



REVIEW

Air Pollution and Asthma: Critical Targets for Effective Action

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ABSTRACT

Evidence to advocate for cleaner air for people with asthma is not in short supply. We know that air pollution is associated with the development and worsening of the condition and that mitigating interventions can improve respiratory outcomes. We have clear targets, particularly traffic emissions, especially in urban areas, and plenty of potentially effective actions. Road traffic must be reduced, and what remains should be cleaner and greener. Urban green spaces, safe cycle networks and wider pavements will promote active travel and leisure time exercise. Healthcare professionals must ensure people are aware of their air quality, its impact on asthma and the appropriate behaviour to safeguard health. What remains are realistic policies and effective measures, based on the correct scientific evidence, to be taken forth with political courage and investment so that air pollution no longer contributes to the development or worsening of respiratory ill health.

Keywords: Air pollution; Asthma; Mitigating interventions; Traffic emissions

Key Summary Points

We know that air pollution is associated with the development and worsening of asthma and that improving air quality can result in respiratory health gains.

The challenge associated with achieving sustained reductions in air pollutants to reduce new-onset asthma and prevent worsening symptoms in those already afflicted should not be considered an intractable one.

We have clear targets and a wealth of opportunities to effectively act and make progress.

In this review, we discuss a broad array of interventions, targeted to multiple sectors of society, with the aim to bring multiple public health benefits, in addition to air quality improvements.

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DIGITAL FEATURES

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INTRODUCTION

Asthma is a common and chronic condition of the lung in which inflammation causes the bronchi to swell and narrow the airways, leading to episodic periods of wheezing, shortness of breath, cough and chest tightness. It affects around 235 million people worldwide [1]. Incidence and prevalence are higher in children, however morbidity and mortality are higher in adults [2]. Asthma tends to be a disease of more developed economies where there is some evidence that prevalence may have peaked [3]. In contrast, rates are increasing in low- and middle-income countries where outcomes are much worst [2, 4]. Superimposed upon day-to-day symptoms, sufferers experience life-threatening exacerbations lasting from days to weeks, which are caused by a variety of stressors, including respiratory viral infections, allergen exposure and air pollution. There is now consistent evidence that exposure to traffic-related air pollution (TRAP; particularly nitrogen dioxide [NO₂]) is associated with an increased risk of developing asthma across the entire life course, and evidence is accumulating for a link between poor indoor air quality and new cases [5, 6]. A recent global (incorporating 194 countries and 125 major cities) estimate of the burden of paediatric asthma incidence attributable to ambient NO₂ at a spatial resolution fine enough to resolve intra-urban and near-roadway exposure gradients reported that each year 4 million new paediatric asthma cases could be attributable to NO₂ pollution; 64% of these in urban centres (Table 1) [7]. The work also estimated that about 97% of children lived, and 92% of new asthma cases attributable to NO₂ occurred, in areas with annual average NO₂ concentrations lower than the World Health

Organisation's annual air quality guideline of 40 µg/m³.

Whilst there is no known cure for asthma, pharmacological intervention significantly improves symptoms [8, 9]. Unfortunately, however, despite international guidelines, treatment compliance rates (> 80%) required to maintain disease control is often poor, even in countries where treatment is readily accessible [10, 11]. Reducing the onset of asthma and safely controlling symptoms through air pollution mitigation strategies, discussed herein, should therefore be regarded a significant component of the overall armamentarium against this debilitating respiratory condition.

The studies selected for inclusion in this review were collected through a search of the PubMed database and grey literature using the following keywords: 'asthma' AND 'air pollution' OR 'traffic' OR 'indoor air' OR 'particulate matter (PM)' OR 'NO₂' OR 'oxides of nitrogen (NO_x)' OR 'diesel' AND 'mitigating' OR 'interventions' OR 'policy' OR 'reducing' OR 'action' OR 'public awareness'. The information included in this review has been chosen to deliver a broad discussion of interventions, targeted to multiple sectors of society, to reduce the burden of air pollution on the prevalence and severity of asthma.

This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

IMPROVING AIR QUALITY CAN RESULT IN RESPIRATORY HEALTH GAINS

Data from many parts of the world strongly suggest that policies designed to reduce air pollution can improve respiratory outcomes. In California, reductions in PM_{2.5} (PM with a diameter < 2.5 µm) and NO₂ between 1993 and 2014 reduced the risk of incident asthma in children by 20% (Fig. 1) [12]. In a Swiss cohort of adults, a decline in PM₁₀ (PM with a diameter < 10 µm) concentrations from 1990 to 2001 was associated with a 9% decrease in the annual rate of decline in forced expiratory volume in 1 s

Table 1 Annual number and percentage of new asthma cases attributable to ambient nitrogen dioxide exposure for children aged 1–18 years

Regions ^a	New asthma cases due to NO ₂ exposure per year, thousands (95% UI) ^b	New asthma cases due to NO ₂ exposure per year, per 100 000 children (95% UI) ^b	New asthma cases due to NO ₂ exposure per year, % of total incidence (95% UI)
High-Income regions			
Australasia	12 (5.2–15)	170 (77–230)	8.7% (3.8–11)
High-income Asia Pacific	97 (46–120)	300 (140–370)	25% (12–32)
High-income North America	270 (120–340)	310 (140–400)	19% (8.5–24)
Southern Latin America	56 (26–72)	290 (130–370)	18% (8.4–23)
Western Europe	150 (70–200)	190 (85–240)	17% (7.8–22)
Latin America and Caribbean			
Andean Latin America	73 (33–94)	340 (150–440)	15% (6.7–19)
Caribbean	39 (17–51)	280 (120–360)	10% (4.4–13)
Central Latin America	240 (110–310)	260 (120–330)	15% (6.7–19)
Tropical Latin America	150 (66–190)	230 (100–290)	13% (5.8–17)
Sub-Saharan Africa			
Central sub-Saharan Africa	61 (27–79)	110 (47–140)	5.1% (2.3–6.7)
Eastern sub-Saharan Africa	150 (63–190)	76 (33–100)	4.4% (1.9–5.9)

Table 1 continued

Regions ^a	New asthma cases due to NO ₂ exposure per year, thousands (95% UI) ^b	New asthma cases due to NO ₂ exposure per year, per 100 000 children (95% UI) ^b	New asthma cases due to NO ₂ exposure per year, % of total incidence (95% UI)
Southern sub-Saharan Africa	46 (20–60)	160 (69–200)	8.6% (3.8–11)
Western sub-Saharan Africa	210 (92–280)	110 (49–150)	7.6% (3.3–9.9)
North Africa and Middle East	570 (260–730)	270 (120–350)	17% (7.6–21)
South Asia	520 (230–680)	82 (37–100)	14% (6.3–18)
Southeast Asia, East Asia, and Oceania			
East Asia	800 (370–1000)	260 (120–340)	19% (8.9–25)
Oceania	3.1 (1.4–4.1)	82 (36–110)	3.1% (1.4–4.1)
Southeast Asia	440 (200–570)	200 (89–260)	9.4% (4.2–12)
Central Europe, Eastern Europe, and Central Asia			
Central Asia	46 (21–60)	160 (70–200)	16% (7.0–20)
Central Europe	29 (13–38)	130 (60–170)	14% (6.1–18)
Eastern Europe	68 (31–88)	180 (80–230)	17% (7.6–21)
Global	4000 (180–5200)	170 (77–220)	13% (5.8–16)

Reprinted from The Lancet Planetary Health, Vol 3(4), Achakulwisut P, Brauer M, Hystad P, Anenberg SC, Global, national, and urban burdens of paediatric asthma incidence attributable to ambient NO₂ pollution: estimates from global datasets, e170., Copyright (2019), with permission from Elsevier

NO₂, Nitrogen dioxide; UI, uncertainty interval (reflect uncertainties in the relative risk estimates of childhood asthma incidence attributable to traffic-related NO₂ pollution)

^a Countries are grouped into regions according to the Institute for Health Metrics and Evaluation (IHME; Seattle, WA, USA) specification

^b Numbers are rounded to two significant figures

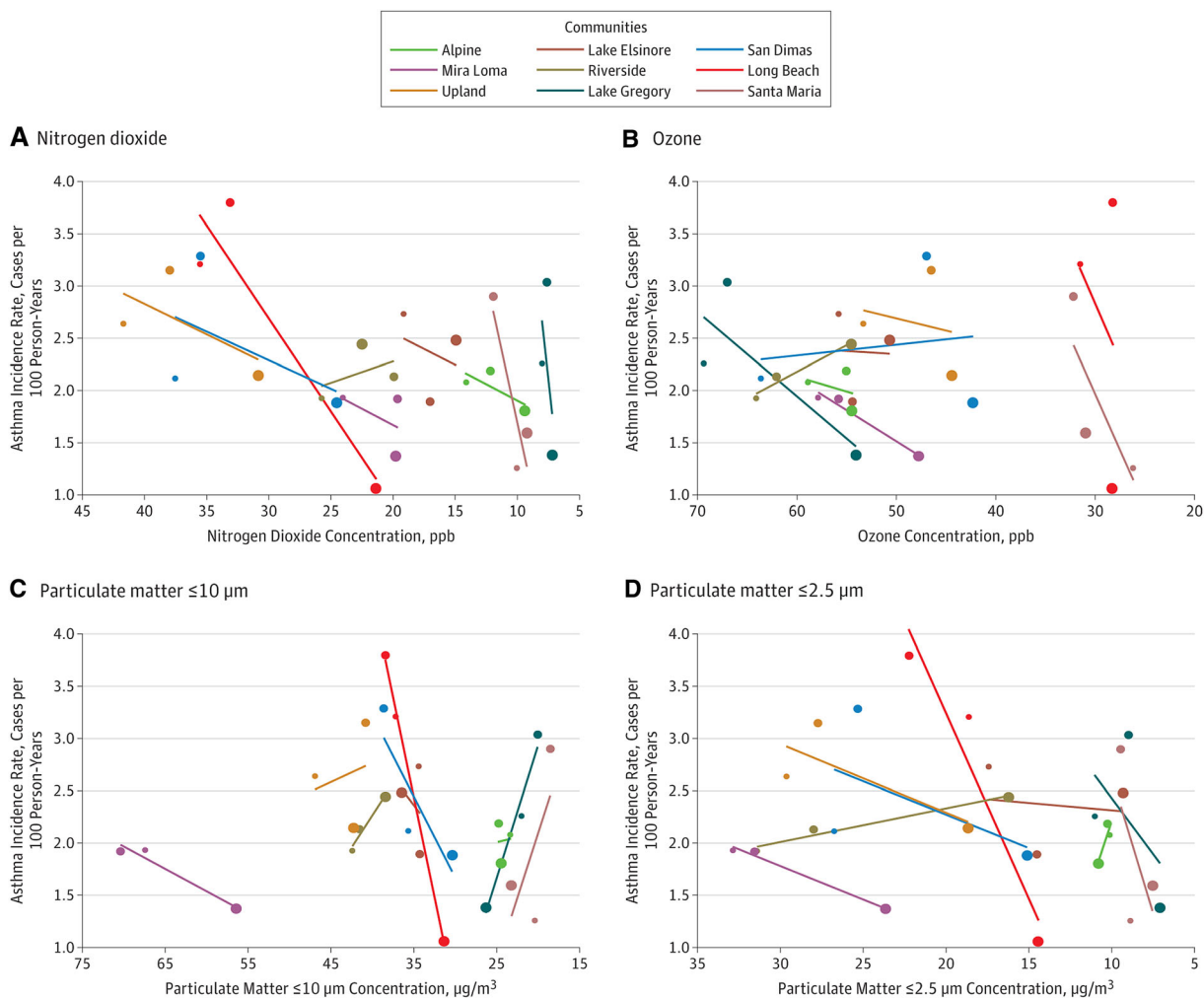


Fig. 1 Asthma incidence rates and air pollutant concentrations in nine communities during the 1993–2001, 1996–2004 and 2006–2014 cohorts of the Southern California Children’s Health Study, 1993–2014 [12]. Symbol colour indicates the community, and symbol size (small, medium, large) indicates the data are from the 1993–2001 (small), 1996–2004 (medium) and 2006–2014 (large) cohorts, respectively. Simple linear

regression models based on asthma incidence and air pollution concentration were used to generate regression lines separately for each community. *ppb* Parts per billion. Reproduced from Garcia et al. (JAMA. 2019; 321(19):1906–1915), with permission from JAMA. Copyright© 2019 American Medical Association. All rights reserved

(FEV₁) [13]. A follow-up study found that for every 10,000 persons in the community, a further decline in PM₁₀ from 1991 to 2002 was associated with 137 fewer people with wheeze or shortness of breath [14]. In Japan, legislation was passed in 2001 to limit transportation-related emissions. By 2009, decreases in PM_{2.5} and NO₂ were linked to a lower (0.6–1.1%) prevalence of paediatric asthma [15]. Benefits have

also been observed following local air quality interventions associated with factory closures and hosting of Olympic games. Hospital admissions for childhood asthma fell by half, in association with a significant reduction in PM_{2.5}, because of a 13-month closure of a steel mill in the Utah valley [16]. A 17-day “alternative transportation strategy” implemented by the City of Atlanta in the summer of 1996

brought about a 23% decrease in peak morning traffic; within 4 weeks of this decrease, there was a 42% reduction in children seeking medical care and a 19% decrease in hospitalisations for asthma [17].

In preparation for the 2008 Beijing Olympics, the Chinese government enacted factory emission and travel restrictions that resulted in pollutant concentrations decreasing by up to 62% [18]. Within 2 months, these reductions were linked to an improvement in lung function among both healthy adults and those with asthma [19] as well as 58% fewer asthma-related physician visits [18]. Benefits of improving indoor air quality have also been documented. Installing less polluting heating appliances (heat pump, wood pellet burner, flued gas) in homes of children with asthma in New Zealand reduced symptoms, days off school, healthcare use and visits to a pharmacist [20]. Australian schools randomly allocated either to retain unflued gas heaters or have replacement flued gas/electric heaters installed reported a significant reduction in breathing difficulties, chest tightness and asthma attacks in the intervention group [21].

CHALLENGES CREATE OPPORTUNITIES

The substantial challenges associated with achieving the sustained reductions in air pollutants necessary to reduce new-onset asthma and to prevent a worsening of symptoms in those already afflicted reflect not only the insidious nature of this environmental insult, but also the wealth and complexity of issues entwined with sub-optimal air quality. Europe's car fleets have been transformed to being powered by diesel (emitting more PM and NO_x than their petrol or hybrid counterparts) [22]. The powering of light and heavy goods vehicles [23], machinery on the ground [24] and ships in the port area [25] are also dominated by diesel. Schools are invariably sited near busy roads and traffic junctions made worse by the 'school run' that is synonymous with idling engines as parents drop off or wait for their children [26]. In 2016, 400 schools within London were in areas

exceeding the annual mean NO₂ EU limit value [27]. People on low incomes and ethnic minorities tend to be more affected than others by equivalent exposure to air pollutants [28] and are also exposed to some of the worst outdoor and indoor air quality [29, 30]. Indoor environments, where most human activities now take place within an enclosed space, are characterised by a chemically diverse and complex air quality [31]. Furthermore, unlike tobacco smoke, healthcare professionals have yet to take effective ownership of the problems that air pollution inflicts on society. On a more optimistic note, and one that this commentary attempts to take, such a challenge should not be regarded as intractable, but one in which there plenty of opportunities and ways, some of which are discussed below, to effectively act and make progress.

TARGETS FOR ACTION

Road Traffic

One of the most significant sources of air pollution in urban areas, where 55% of the world's population now resides [32], is road traffic (exhaust emissions, as well as particles from tyre, brake and road surface wear). It is, as stated earlier, also the source that has repeatedly been shown to cause/worsen asthma. The main TRAPs of concern to health in European cities are PM_{2.5} (particularly the fraction derived from the tailpipe) and NO₂. In London in the UK, traffic is responsible for around 80% of NO_x and 37% of PM₁₀ and PM_{2.5} concentrations at roadside locations [33]. This is not only due to the significant growth in vehicle numbers, but also to failures of vehicle manufacturers to ensure that they meet emissions limits in real-world driving conditions. Across 11 markets, representing approximately 80% of global diesel vehicle sales, Anenberg et al. [34] reported that over one-half of light-duty and nearly one-third of heavy-duty diesel vehicle emissions are in excess of certification limits. Cleaning up the air in heavily populated urban areas to reduce the heavy toll on people with asthma therefore requires a reduction in road traffic as well as a

cleaner and greener element to what remains on the road.

Cleaner Vehicles

Cleaner fossil-fuelled vehicles require tougher regulations to reduce exhaust emissions, not only for new vehicles, but also afterwards in annual safety/roadworthy tests. Commonly cited disincentives aimed at removing the most polluting components of the fleet, i.e. those fuelled by diesel, include levies on fuel, surcharges for parking and the introduction of low-emission zones (LEZ). However, whilst large-scale LEZs can deliver improvements in urban air quality, data suggest that, at least in densely populated European cities, more ambitious schemes are required to meet legislative limits and deliver improvements to childhood respiratory health, including asthma symptoms [35]. The introduction and rigorous evaluation of zones with greater reductions in pollutant concentrations are clearly warranted and may benefit from adjuvant clean air zones that introduce no vehicle idling areas, minimise congestion and support active and low-emission travel through the integration of public transport networks, including park-and-ride schemes.

The continued development of new technologies by motor manufacturers in producing vehicles that rely on alternative fuels (electricity, hydrogen) coupled with seamless interfaces with sustainable energy suppliers must also be actively encouraged and incentivised. Alternatively fuelled vehicles are not however the sole answer to poor air quality since zero-emission road transport does not currently exist. Particulate pollution from road traffic not only includes engine emissions, but also an increasing contribution from brake/tyre wear and road surface abrasions [36]. It is noteworthy that the potential of non-tailpipe emissions to elicit health effects is largely ignored at the regulatory level despite links with pulmonary toxicity [37]. To this end, non-tailpipe particulate pollution must be tackled by considering regulation in line with exhaust emissions and innovations in the development of 'safer' tyres, brakes and road surfaces.

Procurement of appropriate vehicles in the public and commercial sectors is crucially

important and nowhere more so than for school buses. Data from the USA show that although school bus commutes usually make up only a small part of a child's day, they can contribute up to one-third of a child's 24-h overall exposure to black carbon during a school day [38]. Moreover, data support the emission reduction benefits of high-efficiency cabin air filtration system [39] and anti-idling [26], as well as health benefits associated with changing fuel from diesel to compressed natural gas [40].

It should also be stressed that cleaner road transport will not only emerge from the vehicle itself, but also from practices, such improved energy-efficient driving skills that could be introduced through tests and training programmes. For example, a smooth driving style (vs. frequent stopping and starting) ensures that motorists travel steadily at an optimum speed, thereby reducing fuel consumption and in turn air pollution through reduced exhaust emissions, as well as particles emitted from brake and tyre wear [36, 41].

Fewer Vehicles

The safe and efficient movement of people around towns and cities ultimately necessitates fewer vehicles. This can only be achieved through: (1) clean, efficient and expanded public transport systems coupled with car share/club schemes and (2) as much active transport in the form of walking and safe cycling as is feasibly possible. People need to be given more cost-effective and easier alternatives to move through the urban environment, be that on the school run and/or on the commute to work, without necessarily owning a car or taking one out for short journeys. A report by the European Court of Auditors reveals that commuters in Europe are still choosing their cars over public transport, enduring ever-longer journey times into some city centres owing to traffic congestion [42]. Cost, convenience and time-efficiency were all factors cited as challenges in persuading citizens to leave the comfort of their cars for other forms of transport. It is likely however that perception and beliefs also come into play, with car ownership construed to be symbols of success and social status [43].

The Built Environment

The built environment incorporates multiple components that can influence local air quality and in turn ill health. Some examples include neighborhood design (walkability, bikeability, connectivity), housing quality, schools, transport facilities (roads, railways, ports, airports), power plants, industrial facilities, accessibility to shops and green space. Cities created prior to the introduction of cars tend to be more densely populated and more walkable compared to newer conurbations, which tend to be less populated and more reliant on cars for transport. A vicious circle often ensues in that the mass use of cars in newer cities often goes hand in hand with inadequate public transport, poor infrastructure for active commuting, lack of green space and higher exposures to air pollution.

Strategies to clean up the air in cities of all ages should focus on the ‘cleaner/fewer vehicles’ formula already discussed. A cleaner element should be encouraged by not only providing, but also maintaining, adequate charge points for electric vehicles. Fewer vehicles will ensue from siting new buildings in locations near essential amenities, thereby reducing the requirement for motorised travel and thus minimising the exposure of vulnerable/disadvantaged groups to inadequate air quality. This could be achieved by locating new homes for essential workers, schools, nurseries and care homes away from roads and avoiding the creation of configurations such as deep street canyons that encourage dangerous concentrations of air pollution to build up [44]. When air pollution limits are exceeded, local authorities need to act strategically to close or divert roads to reduce the volume of traffic, especially near schools and vulnerable communities. This of course can only be achieved by adequate, accurate and accessible air pollution monitoring programmes. Planting trees and the construction of green walls and roofs to create an organic barrier to intercept PM and absorb gaseous pollutants have had mixed results by either improving air quality or in fact worsening it by restricting street ventilation. That the absolute effect of urban greening

strategies will depend on factors such street configuration and canopy design means that the appropriate management of urban vegetation (siting, choice of species, maintenance regimes) is critical to maximise potential benefits [45]. With relevance to asthma, any beneficial and cost-effective to these greening strategies should avoid the use of highly allergenic plants. Failure to do so risks marginal gains in air quality being offset by a significant increased risk of exposure to known triggers of asthma exacerbations [46].

Getting Active

Compared to the growth in the volumes of road traffic in the UK over the last 60 years, active transport (walking and cycling) has been on the decline [5] despite its social, economic and health benefits [47–49]. Well-designed and maintained urban green spaces, coupled with fewer vehicles on the road to permit expanded safe cycle networks, wider pavements and other public areas (as discussed above) will create the much-needed opportunities for active travel. Additional mechanisms to promote a step change include mandatory cycle training at schools, cycle-to-work schemes and steps to support cyclists and pedestrians by, for example, providing a choice of routes to avoid highly polluted roads.

Beyond active transport to reach schools, higher education establishments and workplaces, the provision of pleasant and mixed-activity spaces will also encourage more exercise taken as a form of leisure. A marvellous exemplar is the infamous La Ciclovía in Bogotá that, every Sunday between 0700 and 1400 hours, hands 75 miles of its usually choking city streets over to over 1 million cyclists, skaters, walkers, runners and other athletes (Fig. 2) [50]. This much-loved programme began in 1974 as a citizen protest that the city was becoming too car-focused, and now attracts city-dwellers of all ages and social backgrounds who exercise alongside each other through the colourful neighbourhoods of Columbia’s capital city [51]. As one of the world’s most successful mass recreation events, it has become one of the



Fig. 2 Active streets during La Ciclovía in Bogotá

city's most famous exports. Ciclovías have sprung up in numerous South American countries as well as cities in Canada and the United States.

We need more Ciclovías around the world to provide a tangible vision of what a city with more cycle paths and fewer cars might look like, not just for weekly recreation, but also how cities could be designed and run differently. In addition, by truly embracing young children, they can create a generation that look at the street from a completely different perspective—one that feels like an extension of their driveway and is therefore a safe place for recreation in a dense urban metropolis. Promoting physical activity in car-free urban spaces is a double positive for asthmatics in reducing TRAP, increasing exercise and promoting healthier lifestyles and wellbeing. Evolving research suggests that structured exercise routines may help improve some aspects of asthma control. Indeed, results from several recent systematic reviews and meta-analyses not only strongly support the safety of structured exercise routines in children and adults with asthma, but also suggest such routines favour improvements in asthma symptoms and quality of life [52].

Indoor Spaces

Up until relatively recently, air pollution was invariably deemed to be solely an outdoor issue,

in the general belief that the confines of an inside space, and particularly one's home, offer protection. There are however unique factors which, when combined, have created challenges to indoor living: increased time spent indoors owing to dramatic changes in the lifestyle and working conditions of modern society [6]; the transition from natural (wooden floors and woolen carpets) to synthetic (synthetic floor coverings with added stain repellants and flame retardants) materials that have been introduced into indoor spaces [53]; the construction of energy-efficient—and with this, airtight—homes that lack inadequate ventilation and promote the buildup of air pollutants [54, 55]. In response to these trends and evidence that ill-health, including the severity and/or prevalence of asthma, is heightened by many indoor air pollutants, including NO_x from gas cooking [56], cleaning products [57], formaldehyde [58], phthalates [59], allergens [60], mould [61] and carbon monoxide [62], a set of recommendations from experts and young people have recently been published [6]. This welcome initiative provides wide-ranging advice for Government, local authorities, building and child healthcare professions and the public about the changes that are needed ensure that air quality in homes, nurseries and schools does not pose a health risk to children.

Scientific Research

There is clearly ample evidence to advocate for cleaner air for people with asthma, but since clear and objective scientific assessments are so crucially important to guide the development of evidence-based public health policies, there remains the need for further cross-disciplinary research into the respiratory health effects of air pollution, as well as the effectiveness of mitigation strategies. For example, the independent effects of NO₂ and PM are still unclear and need to be deciphered, especially at a time when uptake of electric vehicles is eliminating NO₂ emissions, with little or no impact on PM emissions from tyre and brake wear [63]. Another area of uncertainty is the potential of PM from biomass burning to contribute to asthma. This is especially pertinent in the light of the fashionable return of residential wood burning in Europe owing to aesthetic appeal and quest to reduce fossil fuel combustion [64]. Research themes applicable to indoor spaces that require greater scientific understanding include the benefits of indoor air filtration, placement of building air intake away from sources of air pollution and vegetative/physical barriers between roadways and homes and schools. Such areas of research will benefit from the considerable advances in mobile sensors that can be carried by individuals to monitor personal air pollutant exposure, as well by modeled-based approaches using big data. One such exemplar that is the Breathe London: Wearables study that provided 250 children and 33 teachers with wearable sensors to carry to and from school to characterise London's school children's exposure to air pollution [65]. Initiatives such as this one, which gathered 490 million measurements, create unique data sets to determine where children may be exposed to elevated concentrations and which forms of transport are more polluting, and to compare air quality within and surrounding schools. Validation studies are also reporting coherent epidemiological trends that support the use of smart phone application (app)-sourced data to examine relationships between asthma symptoms and air quality [66, 67]. These rapidly evolving technologies will enable estimates of

personal air pollution exposures for large populations—currently an elusive goal, but a central one to determine health impacts, evaluate exposure sources, detect susceptible populations and identify intervention opportunities.

Educate the Professionals

When individuals, especially vulnerable patients with respiratory problems such as asthma and chronic obstructive pulmonary disease, are exposed to such a well-established and preventable cause of ill health and premature death, our public health and healthcare professionals must have the knowledge to provide sound, evidence-based advice. This requires training about air quality and health risks and being equipped with toolkits to screen and identify at risk populations, raise public awareness, influence behavioural change, help prevent and/or control associated disease and take collective action to bring about positive change. Defining patient exposure to air pollution can be difficult since sources and composition vary between communities and within households. One way to open up knowledge and awareness would be for primary healthcare workers to simply pose pertinent questions to patients, alongside those already asked about diet, exercise, smoking and alcohol, and document the answers in medical records [68]. For indoor air pollution, asking what type of fuel is used for cooking and heating, how the home is ventilated and what sort of cleaning, do-it-yourself and personal care products are routinely used may provide important information to help gauge the extent of exposure and advise on lifestyle or products changes that can improve indoor air quality. An understanding of outdoor air pollution exposure requires clinicians to be equipped with reliable local air pollution data supplied by a reputable source, whilst questions to patients should focus on proximity of the household/workplace to urban or industrial environments, commuting practices, occupation and time spent near heavy traffic. Additional inquiries to provide a qualitative picture of exposure should focus on outdoor physical exertion (e.g. active transport

during commutes, manual work, exercising) and open-ended questions about air pollution in the local community to identify any sources of risk that may otherwise go undetected. Such a screening approach will allow clinicians to be better placed to design and discuss individual-tailored strategies. Recommendations to reduce exposure should always emphasize the importance of avoiding the pollutant source—the most effective intervention. They must also be practical and inexpensive and guard against negative behavioural patterns, such as healthy individuals avoiding outdoor exercise. Furthermore, recommendations must avoid advocating the use of inaccurate personal pollution-monitoring devices and any interventions designed to reduce air pollution exposure/the risk of adverse respiratory outcomes that are scientifically unproven. The public must also have access to engaging and high-quality educational materials in primary care and hospital settings. This will go some way in ensuring patients (including low-risk individuals) are better informed on this key issue.

As influential members of the community, healthcare workers have a particularly important role to play in advocating for cleaner and safer air on behalf of their patients and thereby advance the global effort to combat the adverse effects of air pollution. A hugely successful analogy is the effective anti-tobacco campaigns that facilitated the smoke-free legislation. The resulting health gains documented worldwide exceeded expectation, including a reduction in childhood and adult hospital admissions for asthma [69].

Raise Public Awareness

Outside of clinical settings, approaches to raise awareness of air quality where people, and especially susceptible individuals, congregate (e.g. bus stops, rail stations, shopping areas, etc.) are a crucial as a way of warning of the potential health risks. In an ideal world, people should also regularly check an air quality index (using traditional and social media) or a smart phone app before going to work or school or pursuing leisure activities, prompting them to

take action (reduce exposure and/or increase use of inhaled reliever medication) in the event of increased pollution [70]. Alert services accessed via apps are becoming increasingly informative and engaging by providing real-time data and proactively warning registered users of impending pollution events (Fig. 3) [71, 72]. These services also offer tailored advice on how specific groups can reduce emissions by, for example, providing low-pollution journey planners to reduce exposure. The Breathe London: Wearables study described earlier spans the scientific research/public awareness divide by introducing initiatives such the relatable presentation of collected data to participating school communities, science lessons and surveys/focus groups for children and parents to assess views and perceptions of air pollution [65].

CONCLUSIONS

To recap, we do not have a shortage of evidence to advocate for cleaner air for people with asthma. We know that air pollution is associated with the development and worsening of the condition and, importantly, since we are dealing with an avoidable health risk, mitigating interventions can result in prompt and substantial health gains. We also have a clear target, namely traffic emissions, especially in urban areas, and plenty of potential actions to safeguard the health of people of all ages. This is all good news. A crucial component to what remains is political will, guided by the science, since the recommendations discussed herein would need to be supported by a new Clean Air Act, based upon World Health Organisation health-based air quality limits, the adequacy of which are currently being revisited. However, deciding upon and executing the necessary policies is a complex challenge when it necessitates among other measures, a reduction in road traffic and a cleaner and greener element to what remains on the road—coupled to a heavy burden of expenditure. Policymakers are invariably torn between tightening controls on emissions to enhance health and succumbing to economic pressures not to reduce emissions.

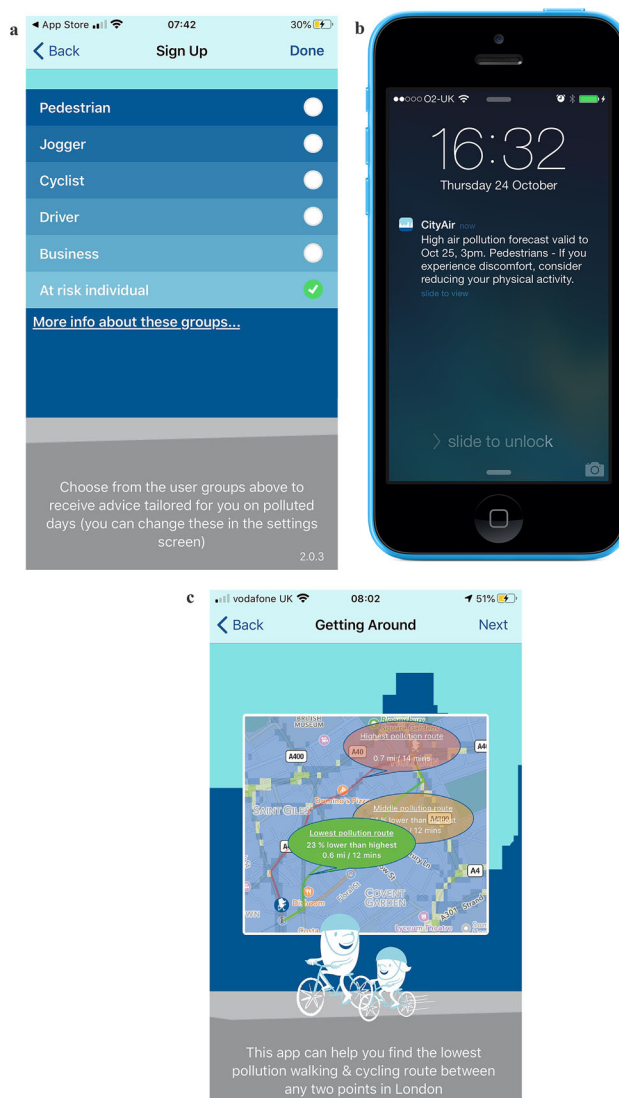


Fig. 3 CityAir smartphone app. The app shows: (1) advice tailored to specific user groups; (2) air pollution forecast; (3) low-pollution journey planners

Several actions in combination must however be taken since multiple measures, each producing a benefit of varying size, are likely to act cumulatively to produce significant change.

The response to the coronavirus disease 2019 (COVID-19) pandemic across the world, in the form of economic rescue packages, has however clearly demonstrated the power of governments and the speed at which they can act when the political will is there and when there is a shared sense of an emergency. We really need to hold onto this, and must guard against voices that

may say we need to de-regulate to get the economy going again in a non-sustainable way. In support, findings suggest that the pandemic and, specifically, imposed lockdown measures could result in behavioural changes and thus environmental improvements to benefit those living with asthma. It has clearly given people the opportunity to appreciate how much they depend on exercise in treasured green spaces. There are also glimmers of hope that reduced reliance on the car and increased active travel may emerge. In the UK, an AA-Populus poll

survey reported that one-fifth of drivers will use their cars less when restrictions are lifted [73]. Fear of contracting coronavirus on public transport has also led to a boom in cycle-to-work schemes, whilst demand for greater mobility and exercise amid lifestyle changes has also boosted bike sales across the UK [74]. Mindset shifts such as these should now be skilfully harnessed with realistic policies and effective measures. In turn, they must be taken forth with political courage and investment so that air pollution no longer contributes to the development or worsening of respiratory ill health.

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Compliance with Ethics Guidelines. This article is based on previously conducted studies and does not contain any new studies with

human participants or animals performed by any of the authors.

Data Availability. Data sharing is not applicable to this article, as no datasets were generated or analysed during the current study.

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