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HEALTH EFFECTS OF AMBIENT AIR POLLUTION AND HOW TO LIMIT PERSONAL EXPOSURE

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INTRODUCTION

Air pollution seems to be continuously in the news nowadays and popular media report on it almost every single day. In many cities worldwide, including London, UK, it has become a political topic as well.

Despite the fact that we hear about air pollution all of the time, many are unaware of the real nature or magnitude of the threat, the health risks and opportunities to reduce personal exposure.

In this article we summarise in lay terms the current knowledge about air pollution and what city dwellers can do to stay healthy in a polluted environment. This article aligns with a strategy to communicate scientific knowledge to patients, practitioners and the larger public. It complements the excellent work being done by the European Lung Foundation in the context of the “Healthy Lungs for Life” campaign (www.european-lung.org/en/projects-and-research/projects/healthy-lungs-for-life/home). In March 2016 the European Respiratory Society/European Lung Foundation hosted a workshop in Brussels (Belgium) to discuss the available evidence and derive clear messages. This article contributes to this initiative. We will summarise those facts that are undisputed and those for which there seems to be a broad consensus among scientists. Those facts can help us to derive strategies to avoid air pollution exposure.

GENERAL FACTS ABOUT AIR POLLUTION AND HEALTH

Air pollution is a mixture of different gases, tiny droplets and fine particles. Air pollution used to be very bad in European cities in the 20th century. After the 1930 Meuse valley disaster in Belgium and the infamous London Great Smog in 1952, measures were taken and concentrations (e.g. soot and sulfur dioxide) have dropped by several orders of magnitude since then [1].

Nevertheless, many recent scientific studies still find associations between exposure to air pollution and cardiovascular morbidity and mortality. This association is deemed causal. In other words inhalation of air pollution increases the risk of dying prematurely [2, 3].

Nowadays, the most important pollutants include ozone (O₃), nitrogen dioxide (NO₂) and fine particles (particulate matter with an aerodynamic cut-off diameter of 10 or 2.5 µm (PM₁₀ and PM_{2.5}) and black carbon). Exposure to air pollution can affect everyone, but it can be particularly harmful to people with a heart disease or a lung condition, elderly people and children. Air pollution also affects apparently healthy individuals. Because exposure to polluted air affects everyone and is not a free choice, it has a large and unacceptable impact on public health. The European Environment Agency states that 58 000 premature deaths

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can be avoided if the European Union Clean Air Policy Package is fully implemented by 2030 and this may result in health benefits with savings worth up to €40 billion.

Inhalation is by far the most important exposure route for air pollution. Particles that are smaller than a hundredth of a millimetre can enter the upper airways. Most are exhaled again, but some of the smallest particles can enter the lung alveoli, continue into the blood and some can even enter the nervous system [4]. Larger particles may be captured by the lining of the nose and throat and then swallowed.

Air pollution causes illness and increased mortality, mostly from effects on the heart and blood vessels, but air pollution inhalation is also associated with the onset and exacerbation of important respiratory illnesses such as lung cancer, chronic obstructive pulmonary disease, chronic bronchitis and asthma [5].

Even the lungs of otherwise healthy people can be affected. Growing up in the vicinity of major roads affects the development of the lungs in children and adolescents, which can result in important deficits in attained lung function in later life [6]. Exposure to ambient air pollution also affects lung function (forced vital capacity and forced expiratory volume in 1 s) in healthy adults, even at concentrations well below the current European Union limit (unpublished observations).

Although regulations have been effective in improving air quality over the past decades, there is still a significant health effect of long-term air pollution exposure. Therefore, further efforts should be made to avoid the remaining negative health effects.

EXPOSURE TO INDOOR AND TRAFFIC-RELATED AIR POLLUTION

Europe specifies limit values for several pollutants. These are levels of specific compounds that should not be exceeded on average (mostly over

1 year). This is verified by measuring those compounds (particles and gases) in official monitoring stations for outside air that are placed strategically near residential areas or industrial sources of air pollution.

While useful, this may not be sufficient to protect public health. First, the European limit values are considerably higher than the effect levels being found in epidemiological studies and higher than the values deemed safe by the World Health Organization (WHO). Secondly, most people spend the majority of their time indoors or at another location away from an official air pollution monitor. They are therefore exposed to concentrations other than ambient outdoor concentrations which are officially monitored [7, 8].

The recent advent of smaller, even portable, instruments to measure air pollution has greatly increased our understanding of air pollution exposure. Such devices used by lay people or in communities supported by scientists have brought the debate on air pollution closer to the public (figure 1).

For example, the MicroAeth (Aethlabs, San Francisco, CA, USA) draws ambient air over a filter and performs regular measurements to quantify the blackening of the filter (figure 1). The blackening of the filter

is then translated to “black carbon” concentrations. Black carbon is associated with cardiopulmonary diseases and is recognised by the WHO as a good indicator of traffic-related air pollution. When MicroAeth is used in combination with GPS, it is possible to derive very detailed exposure maps. In this respect, VITO (Mol, Belgium) has developed the airQmap platform (www.airqmap.be), which allows individuals with limited technical background to perform air quality measurements. The measurements are processed to air quality maps that provide a view on air quality in the city with street-level detail. This solution is being used in cities and municipalities and was used during the 2015 European Respiratory Society International Congress to create a healthy walking route in Amsterdam (the Netherlands). The MicroAeth is a professional device that performs at the highest scientific standards. In the meantime, a large variety of consumer products and apps are being developed and these products have the promise to make air quality measurements affordable for everyone. Unfortunately, at present, the reliability of these first generation devices is often questionable.

Local measurements of traffic-related pollutants and spatial



FIGURE 1. Local politicians, such as London Mayor Sadiq Khan (pictured), have used hand-held instruments (such as the MicroAeth; Aethlabs, San Francisco, CA, USA) to support their view on urban air pollution. Image credit: photographer Graeme Robertson/Guardian News & Media Ltd.

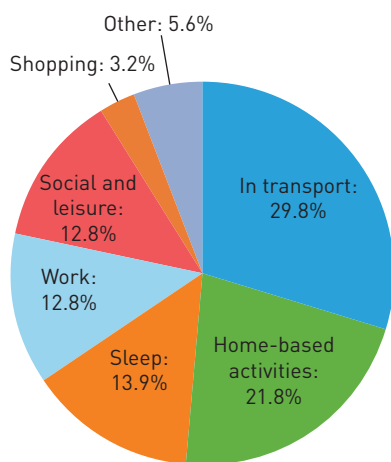


FIGURE 2. Data showing how much air pollution people are exposed to during a typical working day.

(land-use regression) modelling techniques have allowed researchers to discover clear associations with personal exposure to air pollutants in the case of childhood asthma. Individuals living along busy roads experience much higher exposures to traffic-related pollutants than people living only 50–100 m further away. Studies controlled for socioeconomic differences suggest that high levels of pollutants along streets play a key role in the start of asthma.

Because concentrations of traffic-related pollution are so different between nearby places, personal exposure (the concentrations encountered and the amount inhaled) depends, to a large extent, on time-activity pattern. Whereabouts and level of physical activity determine how much pollution you are exposed to. The amount inhaled at home is only a fraction of the total exposure (figure 2).

Traditional pollutants, such as PM_{10} and $PM_{2.5}$, come from many sources, including sources in other countries, and their concentrations are therefore much the same throughout the city. The situation is rather different for traffic-related air pollution. Nearly all of the smallest particles are emitted from cars and lorries driving on nearby roads. Many of those particles consist of carbon (and associated pollutants) and are visible as a black

smudge on the filters of portable air pollution measurement devices. Hence black carbon has quickly become a popular alternative measurement of air pollution. The health effects of these black carbon particles are potentially much higher than those of the general combination of larger (PM_{10} and $PM_{2.5}$) particles [9].

Tiny black carbon particles can readily enter houses and other buildings that are located next to busy roads or intersections. However, the concentration inside houses is not what determines exposure. More than 30% of the black carbon particles we breathe on a single day are inhaled while travelling. Levels of black carbon are higher while travelling in cars than in any other vehicle (figure 3) [10, 11]. Cyclists encounter high peak concentrations when sharing the road with motorised traffic. These peaks can be higher than those encountered in cars on the same route, but they only last for a few seconds at most. Conversely, cyclists actively avoid motorised traffic and choose quieter streets which reduces their overall exposure.

When cycling, respiratory rate increases and more air is breathed than when driving a car. In addition, while exercising people are more likely to breathe through the mouth. During exercise, inhaled particles of very small size can therefore deposit

deeper in the lungs [12]. When accounting for the increased inhalation while cycling or walking, the dose that pedestrians and cyclists inhale is always higher than the dose inhaled by people travelling in cars or on public transport [10, 13].

To date, it is unclear whether exposure to brief high peaks of air pollution is as unhealthy as an equivalent dose of pollution inhaled over a longer period of time. Brief exposure to traffic-related air pollution can trigger acute heart problems [14] and lower forced expiratory volume in 1 s in asthmatics [15]. Brief exposure of healthy cyclists to traffic-related air pollution also triggers a set of immediate subclinical physiological responses (increased white blood cells, exhaled nitric oxide, etc.). It is unclear whether such small changes in healthy cyclists eventually add up or lead to the more severe health problems seen in large epidemiological studies. Increased air pollution exposure during physical activity may also offset some of its health benefits [16–18]. Despite the above, there is a consensus that the protective health benefits of increased physical activity from cycling are much larger than the risks of air pollution, at least in European cities. In a landmark study, DE HARTOG *et al.* [19] concluded that a shift to

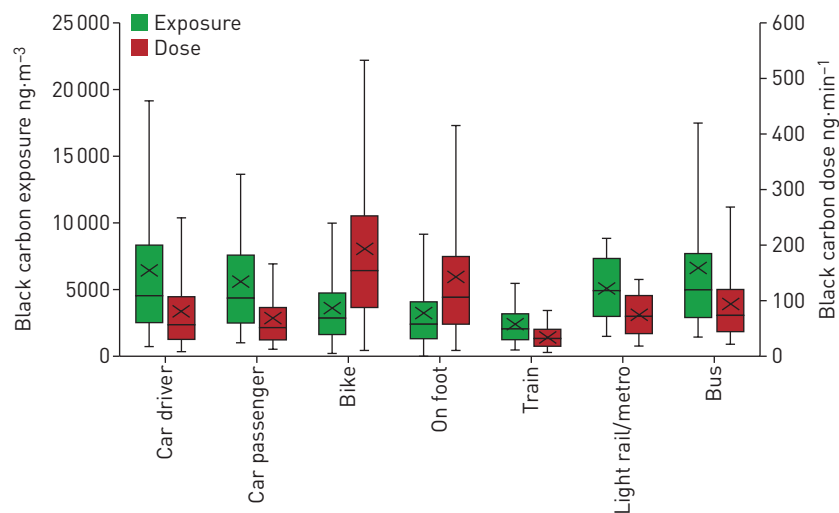


FIGURE 3. Personal exposure to and dose of black carbon for different modes of transport. Reproduced from [10] with permission from the publisher.

cycling would cause a loss of life of only 21 days because of increased air pollution exposure. Regular physical activity would add up to 8 months to the life of new cyclists. Hence, the benefits of regular physical activity clearly outweigh the negative effects of air pollution even when mortality was taken into account at primary endpoint. Despite initial scepticism, more recent studies including different illnesses and other assumptions have further corroborated this conclusion [20].

TENTATIVE GUIDELINES FOR INDIVIDUALS AND PRACTITIONERS TO IMPROVE HEALTH

From the current scientific knowledge it has become clear that current practice and legislation may not be sufficient to protect the general population against the negative effects of air pollution. Although it is still true that air pollution knows no boundaries, much of the most toxic air pollution comes from local sources. The levels of small particles and NO₂ can be very different between different places and at different times of the day. However, the health benefits of increasing physical activity are much larger than the risks of air pollution.

It is possible to derive two sets of guidelines that will allow people to improve their cardiovascular and respiratory health.

First, taking action to reduce personal exposure to air pollution. While there is no way of escaping all air pollution, the dose inhaled from the most toxic sources does depend on your personal behaviour, so: 1) avoid travelling by car during rush hour, on motorways and on busy roads; 2) avoid travelling by bike during smog episodes; 3) while travelling by bicycle avoid busy roads and rush hour; 4) choose quiet roads with safe infrastructure and cycle at normal speed; and 5) use apps that are designed to help policy makers

(<http://heatwalkingcycling.org> and <https://sites.google.com/site/cwicalc/> input) and commuters (<https://sites.google.com/site/bcintransport/>) in their decision about where or when to travel, including apps that plot the most healthy route.

Secondly, being physically active is also important for lung health, both for the general population and people living with chronic lung conditions [21]. Physical activity improves the condition of the heart and blood vessels. This can be walking, cycling, swimming, playing team sports, doing strength training or doing day-to-day activities such as gardening or cleaning, as long as it is enough to make you moderately breathless. Active mobility, walking or cycling to get around the city is a very convenient and cheap way to be sufficiently physically active and improve your quality of life.

It is very important to consider the impact of the air you exercise in. When you are physically active you breathe more air, and particles can penetrate deeper in the lungs. Therefore, if the air quality around you is poor, you may be exposed to more harmful pollutants that may reduce the benefits of exercise. Nevertheless, experts agree that the health risks associated with breathing in air pollution while exercising are smaller than those of an inactive lifestyle [22, 23]. Therefore adhere to the following. 1) Choose healthy travel options. Driving a car contributes to the air pollution problem. Preferably consider “taking the active option”, walking or cycling or use public transport. These options will help you to reach your desired daily physical activity levels and will contribute to a clean environment. 2) Avoid physical exercise during rush hour or smog warnings. The air tends to be cleaner after rainy or windy weather. 3) Avoid cycling near busy roads and intersections. Preferably use a quieter parallel road. 4) If you are exercising in the city, avoid dense urban areas. Preferably use trails, parks and public spaces within the low emission zones.

5) Exercise in green areas. Trees have a positive impact on air quality, but green space itself contributes to health and wellbeing.

CONCLUSION

There are still gaps in our knowledge on the health effects of air pollution and policy makers have not always been able to implement the strictest measures to protect the public from air pollution. Scientific studies will raise new questions and the final answer to solve all air pollution issues may never be known. This inherent uncertainty, especially in fast changing environments, has hampered the implementation of effective policies to protect public health. The good news is that scientific developments provide new opportunities. Improvements in portable measuring equipment have painted a much clearer picture of the local variation in air pollution. Individuals can use this information to actively avoid places and times characterised by high levels of local air pollution.

CONFLICT OF INTEREST

None declared.

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