Adverse Environmental Exposures and Childhood Lung Health.

An Education and Training Session held at the Congress Internationale on Pediatric Pulmonology (CIPP), June 23rd 2018

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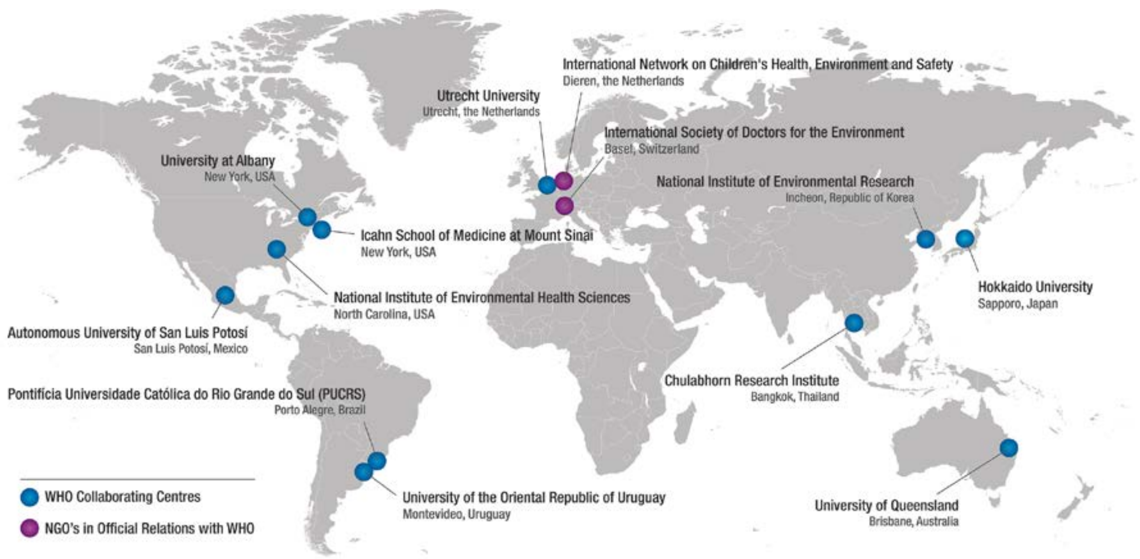
As outlined in the recent Lancet Commission on Pollution and Health[1], pollution is a major cause of global morbidly and mortality. Children are especially vulnerable to the health consequences of adverse environmental exposures and paediatricians have an important role to play in advocating for child health. Environmental health is not taught in most medical school or paediatric training curricula. As such, paediatricians are frequently uninformed and ill prepared to advocate on behalf of children in this area. The American Academy of Physicians recommended, in a position paper published in 2016[2], that physicians: engage in environmentally-sustainable practices that reduce carbon emissions; support efforts to mitigate and adapt to effects of climate change; and educate the public, their colleagues and lawmakers about the health risks of climate change. They considered that tackling climate change presented an opportunity to dramatically improve human health and avert dire environmental outcomes and that Physicians could, and should, play a role in achieving this goal.

Tackling the lack of awareness of, and education on, children's environmental health is firmly on the agenda of the World Health Organization (WHO) and the Network of WHO Collaborating Centres for Children's Environmental Health, coordinated by the Centre located at the National Institute for Environmental Health Sciences (Figure 1).

Figure 1: The Network of WHO Collaborating Centres



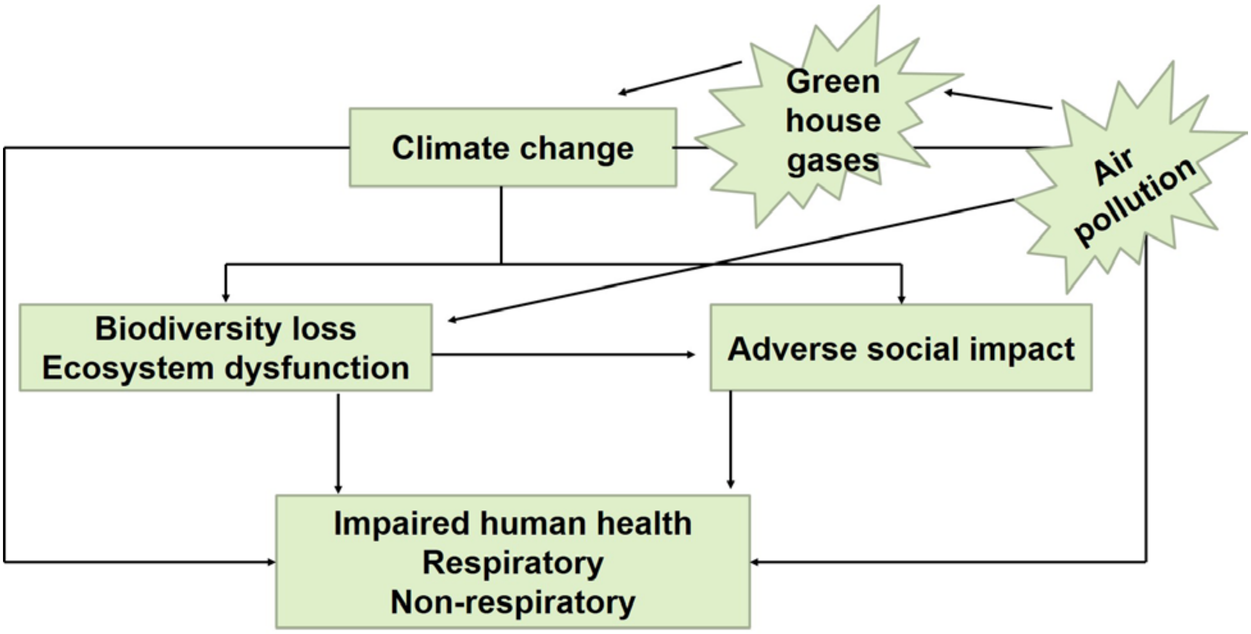
The Network undertakes educational sessions in regional locations and in conjunction with appropriate training events. Created 20 years ago, CIPP is the only international congress fully devoted to Pediatric Pulmonology. In a world where the disparities between North and South keep increasing, and where the gap between the rich and the poor is widening, one of the main goals of the CIPP is also to bring together leading specialists in paediatric pulmonology from both developed and developing countries. The meeting has an emphasis on providing practical education for practicing paediatricians from all parts of the world. In this context, an education and training session on Children's Environmental Health was held at the 18th CIPP in Toledo, Spain on June 23rd, 2018.

The session, chaired by Professor Renato Stein, Director of the Collaborating Centre for Environmental Hazards to Children's Health, Pontifícia Universidade Católica do Rio Grande do Sul, Brazil, included presentations from Professor Peter Sly, Director of the Collaborating Centre for Children's Health and Environment, Brisbane, Australia, Professor Jonathan Grigg, Professor of Paediatrics and Environmental Health, Queen Mary University, London and Dr Aneesa Vanker, Department of Paediatrics and Child Health and MRC Unit on Child and Adolescent Health, University of Cape Town, South Africa. Topics included: Climate change and respiratory health; the health effects of indoor air pollution; and minimizing exposure to traffic-related pollution.

Climate change and respiratory health: Peter D Sly

Climate change is a real and undeniable occurrence, with changes in weather patterns, droughts, floods and extreme weather events becoming more frequent all over the world. The interactions between climate change and health outcomes are complex[3] (Figure 2). Ambient air pollution, with increasing tropospheric particulate matter (PM), SO_2, O_3, and oxides of nitrogen (NO_x), contribute to greenhouse gases, a major contributor to climate change. Air pollution and climate change both contribute to ecosystem dysfunction and biodiversity loss. This, together with the adverse social impacts from climate change directly and from ecosystem dysfunction have adverse impacts on human health.

Figure 2: Schematic representation of the complex interactions between Climate change and health outcomes (adapted from Mirsaeidi et al.[3])



There are a number of mechanisms and pathways by which the consequences of climate change may result in adverse health outcomes. Direct consequences of climate change likely to adversely impact health include: higher ambient temperatures; altered rainfall patterns, increasing in some regions but decreasing in others; rising atmospheric CO_2; rising sea levels; and ocean warming. The pathways by which these effects of climate may affect health and the impact on health are outlined in Table 1.

Table 1		
Consequence of climate change	**Pathway**	**Adverse Health Outcomes**
Higher ambient temperature	Heat waves ↑ temperature variability ↑ surface level O_3 Earlier and longer pollen seasons	↑ cardiopulmonary deaths Heat Stress Asthma exacerbations Altered lung growth
Altered precipitation	Drought / floods Altered raid distribution	Population displacement Mental health disorders Food / water insecurity
Rising CO_2	↑ plant growth ↑pollen production ↓ nutritional value	Food insecurity ↑ allergic rhinitis Asthma exacerbations
Sea level rise	Climate refugees	Population displacement Mental health disorders Altered infectious disease distribution
Ocean warming	↑ severe weather events	Population displacement Mental health disorders Food / water insecurity

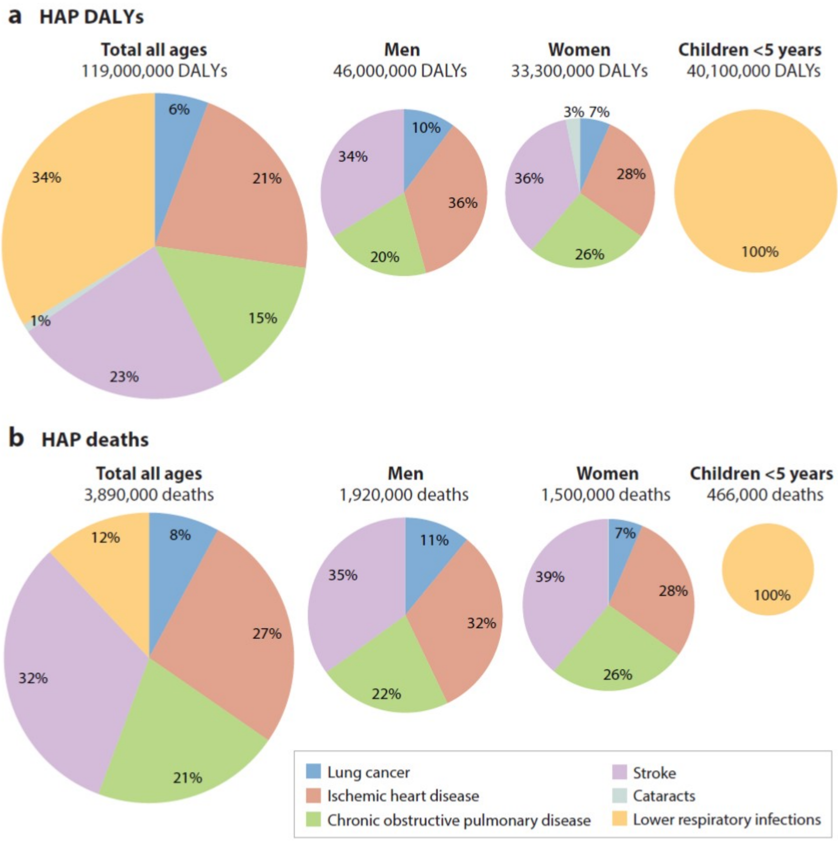
Higher ambient temperatures are likely to have adverse environmental consequences through heat waves[4] and the creation of urban heat islands. Higher temperatures increase the risk of physiological disturbances e.g. dehydration, electrolyte imbalance and heat stress, especially on vulnerable groups[5-7]. Temperature rise is also predicted to contribute to deteriorating air quality, with an increase in particulate matter and surface level O_3[8]. Poor air quality has negative impacts on lung growth and development and on lung function. Higher levels of particulate matter are associated with lower lung function in children [9]. Higher levels of ozone alter lung structure and growth in infant rhesus monkeys[10].

Climate sensitive respiratory diseases include: respiratory infections, asthma, cystic fibrosis and chronic obstructive pulmonary disease (COPD)[11]. The impact of climate change on respiratory infections is complex and depends largely on the local environmental conditions. Pneumonia in the tropics occurs in the rainy season[12], which is anticipated to become more prolonged under climate change scenarios. However, respiratory syncytial virus seasons are becoming shorter in temperate climates[13]. Poor air quality increases the risk of respiratory infections through a variety of mechanisms including increased ambient O_3 reducing vitamin D levels, and increased PM increasing the risk of tuberculosis. Climate change impacts on asthma in a number of ways including changing patterns of acute respiratory infections, greater exposure to pollens and heat-stress and O_3 increasing exacerbation severity. Climate impacts on cystic fibrosis include poor air quality inducing oxidative stress and increasing the risk of earlier acquisition of pathogenic bacteria; increase in surface level O_3 altering lung growth and increasing risk of acute pulmonary exacerbations; and warmer, more humid environments altering the distribution and increasing the risk of acquiring pathogens such as non-tuberculous mycobacteria, pseudomonas aeruginosa and methicillin-resistant staph aureus. Climate impacts on COPD include increased mortality and increased acute pulmonary exacerbations.

Household air pollution and respiratory health. Aneesa Vanker.
There is increasing evidence suggesting that lung health trajectories are set in early life with the antenatal and early-life period as critical exposure time points[14]. Further, childhood respiratory diseases are a global health problem with lower respiratory tract infections (LRTI) remaining the leading cause of under-5 mortality in low and middle income countries.

Household air pollution (HAP) from inefficient combustion or the use of alternate fuels is a major global problem with 3 billion people relying on alternate fuels for cooking and heating, resulting in 4 million premature deaths associated with this[15]. HAP exposure is a major contributor to global burden of disease, with an estimated 199 million disability-adjusted life years (DALYs) and approximately 4 million deaths attributable to HAP in 2010[16].

Figure 3: Global burden of disease in 2010 as a) disability-adjusted life years (DALYs) and b) deaths attributable to household air pollution (HAP)[16].



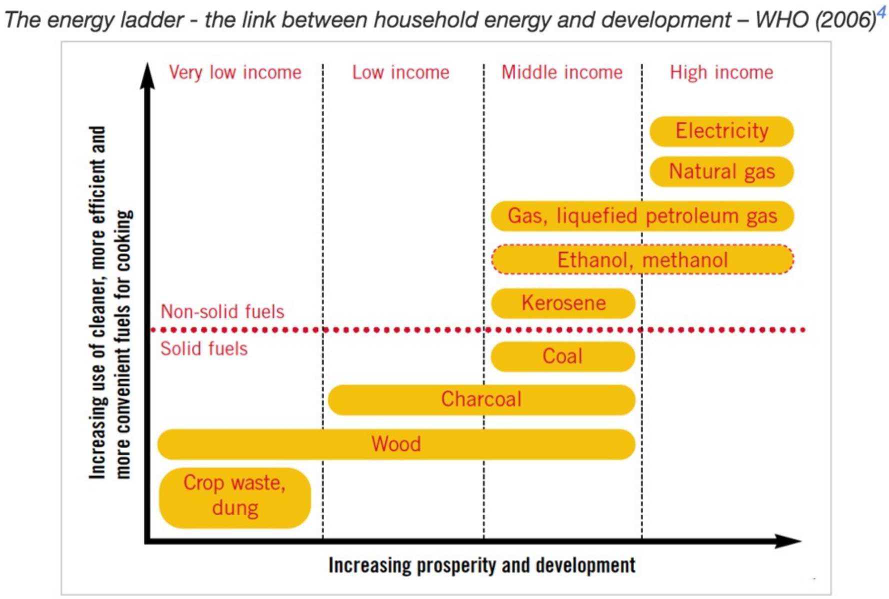
Further, 40% of children are exposed to environmental tobacco smoke, often from within the home[17]. In low and middle-income countries (LMIC), types of alternate fuels used depend on availability and geographic distribution. Burning of alternative fuels (such as paraffin, wood, coal and other biomass substances) contributes to indoor air pollution, a recognised risk factor for respiratory disease[18]. This coupled with inadequate ventilation may result in very high exposure levels particularly to infants and children.

They type of fuel burnt is influenced by local economic factors and in turn influences the health risks[19]. This is reflected by the so-called “energy ladder” that highlights that the poorest economies can only afford the dirtiest fuel (Figure 4). Burning dung, crop residue and solid fuel in open fire places results in inefficient combustion with the production of numerous toxic by-products in addition to carbon monoxide and particulate matter. The by-products are influenced by what is burnt but are likely to include: dioxins and furans, nitrogen oxides, benzene, butadiene, formaldehyde, and polyaromatic hydrocarbons. Burning coal can result in exposures to arsenic, cadmium, chromium, cobalt, lead, mercury, selenium, thorium and uranium, as well as dioxins and poly-aromatic hydrocarbons. In addition, coal from some locations, notably Southern China, has a high sulphur content that can result in exposures to sulphur oxides.

Exposures are also influenced by social factors. The most exposed groups are women and young children, especially girls. Women do the cooking, frequently carrying young children on their backs.

Once the children are too old to carry, girls tend to have greater exposure as they are more likely to stay indoors with their mother.

Figure 4: Schematic representation of the energy ladder[19]



However, HAP exposure may also play a significant role in lung health for children from high income countries (HIC) with exposure from a multitude of sources including combustion, tobacco smoke, furnishings and cleaning products[15]. With rapid urbanisation and mushrooming of peri-urban communities, volatile organic compounds such as benzene and toluene and trace metals (vanadium) are increasingly recognised exposures impacting on lung health[20].

Antenatal air pollution exposure impacts lung development[21] and has been linked to decreased lung function in infancy and childhood, increased respiratory symptoms, and the development of childhood asthma[22]. A large number of studies from both HIC and LMIC explore the associations between HAP and a number of childhood respiratory outcomes[23]. An overall summary risk of HAP and childhood respiratory disease found an almost 2-fold increase[24]. Further, postnatal air pollution exposure is associated with decreased lung function and impaired lung growth[25].

Addressing HAP exposures is vital in decreasing childhood lung disease and improving long-term lung health outcomes. To date intervention studies have been largely inconclusive[26]; and urgent and effective public health interventions focusing on reducing HAP and tobacco smoke exposure are required.

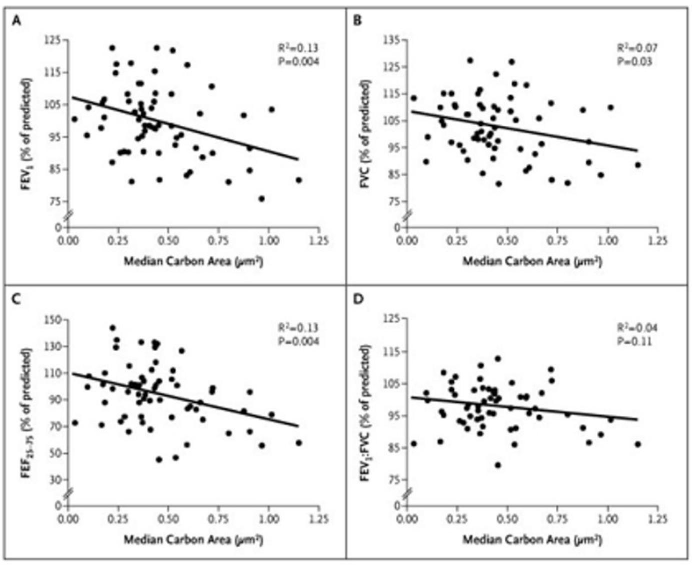
Traffic Pollution: Solutions to Minimize Exposure. Jonathan Grigg

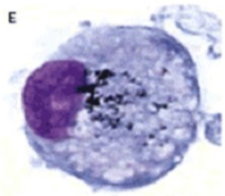
Children are exposed to a mix of air pollutants. In urban areas, the pollutants linked with adverse effects are predominately generated by human activity and include PM and NOx. Particulate matter is a complex mix of carbon, ammonium nitrate and ammonium sulphate, oxides and salts of many metals, and organic materials. However, PM from traffic-related air pollution (TRAP) predominately consists of particles of soot from incomplete combustion of fossil-fuels. Oxides of nitrogen, including nitrogen dioxide (NO_2) are produced directly by combustion and by the oxidation of nitric oxide in the air via either a slow reaction with oxygen or a more rapid reaction with ozone. In some cities, ozone is another major pollutant. Ozone is formed by chemical reactions between other air pollutants, especially oxides of nitrogen with volatile organic compounds (VOCs) that are emitted from petrol car exhausts and directly from petrol. Recent evidence suggests a new source of outdoor VOCs – VOCs from cleaning products used indoors[27].

In urban areas, there is a high correlation between the concentrations of NO_2 and PM, especially from TRAP, and separating out independent effects is difficult in epidemiological studies. Therefore it is reasonable to assume that studies reporting associations with either pollutant reflect exposure to a complex mix of fossil-fuel derived emissions. An important source of outdoor air pollution in urban areas, especially in countries such as the UK and Germany, is diesel vehicles. Diesel exhaust comprises of gases, PM, VOCs and polycyclic aromatic hydrocarbons (PAHs). The smallest, and most inhalable diesel exhaust PM (PM less than 10 microns in aerodynamic diameter; PM_{10}), consists of elemental carbon (soot or "black carbon"), with toxic compounds adsorbed onto its surface - including organic compounds, sulphate, nitrate and reactive transition metals. Diesel vehicles produce disproportionality more NO_2 than equivalent petrol or hybrid cars and vans, and have therefore been a focus of exposure-reduction policies. For example, on 27th February 2018 the German Federal Administrative Court ruled that the cities of Stuttgart and Duesseldorf (and setting a precedent for other cities) can legally ban more older, more polluting diesel cars from zones worst affected by pollution, despite opposition from both the government and the car industry[28].

Long-term exposure of children to air pollution has adverse effects not only in childhood, but also across the lifecourse. From the very start of life, exposure of the mother to air pollution impairs fetal growth. For example, an analysis of pooled data from 14 population-based mother–child cohort studies from 12 European countries found an inverse association between head circumference at term and outdoor air pollution, in addition to increased prevalence of low birth weight at term[29]. Reduced post-natal organ growth was found in a landmark study of over 11,000 schoolchildren from 16 communities in California, where clinically relevant suppression of lung function growth was highest in children living in communities with the highest concentrations of PM_{10}, elemental carbon, and NO_2[28]. In the same study, exposure to higher local concentrations of NO_2 was associated with new-onset asthma, with the risk of lifetime asthma higher in children living closer to a freeway[30]. Indeed, a meta-analysis, which included 19 studies, concluded that increased exposure to either NO2 or PM is associated with incident wheeze[31]. Direct measurement of black carbon reaching the lungs and reflected in macrophages show an inverse association between macrophage carbon content and lung function in children without respiratory disease[9] (Figure 5).

Figure 5: Inverse association between carbon content of sputum macrophages and lung function in school-aged children.





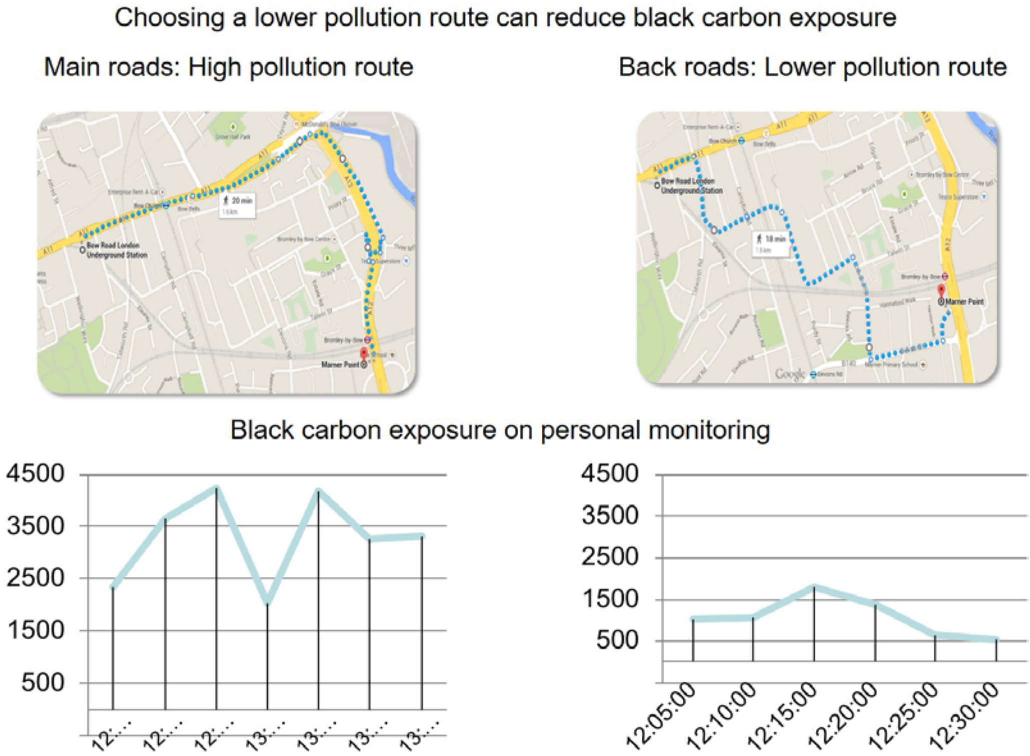
Each increase of 1μm² in carbon content in the alveolar macrophage –

- **17%** ↓ in FEV1
- **12.9%** ↓ in FVC
- **34.7%** ↓ in FEF25-75%

An emerging area of concern is the link between air pollution and risk of pneumonia. For example, a meta-analysis analysis of 10 European birth cohorts, found associations between either PM or NO2 and pneumonia in early childhood[32]. For adults, it is very likely that exposures in childhood contribute to the associations between long term exposure to air pollution and incident cardiovascular disease and lung cancer.

Given the robust evidence that air pollution adverse effects children's health, what should policy makers do? In 2016 the Royal College of Paediatrics and Child Health and the Royal College of Physicians published its report "Every Breath we take; the lifelong impact of air pollution"[33]. Recommendations for policy makers in the report include; i) that governments must empower local authorities and incentivise industry to plan for the long term, ii) alternatives to cars fuelled by petrol and diesel must be actively promoted, along with active travel, iii) polluters must be required to take responsibility for harming health and political leaders must introduce tougher regulations, including reliable emissions testing for cars – and must enforce regulations vigorously, and iv) we must protect those most at risk – especially children. For health professionals, the report concludes that health professionals should be provided with the "tools to discuss air pollution with their patients". To date, relevant guidelines (e.g. for asthma) do not provide these tools. A good start for those revising management guidelines is the advice developed by the British Lung Foundation (BLF)[34], which includes; i) reducing strenuous, outdoor exercise on high pollution days and exercising indoors in a well-ventilated area, and for asthmatics, to ensure a reliever inhaler is to hand, and ii) when travelling to school or work, to stay away from pollution hotspots. Choosing a less polluted route when walking or cycling to work or school can reduce exposure, as shown by personal monitoring data (Figure 6).

Figure 6: Taking a less polluted, back street route can result in lower exposure.



Parents may ask about giving their child a facemask on high pollution days– but the BLF guidance sensibly states that "at the moment there's very little evidence to recommend the use of face masks, and that many people find wearing a mask very uncomfortable, and some people with a lung condition report finding breathing more difficult when there's something covering their mouth". More evidence is needed of how much protection is offered by different types of mask before their routine use can be recommended. There is overwhelming evidence that air pollution harms children's health, with implications across the whole life course. Governments must therefore urgently reduce children's exposure to TRAP. Removing the current toxic fleet of diesel vehicles is an important first step in this process.

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