



fighting heart disease
and stroke
european heart network

Air pollution and cardiovascular diseases – a European Heart Network paper

July 2017

Introduction

The aim of this paper is to provide information about the impact of air pollution on cardiovascular health; when we refer to air pollution, this is outdoor air pollution unless otherwise indicated. The paper presents recommendations to policy makers for action to reduce exposure to this risk factor. It does not provide information for cardiovascular patients on how to protect themselves from exposure. Many of our member organisations do provide such information and we refer readers to their websites.

Cardiovascular disease (CVD) – the main forms of which are coronary heart disease and stroke – accounts for 80% of all premature deaths from air pollution.¹ CVD is the main cause of death in Europe, accounting for over 3.9 million deaths annually, of which over 1.8 million deaths are in the EU.² CVD is also a major cause of disability. In Europe 85 million people live with CVD; of these almost 49 million live in the EU. CVD is a significant economic burden, estimated to cost the EU economy almost 210 billion euros every year.³

About the European Heart Network

The European Heart Network (EHN) is a Brussels-based alliance of heart foundations and other like-minded non-governmental organisations throughout Europe. EHN has members in 25 countries in Europe. EHN plays a leading role in the prevention and reduction of cardiovascular diseases, in particular heart disease and stroke, through advocacy, networking, capacity-building and patient support, so that they are no longer a major cause of premature death and disability throughout Europe.

¹ [Air quality in Europe — 2016 report](#), European Environment Agency 2016;

² Wilkins E, Wilson L, Wickramasinghe K, Bhatnagar P, Leal J, Luengo-Fernandez R, Burns R, Rayner M, Townsend N (2017). [European Cardiovascular Disease Statistics 2017](#). European Heart Network, Brussels.

³ Wilkins E, Wilson L, Wickramasinghe K, Bhatnagar P, Leal J, Luengo-Fernandez R, Burns R, Rayner M, Townsend N (2017). [European Cardiovascular Disease Statistics 2017](#). European Heart Network, Brussels.

Summary

Air pollution is the world's largest single environmental health risk⁴ and it is the number one environmental cause of death in Europe.⁵ Air pollution is linked to increased cardiovascular disease (CVD), hypertension, diabetes, and pulmonary diseases (e.g. asthma, lung cancer).

Coronary heart disease (CHD) and stroke are the most common reasons for premature death attributable to air pollution, accounting for 80% of cases of premature death in Europe – in other words more than 440 000 people die prematurely because of air pollution.⁶

Air pollution increases risk of:

- CHD
- heart failure
- cardiac arrhythmias and out of hospital cardiac arrests
- stroke
- thrombosis
- venous thromboembolism
- atherosclerosis

Air pollution from particulate matter_{2.5} alone increases the risk of premature death from stroke by 19%⁷ and from CHD by 13%.⁸

While harmful to everyone, avoiding exposure to air pollutants is especially important for susceptible individuals with chronic cardiovascular or pulmonary disease, children, and the elderly.⁹ Vulnerable groups suffer more than others because they live in deprived areas or live or learn or work near busy roads for example.¹⁰ It is possible for individuals to reduce their own exposure to air pollution, by staying indoors and limiting their activity when pollution levels are high. However, this carries a cost: from missed work and school to further health problems due to lack of exercise, and social isolation.¹¹

Measures such as action on early detection of CVD and urban planning measures (e.g. optimal design of cycle paths in relation to roads, or policy measures to promote electric and hybrid cars) play a role in reducing the effects of air pollution; but the largest benefits are to be expected from measures that reduce emissions.¹²

WHO guidelines on air pollution show that by taking the right policy measures to reduce particulate matter (PM₁₀), deaths from all diseases can be cut by 15% world-wide.¹³

⁴ http://www.who.int/phe/health_topics/outdoorair/databases/en/

⁵ http://ec.europa.eu/environment/air/index_en.htm

⁶ [Air quality in Europe — 2016 report](#), European Environment Agency 2016;

⁷ [Long-Term Exposure to Ambient Air Pollution and Incidence of Cerebrovascular Events: Results from 11 European Cohorts within the ESCAPE Project](#)

⁸ [Long term exposure to ambient air pollution and incidence of acute coronary events: prospective cohort study and meta-analysis in 11 European cohorts from the ESCAPE Project](#)

⁹ <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4311076/>

¹⁰ Royal College of Physicians. [Every breath we take: the lifelong impact of air pollution](#). Report of a working party. London: RCP, 2016

¹¹ Royal College of Physicians. [Every breath we take: the lifelong impact of air pollution](#). Report of a working party. London: RCP, 2016

¹² [Economic cost of the health impact of air pollution in Europe](#), WHO European Union and OECD research paper

¹³ [WHO air quality guidelines, global update 2005](#)

The health problems resulting from exposure to air pollution have considerable economic impact, increasing health care costs and reducing productivity through working days lost and premature death.¹⁴

Notwithstanding relative progress in Europe in terms of reducing air pollution, which has led to a decrease in premature mortality from air pollution (of about 12% between 2005 and 2010)¹⁵, efforts to further reduce air pollution must be increased. Policy measures must address emission sources as well as air concentrations and include pricing, investments, and regulatory measures.¹⁶

EHN recommendations:

- Clean air needs to be promoted and incentivised across all policy areas, including in the area of urban planning. It also needs to be part of the framework of a comprehensive EU strategy for the prevention and control of chronic diseases.
- EU must bring forward robust legislation tackling ambient air concentrations to protect health, cut healthcare costs and save lives; to that end EU should revise the ambient air quality directive and adopt the WHO Air Quality Guideline values as Limit Values.
- EU Member States must fulfil their obligations and ensure compliance with EU legislation; they should drastically increase their efforts to achieve better national emission targets, including pricing, investments, and regulatory measures; and perform a health impact assessment for new policy developments, in particular for urban planning.

¹⁴ http://ec.europa.eu/environment/archives/air/pdf/Impact_assessment_en.pdf

¹⁵ [Economic cost of the health impact of air pollution in Europe](#), WHO European Union and OECD research paper

¹⁶ [Economic cost of the health impact of air pollution in Europe](#), WHO European Union and OECD research paper

What is air pollution?

Almost all economic and societal activities produce air pollutants in one form or another. Road transport, industry, power plants, households and agricultural activities continue to emit significant amounts of air pollution.

Main sources of air pollution are: particulate matter (PM), ozone pollution (O₃), carbon monoxide (CO), lead (Pb), Nitrogen dioxide NO₂, Volatile organic compounds (VOC) and sulphur dioxide (SO₂).^{17,18}

Particulate matter is the sum of all microscopic solid and liquid particles, of human and natural origin, that remain suspended in a medium such as air for some time. Particulate matter may be in the form of fly ash, soot, dust, fog, fumes. These particles vary greatly in size, composition, and origin; they are the main cause of heart disease related to air pollution. Based on the size of their aerodynamic diameter particles, they can be classified as PM₁₀ (coarse and fine particles), PM_{2.5} (fine particles) or PM_{0.1} (ultrafine particles). Long term exposure and incidence of acute coronary events has been shown in a prospective cohort study and meta-analysis in 11 European cohorts from the ESCAPE Project and this association persists at levels of exposure below the current European limit values.¹⁹ Researchers also found suggestive evidence of an association between fine particles and incidence of cerebrovascular events in Europe, even at lower concentrations than those set by the current air quality limit value.²⁰

Ozone pollution (O₃) has been recognised since the 1950s as the principal component of photochemical smog and tends to be greatest on warm, sunny days.²¹ Ground-level ozone, known for years to worsen lung disease, may also trigger heart attacks and strokes in susceptible people.²²

Carbon monoxide (CO) is a product of incomplete combustion of carbon-containing fuels. In some situations (e.g. insufficiently ventilated parking structures), CO can attain concentrations sufficient to lead to physiologically meaningful increases in carboxyhaemoglobin in persons with significant atherosclerotic disease or other cardiac conditions.²³

Nitrogen Oxides (NO, NO₂, 4, 5, x). The main source of NO in ambient air is fossil fuel combustion in motor vehicles and industrial processes, particularly in power generation. NO react with ammonia, moisture, and other compounds to form small particles.²⁴ These small particles can aggravate existing heart disease, leading to increased hospital admissions and premature death.²⁵

¹⁷ Mills NL, Donaldson K, Hadoke PW, Boon NA, MacNee W, Cassee FR, Sandstrom T, Blomberg A, Newby DE. [Adverse cardiovascular effects of air pollution](#). Nat Clin Pract Cardiovasc Med 2009;6:36–44.

¹⁸ Uzoigwe JC, Prum T, Bresnahan E, Garelnabi M. [The emerging role of outdoor and indoor air pollution in cardiovascular disease](#). N Am J Med Sci 2013;5:445–453.

¹⁹ [Long term exposure to ambient air pollution and incidence of acute coronary events: prospective cohort study and meta-analysis in 11 European cohorts from the ESCAPE Project](#)

²⁰ [Long-Term Exposure to Ambient Air Pollution and Incidence of Cerebrovascular Events: Results from 11 European Cohorts within the ESCAPE Project](#)

²¹ [Air Pollution and Cardiovascular Disease](#), American Heart Association, Circulation.2004;109:2655-2671.

²² Diane R. Gold, MD, MPH, DTM&H; Jonathan M. Samet, MD, MS; [Air Pollution, Climate, and Heart Disease](#); Circulation. 2013;128:e411-e414

²³ [Air Pollution and Cardiovascular Disease](#), American Heart Association, Circulation.2004;109:2655-2671.

²⁴ [Air Pollution and Cardiovascular Disease](#), American Heart Association, Circulation.2004;109:2655-2671

²⁵ <https://www.epa.gov/airquality/nitrogenoxides/health.html>

Sulphur Dioxide (SO₂). In ambient air, the principal sources of SO₂ include combustion of sulphur-containing fuels, especially in power plants and diesel engines (prior to the reformulation of diesel fuels), and roasting of metal sulfide ores.²⁶ Hospital admissions for cardiac disease and mortality increase on days with higher sulphur dioxide levels.²⁷

Volatile organic compounds (VOC) are a class of chemical compounds whose molecules contain carbon. Concentrations of many VOCs are found both indoors and outdoors; they are consistently higher indoors (up to ten times higher) than outdoors. They are found in household products, including paints, paint strippers, wood preservatives, aerosol sprays, cleansers and disinfectants, moth repellents and air fresheners, dry-cleaned clothing, pesticide.²⁸

This paper has a main focus on outdoor air pollution. However, indoor air pollution should not be ignored. Health effects from indoor air pollutants may be experienced soon after exposure. Other health effects (including coronary heart disease, cancer and some respiratory diseases,) may show up either years after exposure has occurred or only after long or repeated periods of exposure.

Understanding and controlling both indoor and outdoor pollutants can help reduce the risk of health concerns.

General health effects of air pollution

Air pollution is the world's largest single environmental health risk²⁹ and it is the number one environmental cause of death in the EU. It is linked to increased cardiovascular disease (CVD), hypertension, diabetes, and pulmonary diseases (e.g. asthma, lung cancer).

In terms of harm to human health, the most problematic pollutants are PM, O₃ and NO₂. Estimates of health impacts attributable to exposure to air pollution indicate that PM_{2.5} concentrations in 2013 were responsible for about 467 000 premature deaths originating from long-term exposure in Europe (over 41 countries), of which around 436 000 were in the EU-28. In the same year, the estimated impact of exposure to NO₂ (long-term exposure) and O₃ (short-term exposure) concentrations on the population, in the same 41 European countries, was around 71 000 and 17 000 premature deaths, respectively, and around 68 000 and 16 000 premature deaths, respectively, in the EU-28³⁰ (for a breakdown per country, see table in annex).

The overall absolute risk for mortality due to PM exposure is greater for cardiovascular than pulmonary diseases after both short- and long-term exposures. Even if similar acute relative risk elevations are estimated between cardiovascular and pulmonary mortality, CVD account for 69% of the increase in absolute mortality rates compared with 28% for pulmonary diseases attributable to short-term PM exposure.³¹

²⁶ [Air Pollution and Cardiovascular Disease](#), American Heart Association, Circulation.2004;109:2655-2671.

²⁷ World Health Organization. Fact sheet 313: [Ambient \(outdoor\) air quality and health](#). Latest update September 2016

²⁸ <https://www.epa.gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality>

²⁹ http://www.who.int/phe/health_topics/outdoorair/databases/en/

³⁰ [Air quality in Europe — 2016 report](#), European Environment Agency 2016;

³¹ Brook RD, Rajagopalan S, Pope CA 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, Holguin F, Hong Y, Luepker RV, Mittleman MA, Peters A, Siscovick D, Smith SC Jr, Whitsel L, Kaufman JD; on behalf of the American Heart Association

Air pollution is harmful to everyone, but avoiding exposure to air pollutants is especially important for susceptible individuals with chronic cardiovascular or pulmonary disease, children and the elderly.³² Moreover, some people suffer more than others because they live in deprived areas, which often have higher levels of air pollution, or they live, learn or work near busy roads, or they are more vulnerable because of their age or existing medical conditions.³³

Measures such as action on early detection of CVD and urban planning measures (e.g. optimal design of cycle paths in relation to roads, or policy measures to promote electric and hybrid cars) play a role in reducing the effects of air pollution; but the largest benefits are to be expected from measures that reduce emissions.³⁴

WHO guidelines on air pollution show that by taking the right policy measures to reduce particulate matter (PM₁₀), deaths from all diseases can be cut by 15% world-wide.³⁵

The health problems resulting from exposure to air pollution have considerable economic impact increasing medical costs and reducing productivity through working days lost and premature death. The health-related external costs due to air pollution are estimated to range between euros 330 and 940 billion per year in the EU (2010 figures).³⁶ These costs include the impact of ill-health on those citizens who experience it, but also the direct cost to the economy.

Effects of air pollution on cardiovascular health

Coronary heart disease (CHD) and stroke account for 80% of premature death attributable to air pollution, which makes it the most common cause of premature death from air pollution in Europe.³⁷

According to the *Air quality in Europe – 2016 report* this translates into 444 000 people dying prematurely from CHD and stroke due to air pollution (in the 41 European countries covered by the report); and, in the EU, 416 000 people die prematurely from CHD and stroke because of air pollution (2013 figures).

The mechanisms by which air pollution causes cardiovascular disease are thought to be the same as those responsible for respiratory disease: pulmonary inflammation and oxidative stress.³⁸

Council on Epidemiology and Prevention, Council on the Kidney in Cardiovascular Disease, and Council on Nutrition, Physical Activity and Metabolism. [Particulate matter air pollution and cardiovascular disease: an update to the scientific statement from the American Heart Association](#). *Circulation*. 2010;121:2331–2378

³² <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4311076/>

³³ Royal College of Physicians. [Every breath we take: the lifelong impact of air pollution](#). Report of a working party. London: RCP, 2016

³⁴ [Economic cost of the health impact of air pollution in Europe](#), WHO European Union and OECD research paper

³⁵ [WHO air quality guidelines, global update 2005](#): <http://www.who.int/mediacentre/news/releases/2006/pr52/en/>

³⁶ http://ec.europa.eu/environment/archives/air/pdf/Impact_assessment_en.pdf

³⁷ [Air quality in Europe — 2016 report](#), European Environment Agency 2016

³⁸ Physicians for Social Responsibility, [How air pollution contributes to Heart Disease](#)

Ongoing exposure to air pollution provides a scenario where chronic low-level inflammation can arise in the lungs. During exposure to airborne pollutants, the normal phagocytes of the lung surfaces and, to an extent, the epithelial cells generate oxygen radicals and can become oxidatively stressed. Oxidative stress occurs when there is increased production of oxidising species in cells and tissues, such as mediated by NADPH oxidase, or a significant decrease in the effectiveness of antioxidant defences: air pollution causes oxidative stress via both of these pathways.³⁹

The increase in risk for acute PM_{2.5}-associated cardiovascular morbidity and mortality is principally among susceptible, but not necessarily critically ill, individuals. Several studies suggest that susceptible individuals at greater risk may include the elderly, patients with pre-existing coronary artery disease, and perhaps those with diabetes.⁴⁰ Obese individuals (and/or those with the metabolic syndrome) may be a susceptible population at greater risk for cardiovascular events due to PM_{2.5} exposure. This is a tremendously important public health issue to corroborate because of the high and growing prevalence of obesity worldwide.⁴¹

A 5 µg/m³ increase in estimated annual mean PM_{2.5} is associated with a 13% increased risk of coronary events⁴² and a 19% increased risk of cerebrovascular events.⁴³

Short-term health effects

Many studies on the effects of acute air pollution exposure have shown increases in short-term mortality rates, hospital admissions and emergency room visits; and symptom exacerbations have been shown to increase in relation to variations in air pollution levels (time-series studies).⁴⁴ Direct associations have also been identified with respect to incidence of coronary heart disease, arrhythmias and heart failure.⁴⁵

Studies have also shown that short-term elevations in ambient particle levels are capable of evoking cardiac arrhythmias, worsening heart failure, and triggering acute atherosclerotic/ischaemic cardiovascular complications.⁴⁶ PM_{2.5} generally has been associated with increased risks of myocardial infarction, stroke, arrhythmia, and heart failure exacerbation within hours to days of exposure in susceptible individuals.⁴⁷ Several studies

³⁹ [ESC Expert position paper on air pollution and cardiovascular disease](#), European Heart Journal (2015) 36, 83–93

⁴⁰ Brook RD, Rajagopalan S, Pope CA 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, Holguin F, Hong Y, Luepker RV, Mittleman MA, Peters A, Siscovick D, Smith SC Jr, Whitsel L, Kaufman JD; on behalf of the American Heart Association Council on Epidemiology and Prevention, Council on the Kidney in Cardiovascular Disease, and Council on Nutrition, Physical Activity and Metabolism. [Particulate matter air pollution and cardiovascular disease: an update to the scientific statement from the American Heart Association](#). Circulation. 2010;121:2331–2378.

⁴¹ Brook RD, Rajagopalan S, Pope CA 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, Holguin F, Hong Y, Luepker RV, Mittleman MA, Peters A, Siscovick D, Smith SC Jr, Whitsel L, Kaufman JD; on behalf of the American Heart Association Council on Epidemiology and Prevention, Council on the Kidney in Cardiovascular Disease, and Council on Nutrition, Physical Activity and Metabolism. [Particulate matter air pollution and cardiovascular disease: an update to the scientific statement from the American Heart Association](#). Circulation. 2010;121:2331–2378

⁴² [Long term exposure to ambient air pollution and incidence of acute coronary events: prospective cohort study and meta-analysis in 11 European cohorts from the ESCAPE Project](#)

⁴³ [Long-Term Exposure to Ambient Air Pollution and Incidence of Cerebrovascular Events: Results from 11 European Cohorts within the ESCAPE Project](#)

⁴⁴ [Air Pollution and Cardiovascular Disease](#), American Heart Association, Circulation.2004;109:2655–2671.

⁴⁵ Hoek G, Brunekreef B, Fischer P, et al. [The association between air pollution and heart failure, arrhythmia, embolism, thrombosis, and other cardiovascular causes of death in a time series study](#). Epidemiology. 2001;12:355–357.

⁴⁶ [Air Pollution and Cardiovascular Disease](#), American Heart Association, Circulation.2004;109:2655–2671.

⁴⁷ Brook RD, Rajagopalan S, Pope CA 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, Holguin F, Hong Y, Luepker RV, Mittleman MA, Peters A, Siscovick D, Smith SC Jr, Whitsel L, Kaufman JD; on behalf of the American Heart Association Council on Epidemiology and Prevention, Council on the Kidney in Cardiovascular Disease, and Council on Nutrition,

have also demonstrated that residing in locations with higher long-term average PM levels elevates the risk for cardiovascular morbidity and mortality.⁴⁸

Long-term health effects

There are fewer studies examining the long-term health effects of air pollution than studies on short-term health effects. The first large, prospective cohort study that demonstrated an adverse health impact of long-term air pollution exposure was the Harvard Six Cities study by Dockery et al.⁴⁹ This study demonstrated that chronic exposure to air pollutants is independently related to cardiovascular mortality.⁵⁰ Other studies have confirmed that long-term exposure to air pollution increases an individual's lifetime risk of death from coronary heart disease.⁵¹ Most studies support the idea that longer-term PM_{2.5} exposures increase the risk for cardiovascular mortality to an even greater extent than short-term exposures. Because most studies have focused on mortality data, the effect of long-term exposures on nonfatal cardiovascular events is less consistent and requires more investigation.⁵²

Specific impacts

In 2015, the European Society of Cardiology (ESC) published an expert position paper on air pollution and cardiovascular diseases.⁵³ The information in the box below is based on that paper (unless otherwise indicated). For more details, we refer to the ESC expert position paper.

- **Air pollution and Coronary Heart Disease**

The majority of cohort studies in diverse populations link long-term exposure to air pollution with an increased risk of incident fatal or non-fatal coronary artery disease. There seems to be strong support to the hypothesis that chronic exposure to air pollution influences the development of atherosclerosis and increases the risk for coronary heart disease.⁵⁴

Physical Activity and Metabolism. [Particulate matter air pollution and cardiovascular disease: an update to the scientific statement from the American Heart Association](#). *Circulation*. 2010;121:2331–2378.

⁴⁸ Brook RD, Rajagopalan S, Pope CA 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, Holguin F, Hong Y, Luepker RV, Mittleman MA, Peters A, Siscovick D, Smith SC Jr, Whitsel L, Kaufman JD; on behalf of the American Heart Association Council on Epidemiology and Prevention, Council on the Kidney in Cardiovascular Disease, and Council on Nutrition, Physical Activity and Metabolism. [Particulate matter air pollution and cardiovascular disease: an update to the scientific statement from the American Heart Association](#). 2010;121:2331–2378

⁴⁹ Dockery DW, Pope CA, Xu X, et al. [An association between air pollution and mortality in six US cities](#). *N Engl J Med*. 1993;329: 1753–1759.

⁵⁰ [Air Pollution and Cardiovascular Disease](#). American Heart Association, *Circulation*.2004;109:2655-2671

⁵¹ Mills NL, Donaldson K, Hadoke PW, Boon NA, MacNee W, Cassee FR, Sandstrom T, Blomberg A, Newby DE. [Adverse cardiovascular effects of air pollution](#). *Nat Clin Pract Cardiovasc Med* 2009;6:36–44

⁵² Brook RD, Rajagopalan S, Pope CA 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, Holguin F, Hong Y, Luepker RV, Mittleman MA, Peters A, Siscovick D, Smith SC Jr, Whitsel L, Kaufman JD; on behalf of the American Heart Association Council on Epidemiology and Prevention, Council on the Kidney in Cardiovascular Disease, and Council on Nutrition, Physical Activity and Metabolism. [Particulate matter air pollution and cardiovascular disease: an update to the scientific statement from the American Heart Association](#). 2010;121:2331–2378.

⁵³ [ESC Expert position paper on air pollution and cardiovascular disease](#), *European Heart Journal* (2015) 36, 83–93

⁵⁴ [Long term exposure to ambient air pollution and incidence of acute coronary events: prospective cohort study and meta-analysis in 11 European cohorts from the ESCAPE Project](#)

- **Air pollution and heart failure**

A systematic review⁵⁵ and meta-analysis of the current evidence of the association between air pollution and heart failure showed a positive association between short-term increases in gaseous components (CO, SO₂ and NO₂) and PM with the risk of hospitalisation or death from congestive heart failure.

- **Air pollution and cardiac arrhythmias and out of hospital cardiac arrests**

The current evidence suggests that air pollution may have a weak direct effect on ventricular arrhythmogenesis.

- **Air pollution and cerebrovascular disease stroke**

The ESCAPE⁵⁶ study found a 19% (21–62%) increased risk of stroke per 5 mg/m³ increase in PM_{2.5} in nearly 100 000 participants from 11 cohorts across Europe. Higher risk was especially seen in subjects above age 60 and in non-smokers and was consistently observed at PM_{2.5} concentrations below 25 mg/m³. All in all, there is need for systematic assessment of the evidence for the role of air pollution in cerebrovascular disease stroke.

- **Air pollution and thrombosis**

Short-term associations between PM exposure and cardiovascular mortality suggest a rapidly inducible effector pathway such as thrombogenicity. Exposure to traffic has been linked to triggering of myocardial infarction within hours.^{57,58}

- **Air pollution and venous thromboembolism**

The relationship between chronic exposure to ambient air pollution and venous thromboembolism is uncertain.

- **Air pollution and atherosclerosis**

Positive association between PM_{2.5} exposures and atherosclerotic burden maybe important and support a biological relationship between air pollution exposure and atherosclerosis.

- **Air pollution and systemic vascular dysfunction**

Observational studies suggest that exposure to air pollution may increase blood pressure, exacerbate myocardial ischaemia, and trigger myocardial infarction.⁵⁹ Many

⁵⁵ Shah ASV, Langrish JP, Nair H, McAllister DA, Hunter AL, Donaldson K, Newby DE, Mills NL. [Global association of air pollution and heart failure: a systematic review and meta-analysis](#). Lancet 2013;382:1039–1048

⁵⁶ [Long-Term Exposure to Ambient Air Pollution and Incidence of Cerebrovascular Events: Results from 11 European Cohorts within the ESCAPE Project](#)

⁵⁷ Peters A, von Klot S, Mittleman MA, Meisinger C, Hoffmann A, Kuch B, Wichmann HE. [Triggering of acute myocardial infarction by different means of transportation](#). Eur J Prev Cardiol 2013;20:750–758.

⁵⁸ RichDQ, Kipen HM, Zhang J, Kamat L, WilsonAC, Kostis JB. [Triggering of transmural infarctions, but not nontransmural infarctions, by ambient fine particles](#). Environ Health Perspect 2011;118:1229–1234.

of these effects may be mediated through direct or indirect effects on the systemic vasculature. PM is considered to be the primary mediator of systemic vascular dysfunction.⁶⁰

Policy and regulatory frameworks on air pollution

Individuals can reduce their own exposure to air pollution, but this comes at a high convenience price. Particularly, vulnerable people become prisoners of air pollution, having to stay indoors, missing work and school, from more health problems due to lack of exercise, and from social isolation.⁶¹ Sources of air pollution are well beyond the control of individuals and demand action by cities (urban planning), as well as national and international policymakers in sectors like transport, energy waste management, buildings and agriculture.

Notwithstanding relative progress in Europe in terms of reducing air pollution, which has led to a decrease in premature mortality from air pollution (about 12% between 2005 and 2010), and which has largely followed in the wake of regulatory intervention across relevant sectors within the EU⁶², efforts to further reduce air pollution must be increased.

WHO Air quality guidelines

In 2005, WHO published "WHO Air quality guidelines"⁶³ which set global guidance on thresholds and limits for key air pollutants that pose health risks. The Guidelines indicate amongst other things that by reducing particulate matter (PM₁₀) pollution from 70 to 20 micrograms per cubic metre ($\mu\text{g}/\text{m}^3$), air pollution-related deaths can be cut by around 15%. The Guidelines apply worldwide and are based on expert evaluation of current scientific evidence for:

- particulate matter (PM)
 - limits for PM_{2.5}: $10\mu\text{g}/\text{m}^3$ annual mean; $25\mu\text{g}/\text{m}^3$ 24-hour mean
 - limits for PM₁₀: $20\mu\text{g}/\text{m}^3$ annual mean; $50\mu\text{g}/\text{m}^3$ 24-hour mean
- ozone (O₃): $100\mu\text{g}/\text{m}^3$ 8-hour mean
- nitrogen dioxide (NO₂): $40\mu\text{g}/\text{m}^3$ annual mean; $200\mu\text{g}/\text{m}^3$ 1-hour mean
- sulphur dioxide (SO₂): $20\mu\text{g}/\text{m}^3$ 24-hour mean; $500\mu\text{g}/\text{m}^3$ 10-minute mean

⁵⁹ Mills NL, Donaldson K, Hadoke PW, Boon NA, MacNee W, Cassee FR, Sandstrom T, Blomberg A, Newby DE. [Adverse cardiovascular effects of air pollution](#). Nat Clin Pract Cardiovasc Med 2009;6:36–44.

⁶⁰ Mills NL, Miller MR, Lucking AJ, Beveridge J, Flint L, Boere AJ, Fokkens PH, Boon NA, Sandstrom T, Blomberg A, Duffin R, Donaldson K, Hadoke PW, Cassee FR, Newby DE. [Combustion-derived nanoparticulate induces the adverse vascular effects of diesel exhaust inhalation](#). Eur Heart J 2011;32:2660–2671.

⁶¹ Royal College of Physicians. [Every breath we take: the lifelong impact of air pollution](#). Report of a working party. London: RCP, 2016

⁶² [Economic cost of the health impact of air pollution in Europe](#). WHO European Union and OECD research paper

⁶³ http://www.who.int/phe/health_topics/outdoorair/outdoorair_aqg/en/

The European Union (EU)

The EU has two major Directives on air pollution:

- The Directive on ambient air quality⁶⁴ and cleaner air for Europe, which regulates concentrations of air pollutants
- The National Emissions Ceilings Directive which sets maximum limits for six main pollutants. The NEC directive is part of the Clean Air Policy package.⁶⁵

Apart from these two Directives (focusing on *total quantity of air pollutants*), the EU has also developed legislation which sets rules for different *sources of air polluters* (e.g., large combustion plants, waste incineration plants, pollutant emissions from ships), irrespective of the air pollutant that is produced. This note focuses on legislation on air pollutants.

Directive on ambient air quality and cleaner air for Europe

This Directive regulates ambient air concentrations of ambient air of SO₂, NO₂ and other nitrogen oxides, particulate matters PM₁₀ and PM_{2.5}, and O₃ amongst others. It aims to prevent or reduce the harmful effects of air pollutants on human health and the environment by implementing limit or target values for ambient concentrations of air pollutants. The norms used are less strict than those set in the WHO guidelines

- Limits for particulate matter
 - PM_{2.5} exposure: 20 µg/m³ in urban areas and below 25 µg/m³ on the whole territory of every EU member state.
 - Limits for PM₁₀ exposure: 40 µg /m³ annual mean; 50µg/m³ 24-hour mean not to be exceeded more than 35 times a year.
- Limits for O₃: 120 µg/ m³ 8-hour mean, not to be exceeded on more than 25 days per calendar year averaged over three years.
- Limits for NO₂: 40µg/m³ annual mean; 200 µg/m³ hour mean, not to be exceeded more than 18 times a calendar year
- Limits sulphur dioxide (SO₂): 350 µg/m³ per hour, not to be exceeded more than 24 times per calendar year. Daily limit value: 125 µg/m³, not to be exceeded more than 3 times per calendar year

National Emissions Ceilings Directive

The current National Emission Ceilings Directive (2001/81/EC) dates from 2001 and sets emission limits that EU Member States must respect. The Commission adopted its new draft proposal on reduction of national emissions of certain atmospheric pollutants in 2013. This text sets national emission reduction commitments (expressed in %) for each EU member state for sulphur dioxide (SO₂), nitrogen oxides (NOX), non-methane volatile organic compounds (NMVOC) and ammonia (NH₃).

The new proposal for a directive is part of the clean air policy package, which updates existing legislation controlling harmful emissions from industry, traffic, energy plants and

⁶⁴ <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:en:PDF>

⁶⁵ http://ec.europa.eu/environment/air/clean_air_policy.htm

agriculture, with a view to reducing their impact on human health and the environment. The clean air package has three components:

- a new clean air programme for the EU, with measures to ensure that existing targets are met in the short term, and to set new air quality objectives for the period up to 2030
- the proposal for the National Emissions Ceilings Directive (NEC), and
- a Directive adopted in 2015⁶⁶ to reduce pollution from medium-sized combustion installations of between 1 thermal megawatt (MWth) and 50 MWth, such as energy plants for street blocks or large buildings, and small industrial installations

After several negotiation rounds, the European Parliament approved the revised NEC directive on 25 November 2016. This was followed by a formal adoption by the Council on 14 December 2016. The new directive entered into force on 31 December 2016.⁶⁷

The updated NEC directive sets air pollution limits that are expected to halve the health impact of air pollution by 2030, compared to 2005 levels. But this is far from sufficient: even after full implementation of the directive in 2030, around 250 000 Europeans are still likely to die prematurely because of air pollution every year. The new Directive has stricter national emission ceilings for five main pollutants (sulphur dioxide (SO₂), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), ammonia (NH₃) and fine particulate matter (PM_{2,5}), as well as provisions on black carbon. The new limits are not as strict as the norms set by the WHO. The list of national emission ceilings for each country is included in the annex to the directive and can be [consulted here](#).

Member States will now have to develop air pollution plans demonstrating how they will achieve the new limits. These plans will have to be updated regularly and are subject to public consultations.

There is no dedicated EU legislation on indoor air quality. The need for a horizontal policy framework which bridges safety, health, energy efficiency and sustainability aspects across existing legislative instruments and standardisation activities related to the built environment is widely recognised.⁶⁸

Conclusions and recommendations

There is a substantial body of evidence that air pollution contributes to premature death from cardiovascular diseases: air pollution from PM_{2,5} alone leads to a 19% increased risk of stroke⁶⁹ and a 13% increased risk of CHD⁷⁰. Air pollution is also a risk factor for other major diseases such as respiratory diseases and cancer and it imposes significant health-related costs on societies across Europe.

⁶⁶ <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L2193&from=EN>

⁶⁷ <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016L2284&from=EN>

⁶⁸ [Environment and human health: joint EEA-JRC report 2013](#);

⁶⁹ [Long-Term Exposure to Ambient Air Pollution and Incidence of Cerebrovascular Events: Results from 11 European Cohorts within the ESCAPE Project](#)

⁷⁰ [Long term exposure to ambient air pollution and incidence of acute coronary events: prospective cohort study and meta-analysis in 11 European cohorts from the ESCAPE Project](#)

Individuals can reduce their own exposure to air pollution, but this comes at a high convenience price. Particularly, vulnerable people become prisoners of air pollution, having to stay indoors, missing work and school, from more health problems due to lack of exercise, and from social isolation.⁷¹

The largest benefits are to be expected from measures that reduce emissions.⁷² Addressing air pollution at source is well beyond the control of individuals and demands action by policymakers.

Notwithstanding relative progress in Europe in terms of reducing air pollution leading to a decrease in premature mortality of about 12%⁷³, efforts to further reduce air pollution must be increased. Policy measure must address emission sources as well as air concentrations and include pricing, investments, and regulatory measures.⁷⁴

To help fight CVD, EHN recommends:

- Clean air needs to be promoted and incentivised across all policy areas, including within the framework of a comprehensive EU strategy for the prevention and control of chronic diseases.
- EU must bring forward robust legislation tackling ambient air concentrations to protect health, cut healthcare costs and save lives; to that end EU should revise the ambient air quality Directive and adopt the WHO Air Quality Guideline values as Limit Values.
- EU Member States must fulfil their obligations and ensure compliance with EU legislation; they should drastically increase their efforts to achieve better national emission targets, including pricing, investments, and regulatory measures; and perform a health impact assessment for new policy developments, in particular for urban planning.

⁷¹ Royal College of Physicians. [Every breath we take: the lifelong impact of air pollution](#). Report of a working party. London: RCP, 2016

⁷² [Economic cost of the health impact of air pollution in Europe](#). WHO European Union and OECD research paper

⁷³ [Economic cost of the health impact of air pollution in Europe](#). WHO European Union and OECD research paper

⁷⁴ [Economic cost of the health impact of air pollution in Europe](#). WHO European Union and OECD research paper:

Annex

Premature deaths attributable to PM_{2.5}, NO₂ and O₃ exposure in the EU 28 and four other countries in 2013⁷⁵

Country	PM _{2.5}	NO ₂	O ₃	Total deaths	Of which CHD and stroke (=80%)
Austria	6 960	910	330	8 200	6 560
Belgium	10 050	2 320	210	12 580	10 064
Bulgaria	13 700	570	330	14 600	11 680
Croatia	4 820	160	240	5 220	4 176
Cyprus	450	<5	30	485	388
Czech Republic	12 030	330	370	12 730	10 184
Denmark	2 890	60	110	3 060	2 448
Estonia	690	<5	30	725	580
Finland	1 730	<5	80	1 815	1 452
France	45 120	8 230	1 780	55 130	44 104
Germany	73 400	10 310	2 500	86 210	68 968
Greece	13 730	1 490	840	16 060	12 848
Hungary	12 890	390	460	13 740	10 992
Ireland	1 520	30	50	1 600	1 280
Italy	66 630	21 040	3 380	91 050	72 840
Latvia	2 080	110	60	2 250	1 800
Lithuania	3 170	<5	90	3 265	2 612
Luxembourg	280	80	10	370	296
Malta	230	<5	20	255	204
Netherlands	11 530	1 820	270	13 620	10 896
Poland	48 270	1 610	1 150	51 030	40 824
Portugal	6 070	150	420	6 640	5 312
Romania	25 330	1 900	430	27 660	22 128
Slovakia	5 620	<5	200	5 825	4 660
Slovenia	1 960	150	100	2 210	1 768
Spain	23 940	4 280	1 760	29 980	23 984
Sweden	3 020	<5	160	3 185	2 548
United Kingdom	37 930	11 940	710	50 580	40 464
Bosnia and Herzegovina	3 620	80	180	3 880	3 104
Iceland	80	<5	<5	90	72
Serbia	10 730	1 340	320	12 390	9 912
Switzerland	4 980	1 140	240	6 360	5 088
Total	455,450	70 480	16 865	542 795	434 236
Total EU	436,040	67 915	16 120	520 075	416 060

⁷⁵ Table from the Air quality in Europe – 2016 report