sup> Chen Z, Salam MT, Eckel SP, Breton CV, Gilliland FD. Chronic effects of air pollution on respiratory health in Southern California children: findings from the Southern California Children’s Health Study. *J Thorac Dis* 2015; 7:46–58.
- <sup>xxiii</sup> Young MT, Sandler DP, DeRoo LA et al. Ambient air pollution exposure and incident adult asthma in a nationwide cohort of U.S. women. *Am J Respir Crit Care Med* 2014; 190:914–21.
- <sup>xxiv</sup> Perinatal air pollution exposure and development of asthma from birth to age 10 years. Sbihi H, Tamburic L, Koehoorn M, Brauer M. *Eur Respir J*. 2016 Apr;47(4):1062-71.
- <sup>xxv</sup> Perinatal Exposure to Traffic-Related Air Pollution and Atopy at 1 Year of Age in a Multi-Center Canadian Birth Cohort Study. Sbihi H, Allen RW, Becker A, Brook JR, Mandhane P, Scott JA, Sears MR, Subbarao P, Takaro TK, Turvey SE, Brauer M. *Environ Health Perspect*. 2015 Sep;123(9):902-8.
- <sup>xxvi</sup> Asthma Trajectories in a Population-based Birth Cohort. Impacts of Air Pollution and Greenness. Sbihi H, Koehoorn M, Tamburic L, Brauer M. *Am J Respir Crit Care Med*. 2017 Mar 1;195(5):607-613.
- <sup>xxvii</sup> Timing and Duration of Traffic-related Air Pollution Exposure and the Risk for Childhood Wheeze and Asthma. Brunst KJ, Ryan PH, Brokamp C, Bernstein D, Reponen T, Lockey J, Khurana Hershey GK, Levin L, Grinshpun SA, LeMasters G. *Am J Respir Crit Care Med*. 2015 Aug 15;192(4):421-7
- <sup>xxviii</sup> Brook RD, Rajagopalan S, Pope CA 3rd et al. Particulate matter air pollution and cardiovascular disease: an update to the scientific statement from the American Heart Association. *Circulation* 2010;121:2331–78.
- <sup>xxix</sup> World Health Organization. Review of evidence on health aspects of air pollution – REVIHAAP Project. Bonn: WHO, 2013. [www.euro.who.int/\\_data/assets/pdf\\_file/0004/193108/REVIHAAP-Final-technical-report-final-version.pdf/](http://www.euro.who.int/_data/assets/pdf_file/0004/193108/REVIHAAP-Final-technical-report-final-version.pdf/) [Accessed 2 December 2015].
- <sup>xxx</sup> Newby DE, Mannucci PM, Tell GS et al. Expert position paper on air pollution and cardiovascular disease. *Eur Heart J* 2015;36:83–93b.

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- <sup>xxx</sup> Ailshire JA, Crimmins EM. Fine particulate matter air pollution and cognitive function among older US adults. *Am J Epidemiol* 2014;180:359–66.
- <sup>xxxii</sup> Association between environmental factors and emergency hospital admissions due to Alzheimer's disease in Madrid. Culqui DR, Linares C, Ortiz C, Carmona R, Díaz J. *Sci Total Environ*. 2017 Mar 22;592:451-457.
- <sup>xxxiii</sup> Cerebrospinal Fluid Biomarkers in Highly Exposed PM2.5 Urbanites: The Risk of Alzheimer's and Parkinson's Diseases in Young Mexico City Residents. Calderón-Garcidueñas L, Avila-Ramírez J, Calderón-Garcidueñas A, González-Heredia T, Acuña-Ayala H, Chao CK, Thompson C, Ruiz-Ramos R, Cortés-González V, Martínez-Martínez L, García-Pérez MA, Reis J, Mukherjee PS, Torres-Jardón R, Lachmann I. *J Alzheimers Dis*. 2016 Sep 6;54(2):597-613.
- <sup>xxxiv</sup> Exposure to air pollution as a potential contributor to cognitive function, cognitive decline, brain imaging, and dementia: A systematic review of epidemiologic research. Power MC, Adar SD, Yanosky JD, Weuve J. *Neurotoxicology*. 2016 Sep;56:235-253.
- <sup>xxxv</sup> Association between air pollutants and dementia risk in the elderly. Wu YC, Lin YC, Yu HL, Chen JH, Chen TF, Sun Y, Wen LL, Yip PK, Chu YM, Chen YC. *Alzheimers Dement (Amst)*. 2015 May 14;1(2):220-8.
- <sup>xxxvi</sup> Telomere Length, Long-Term Black Carbon Exposure, and Cognitive Function in a Cohort of Older Men: The VA Normative Aging Study. Colicino E, Wilson A, Frisardi MC, Prada D, Power MC, Hoxha M, Dioni L, Spiro A, Vokonas PS, Weisskopf MG, Schwartz JD, Baccarelli AA. *Environ Health Perspect*. 2017 Jan;125(1):76-81.
- <sup>xxxvii</sup> Fine particulate matter air pollution and cognitive function among U.S. older adults. Ailshire JA, Clarke P. *J Gerontol B Psychol Sci Soc Sci*. 2015 Mar;70(2):322-8.
- <sup>xxxviii</sup> Royal College of Physicians. Every breath we take: the lifelong impact of air pollution. Report of a working party. London: RCP, 2016
- <sup>xxxix</sup> Bell ML, Zanobetti A, Dominici F. Evidence on vulnerability and susceptibility to health risks associated with shortterm exposure to particulate matter: a systematic review and meta-analysis. *Am J Epidemiol* 2013;178:865–76.
- <sup>xl</sup> Royal College of Physicians. Every breath we take: the lifelong impact of air pollution. Report of a working party. London: RCP, 2016. p.71
- <sup>xli</sup> Adverse effects of outdoor pollution in the elderly. Simoni M, Baldacci S, Maio S, Cerrai S, Sarno G, Viegi G. *J Thorac Dis*. 2015 Jan;7(1):34-45.
- <sup>xlii</sup> Royal College of Physicians. Every breath we take: the lifelong impact of air pollution. Report of a working party. London: RCP, 2016
- <sup>xliii</sup> Royal College of Physicians. Every breath we take: the lifelong impact of air pollution. Report of a working party. London: RCP, 2016. P.72
- <sup>xliv</sup> Royal College of Physicians. Every breath we take: the lifelong impact of air pollution. Report of a working party. London: RCP, 2016. P.73
- <sup>xlv</sup> KJ, De Roos AJ, Mayer JD, Kaufman JD, Wakefield J, Rosenfeld M. Fine particulate matter exposure and initial *Pseudomonas aeruginosa* acquisition in cystic fibrosis. *Ann Am Thorac Soc*. 2015 Mar;12(3):385-91. doi: 10.1513/AnnalsATS.201408-400OC. PubMed PMID: 25594356.
- <sup>xlvi</sup> The Marmot Review. Fair society, healthy lives: strategic review of health inequalities in England post-2010. London: Marmot Review, 2010. [www.instituteofhealthequity.org/projects/fair-society-healthy-lives-the-marmot-review](http://www.instituteofhealthequity.org/projects/fair-society-healthy-lives-the-marmot-review) [Accessed 11 December 2015].
- <sup>xlvii</sup> Deguen S, Zmirou-Navier D. Social inequalities resulting from health risks related to ambient air quality – a European review. *Eur J Public Health* 2010;20:27–35.
- <sup>xlviii</sup> Air pollution, deprivation and health: understanding relationships to add value to local air quality management policy and practice in Wales, UK. Brunt H, Barnes J, Jones SJ, Longhurst JW, Scally G, Hayes E. *J Public Health (Oxf)*. 2016 Sep 9. [Epub ahead of print]