WORLD HEART FEDERATION

# WORLD HEART REPORT 2024

## CLEARING THE AIR TO ADDRESS POLLUTION'S CARDIOVASCULAR HEALTH CRISIS

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# EXECUTIVE SUMMARY

## EVERYONE IS EXPOSED TO AIR POLLUTION THROUGHOUT THEIR LIVES, NO MATTER WHERE THEY LIVE IN THE WORLD. ITS IMPACTS ARE FAR-REACHING – FROM CAUSING AND EXACERBATING ILL HEALTH, TO LOSS OF LIFE

In 2019, almost 7 million deaths were attributed to air pollution.

Together, ambient and household air pollution contribute to more deaths than all wars, malaria, tuberculosis, HIV, and other infectious diseases combined. These figures are likely to be underestimates and the true impact of air pollution remains underappreciated, even within health communities.

The links between air pollution and its damaging effects on almost all organs of the body are undeniable. The cardiovascular effects in particular—the focus of this report—are stark. Exposure to air pollution is linked to the exacerbation of all major cardiovascular diseases (CVDs). Almost 70% of the 4.2 million deaths in 2019 attributed to ambient air pollution were caused by cardiovascular conditions, notably ischaemic heart disease (IHD) (1.9 million deaths) and stroke (900,000 deaths). A similar dynamic is evident in the 3.2 million deaths attributed to household air pollution in 2019 – 1 million deaths were from IHD and 700,000 from stroke. Globally, 22% of deaths from ischaemic heart disease and 15% from stroke were attributable to air pollution in 2019.

As CVDs are the leading cause of death globally, the ubiquity of air pollution exposure and its effects on cardiovascular health represents a staggering challenge for global health. Within the global picture of air pollution and CVDs is a story of significant regional and country differences. As with many other areas of health, lower-income countries bear a disproportionate burden. Regions outside of the Americas and Europe experienced the most significant rises in IHD and stroke deaths attributable to ambient air pollution from 2010 to 2019, for example, with Europe seeing declines in deaths from both conditions during the same period. Lower-income countries experience far greater health impacts from household air pollution. World Health Organization (WHO) estimates that over 2 billion people worldwide still rely on polluting fuels, such as wood, coal, crop waste, or charcoal paired with inefficient stoves for cooking.

The Global South's burden is exacerbated by gaps in air pollution monitoring, policy and health interventions and heightened vulnerabilities to the climate crisis and its environmental events – phenomena that both worsen and are worsened by air pollution.

Despite the awareness of air pollution harms, particulate matter ($PM_{2.5}$) concentration levels—the key pollutant for human health—declined globally by just 1% annually between 2010 and 2019. Global levels remained alarmingly high at 31.7 $\mu g/m^3$ in 2019, far above the 2021 WHO recommended air quality guidance level of 5 µg/m3. While hitting these targets is paramount for countries to protect the health and wellbeing of their populations, few countries have reached or are even close to reaching recommended levels. Worse, while 64% of countries have in place legislation that includes ambient air quality standards, none of these align with WHO air quality guidelines.

## AN URGENT NEED FOR COMPREHENSITVE STRATEGIES

It is an understatement to say that the need is urgent for comprehensive strategies that mitigate air pollution and its profound health, societal and economic consequences. There are bright spots and exemplar air pollution tackling initiatives at city and national level, as this report shows – but these are too few and far between. Many air pollution interventions will also help tackle the climate crisis and the health benefits of reducing air pollution far outweigh the economic requirements to achieve them. A long-term vision is needed to realise these benefits, but the commitment to address them is needed now.

World Heart Federation (WHF)—with its membership of more than 200 heart foundations, scientific societies, and patient organizations across more than 100 countries—is committed to not only promoting policies and actions that protect cardiovascular health, but also advocating for urgent efforts to stem some of the major contributors to air pollution, namely, the climate crisis and fossil fuels emissions.


## THIS REPORT PROVIDES THE FOLLOWING KEY RECOMMENDATIONS:

1. All countries must adopt the new WHO global guidelines on air quality. This includes making a roadmap of strategies to meet the interim targets outlined by WHO whilst progressing to the overall guideline level. Policies should be multifaceted and multi-sectoral, encompassing, among others, health, housing, city design, transport, and agriculture.

2. WHF supports the implementation of a global fossil fuel non-proliferation treaty. Country commitments to these treaties must be maintained, ideally through legally binding agreements, and suitable implementation strategies must be employed to rapidly reduce the use of fossil fuels.

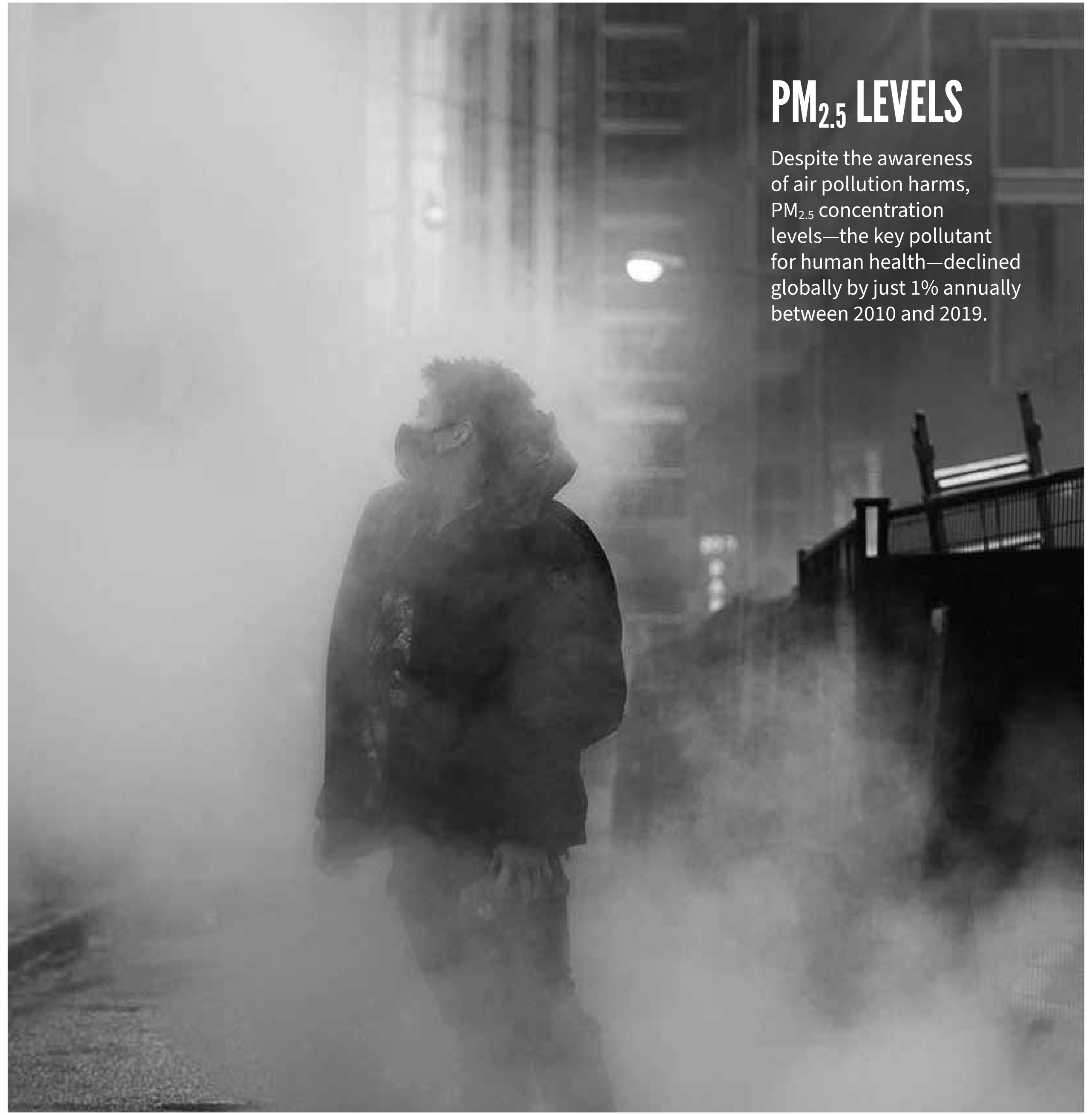
3. Countries and technical bodies, particularly in low- and middle-income countries (LMICs), should urgently improve air pollution monitoring and modelling where there are gaps. This includes expansion of the stationary monitoring network in both rural and urban areas that will help provide more accurate estimates of air pollution levels and trends.

4. Countries, multilaterals, and philanthropies must increase funding into multidisciplinary air pollution research and technological innovations to improve air quality and strategies to implement interventions to reduce air pollution.

5. Health and research agencies at country, regional, and global levels should conduct additional studies into the cardiovascular effects of air pollution and CVDs linked to ambient and household air pollution, in addition to the role of the cardiovascular system in the disease of other organs. This should include the study of the cardiovascular effects of less-well-researched air pollutants, so that policies and interventions can target the air pollutants that are most harmful. This will support the design and implementation of health interventions.

## OVER 2 BILLION PEOPLE WORLDWIDE STILL RELY ON POLLUTING FUELS.

THESE INCLUDE COAL, CROP WASTE, AND CHARCOAL PAIRED WITH INEFFICIENT STOVES FOR COOKING.



## $PM_{2.5}$ LEVELS

Despite the awareness of air pollution harms, $PM_{2.5}$ concentration levels—the key pollutant for human health—declined globally by just 1% annually between 2010 and 2019.

# INTRODUCTION

## CARDIOVASCULAR DISEASES (CVDs) AFFECT THE HEART, BLOOD VESSELS, AND BLOOD, AND CAN BE CAUSED BY A COMBINATION OF GENETIC, METABOLIC, SOCIO-ECONOMIC, BEHAVIOURAL, AND ENVIRONMENTAL RISK FACTORS.

Among these many risk factors, this report will focus on air pollution. Air pollution—which has been shown to have damaging effects on most organs of the body—is the sixth biggest risk factor for mortality globally, the seventh for disability-adjusted life years (DALYs)*, and the number one environmental risk factor for ill health and death [1].

As this report will show, the impacts of air pollution on cardiovascular health are profound, with exposure linked to the exacerbation of all major CVDs, including ischaemic heart disease (IHD) and stroke. Several air pollutants are linked to biological actions that can drive the initial events of atherosclerosis, accelerate multiple disease processes, and consequently trigger cardiovascular events that result in death. The ubiquity of air pollution exposure, together with the high global prevalence of CVDs, imposes a staggering burden on morbidity and mortality the world over.

Beyond the obvious health impacts, air pollution has a significant impact on economies. The World Bank estimates that the global cost of health damages associated with exposure to air pollution is US$8.1 trillion, equivalent to 6.1% of the global GDP, with 1.2 billion annual workdays lost [2]. Predictions indicate that global air pollution-related healthcare costs will surge from US$21 billion in 2015 to US$176 billion in 2060 [3].

* One DALY represents the loss of the equivalent of one year of full health. DALYs for a disease or health condition are the sum of the years of life lost to due to premature mortality (YLLs) and the years lived with a disability (YLDs) due to prevalent cases of the disease or health condition in a population.

This second World Heart Report is aimed at equipping policymakers and advocates around the world with a consolidated analysis of the interplay between air pollution and CVDs, with the goal of identifying areas for concrete action that will mitigate air pollution's harms not only on cardiovascular health but also overall health.

The report begins by exploring what exactly constitutes ambient air pollution and the latest evidence regarding $PM_{2.5}$ trends and levels globally, before moving on to the relationship between air pollution (both ambient and household) and health and CVDs.

In addition to presenting and analysing the most recent publicly available data in this area, the report will briefly examine interactions between air pollution and susceptible population groups, the dynamic between air pollution and climate change, and policy efforts (international, country, and local levels) to curb air pollution's harms.

Global, regional, and country WHO estimates for $PM_{2.5}$ and ambient and household air pollution attributable mortality (overall and CVD) are presented in this report. Data for air quality guidelines and policies are from the United Nations Environment Programme's (UNEP) global assessment of air pollution legislation, WHO health and environment scorecards, and Clean Air Fund's assessment of country commitments related to the Paris Climate Agreement. In places where air pollution is referred to without either ambient or household preceding it, this refers to ambient air pollution.

In 2021, the World Heart Federation (WHF) established its Air Pollution Expert Group with a remit to convey the serious threat of air pollution to WHF members and the cardiovascular community, inform stakeholder groups and the public, and advocate for change to improve air quality. The group's work has led to high-profile statements in major cardiovascular journals [4,5], the publication of a policy brief [6], and collaborations with WHO to develop a toolkit to educate and train health practitioners with guidance for their patients [7]. This report continues WHF's commitment to highlighting the threat of air pollution to cardiovascular health.

# OVERVIEW: AMBIENT (OUTDOOR) AIR POLLUTION

Ambient (outdoor) air pollution is a complex mixture of individual pollutants composed of many thousands of different chemicals that have negative effects on the environment and human health.

Anthropogenic sources of air pollution include industrial emissions, vehicle exhaust, household energy, waste burning, construction, and agricultural burning. Naturally produced sources of air pollution include sea spray, volcanic eruptions, and desert dust.

Household (indoor) air pollution will be addressed later in this report.

| SOURCES | POLLUTANT | BIOLOGICAL EFFECTS & INTERACTIONS WITH OTHER AIR POLLUTANTS |
|---|---|---|
| Particulate matter (PM), e.g., $PM_{10}$, $PM_{2.5}$, and ultrafine PM | - Household energy, e.g., wood, charcoal, coal, and kerosene<br>- Industrial combustion<br>- Road transport<br>- Industrial solvents<br>- Wildfires<br>- Formed from the reactions between other pollutants in the air | - Inhaled PM has a detrimental effect on most organs of the body, including the lungs and cardiovascular system.<br>- The biological effects are determined by the size and composition of the PM. |
| Nitrogen oxides ($NO_x$), e.g., nitrogen dioxide ($NO_2$) | - Road transport<br>- Energy generation<br>- Household energy, e.g., liquid gas/propane | - Nitrogen oxides harm the body by processes called oxidative stress and inflammation.<br>- The effects of $NO_2$ are most noticeable in the lungs; however, long-term exposure is linked to cardiovascular issues and effects in other organs of the body.<br>- $NO_2$ can undergo chemical reactions in the air to form other air pollutants such as particles and ozone. |
| Sulphur dioxide ($SO_2$) | - Energy generation<br>- Industrial combustion<br>- Household energy, e.g., burning of coal and/or oil | - $SO_2$ is a respiratory irritant and has been found to exacerbate asthma.<br>- $SO_2$ is associated with cardiovascular conditions.<br>- Acidified $SO_2$ is a precursor for the formation of secondary particulate matter. |
| Ozone ($O_3$) | - Atmospheric reactions between other pollutants from vehicles, industry, and consumer products | - Ozone's effects are more notable in the lungs; however, epidemiological studies have found associations with cardiovascular and other diseases. |
| Ammonia ($NH_3$) | - Agriculture, e.g., animal waste, fertilizers, anaerobic digestion | - At high concentrations, ammonia gas is an irritant to the eyes, nose, throat, and lungs.<br>- Ammonia can react with nitric and sulphuric acid in the air to form secondary particulate matter. |
| Volatile organic carbon compounds (VOCs) | - Industry<br>- Household products<br>- Agriculture<br>- Transport | - VOCs are a wide class of chemicals with different properties. Their health effects are varied.<br>- VOCs can react with other chemicals in the atmosphere to form other air pollutants, as such ozone. |

# PARTICULATE MATTER (PM) EXPLAINED

PM comes from a wide variety of sources and can have very different compositions and particle sizes (Figure 1).

It is composed of different chemicals, the most harmful of which are yet to be fully identified. However, elemental and organic carbon, reactive transition metals, and polyaromatic hydrocarbons are anticipated to be key drivers of toxicity.

PM is most commonly measured as $PM_{10}$ and $PM_{2.5}$ (particles with a diameter of less than 10 and 2.5 micrometres, respectively) across the world by air quality monitors, including both governmental stationary monitoring networks and non-reference grade monitors.

$PM_{2.5}$ is the indicator of air pollution most consistently associated with detrimental effects on human health. It can deposit deep in the alveoli of the lungs.

Ultrafine particles (particles with a diameter of less than 100 nanometres) cannot be routinely measured by reference grade monitors. However, these particles may be especially harmful to human health due to their large reactive surface area and ability to carry surface chemicals into the body. Inhaled ultrafine particles can also penetrate the circulatory system. Combustion is a major source of these particles, e.g., vehicle exhaust.

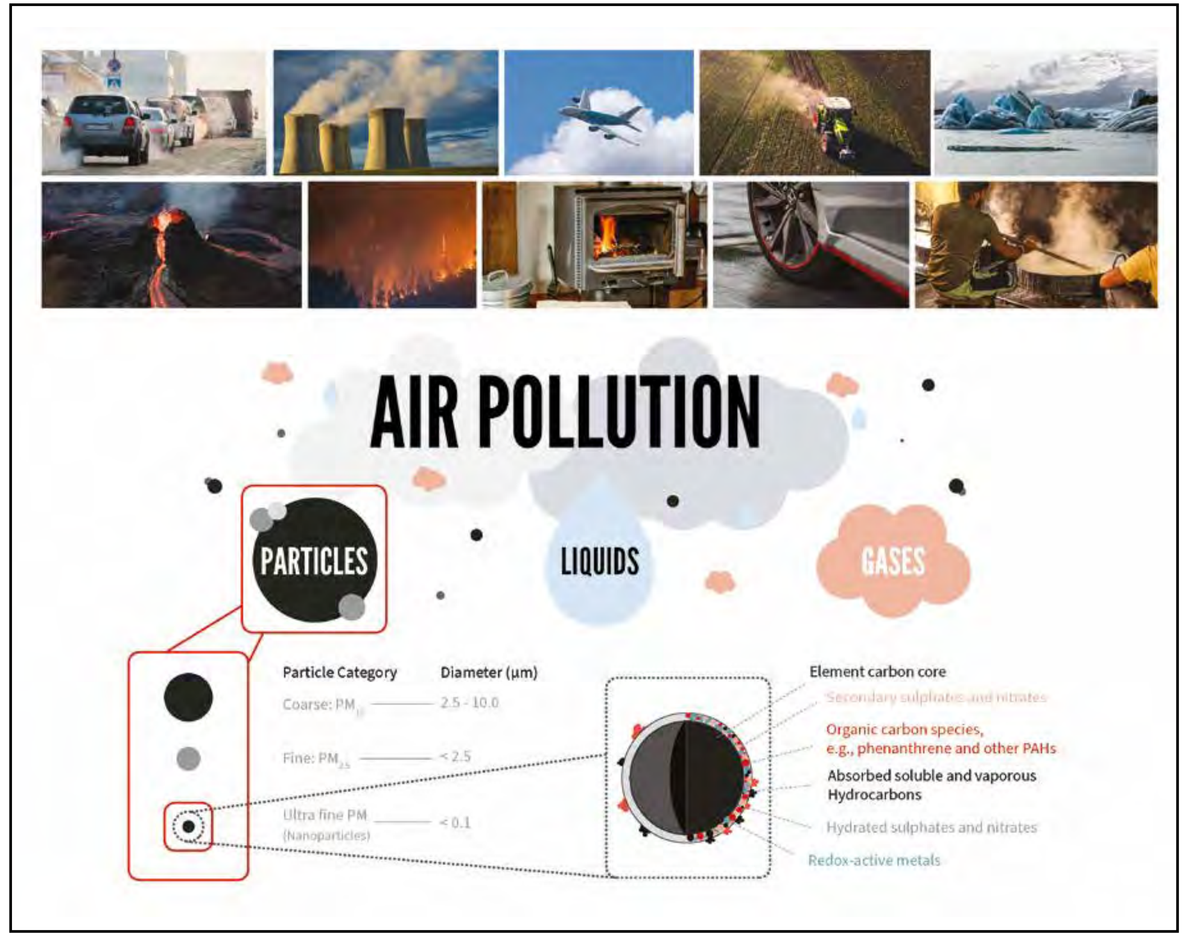



FIGURE 1
Particulate matter sources and sizes

Adapted from: Miller, The cardiovascular effects of air pollution: Prevention and reversal by pharmacological agents. https://doi.org/10.1016/j.pharmthera.2021.107996

# GLOBAL LEVELS AND TRENDS OF AMBIENT AIR POLLUTION

## $PM_{2.5}$ TRENDS

FROM 2010 TO 2019, $PM_{2.5}$ GLOBAL LEVELS REMAINED LARGELY STABLE (FIGURE 2), WITH AN ANNUAL REDUCTION OF 1% (FROM 35.3 UG/M³ IN 2010 TO 31.7µG/M³ IN 2019).

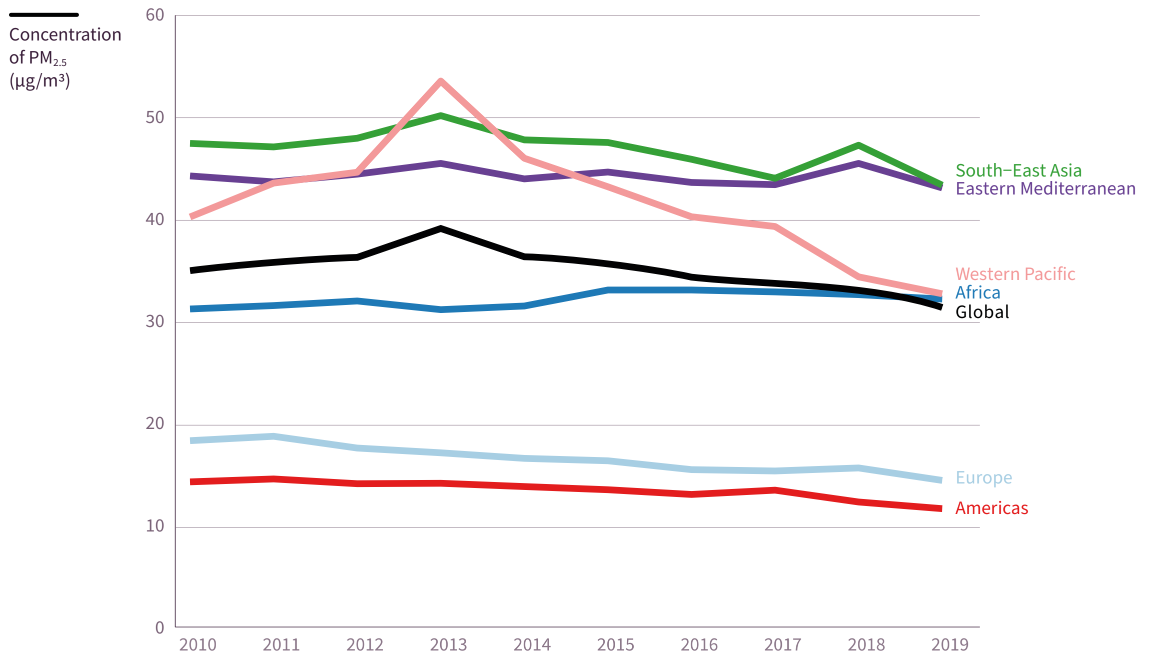
IN THIS PERIOD, THE LARGEST $PM_{2.5}$ DECLINE WAS RECORDED IN EUROPE (2.1% AVERAGE ANNUAL CHANGE).

WHILE $PM_{2.5}$ LEVELS INCREASED ANNUALLY BY 0.3% IN AFRICA.

## ONLY 14% OF COUNTRIES EXPERIENCED LARGE DECLINES (BETWEEN 5µG/M³ AND 10µG/M³) FROM 2010 TO 2019, WHILE OTHERS SHOWED NO CHANGE OR INCREASES.

**FIGURE 2**

Trends in mean annual $PM_{2.5}$ concentrations by WHO regions, 2010-2019




Source: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/concentrations-of-fine-particulate-matter-(pm2-5)

Countries with the largest absolute decrease from 2010 to 2019 were Tajikistan (9.8 μg/m³), North Macedonia (9.4 μg/m³), and China (9.0 μg/m³), while the largest absolute increases were observed in Mauritania (3.1 μg/m³) and Sierra Leone (3.1 μg/m³).

**FIGURE 2.1**

Trends in mean annual $PM_{2.5}$ concentrations by WHO regions, 2010-2019

Note: The shaded areas show uncertainty in estimates. See Online Appendix for countries included in each WHO region.

Source: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/concentrations-of-fine-particulate-matter-(pm2-5)

**FIGURE 2.1**


The largest relative declines were observed in most European countries (between 25% and 30% relative change), while the largest relative increases were recorded in Angola (12.2%), Cabo Verde (10.3%), Liberia (8.9%), Sierra Leone (8.5%), and Palau (8.2%) (Figure 3).

All countries in the Europe and South-East Asia regions experienced a decline in $PM_{2.5}$ levels between 2010 and 2019, while 60% of the countries in Africa observed an increase. In the Eastern Mediterranean, Americas, and Western Pacific regions, 36%, 43%, and 45% of countries, respectively, recorded an increase in the level of $PM_{2.5}$ concentration.

It should be noted that some trends in $PM_{2.5}$ levels are uncertain (represented by the shaded area in Figure 2.1) owing to the differing strength of regional data sets available. The Africa (Box 1) and Eastern Mediterranean regions have notably sparse and limited data.

# $PM_{2.5}$ LEVELS

In 2021, WHO established air quality guidance [8] that set the recommended level of annual average concentrations of $PM_{2.5}$ at no more than 5 μg/m³. In 2019—the most recent WHO data on record—no country in the world had $PM_{2.5}$ concentrations below this threshold (Figure 4).

Average regional $PM_{2.5}$ concentration levels in 2019 could be grouped into three clusters – South-East Asia and Eastern Mediterranean regions, which recorded an annual $PM_{2.5}$ concentration of around 43 μg/m³; Africa and Western Pacific regions around 33 μg/m³; and Europe and the Americas below 15 μg/m³ (12.1 μg/m³ and 14.9 μg/m³, respectively) (Figure 2.1).

The highest levels of annual average $PM_{2.5}$ concentrations were recorded in the Global South, with the highest levels in Kuwait (64.1 μg/m³; Confidence Interval [CI] 55.7-72.5), Egypt (63.2 μg/m³; CI 40.4-92.3), and Afghanistan (62.5 μg/m³; CI 45.0-86.5).

Countries with the lowest levels of $PM_{2.5}$ concentration were the Bahamas (5.2 μg/m³; CI 3.8-7.1), Finland (5.5 μg/m³; CI 5.2-5.8), Iceland (5.8 μg/m³; CI 5.1-6.5), and Sweden (6.0 μg/m³; CI 5.7-6.2).

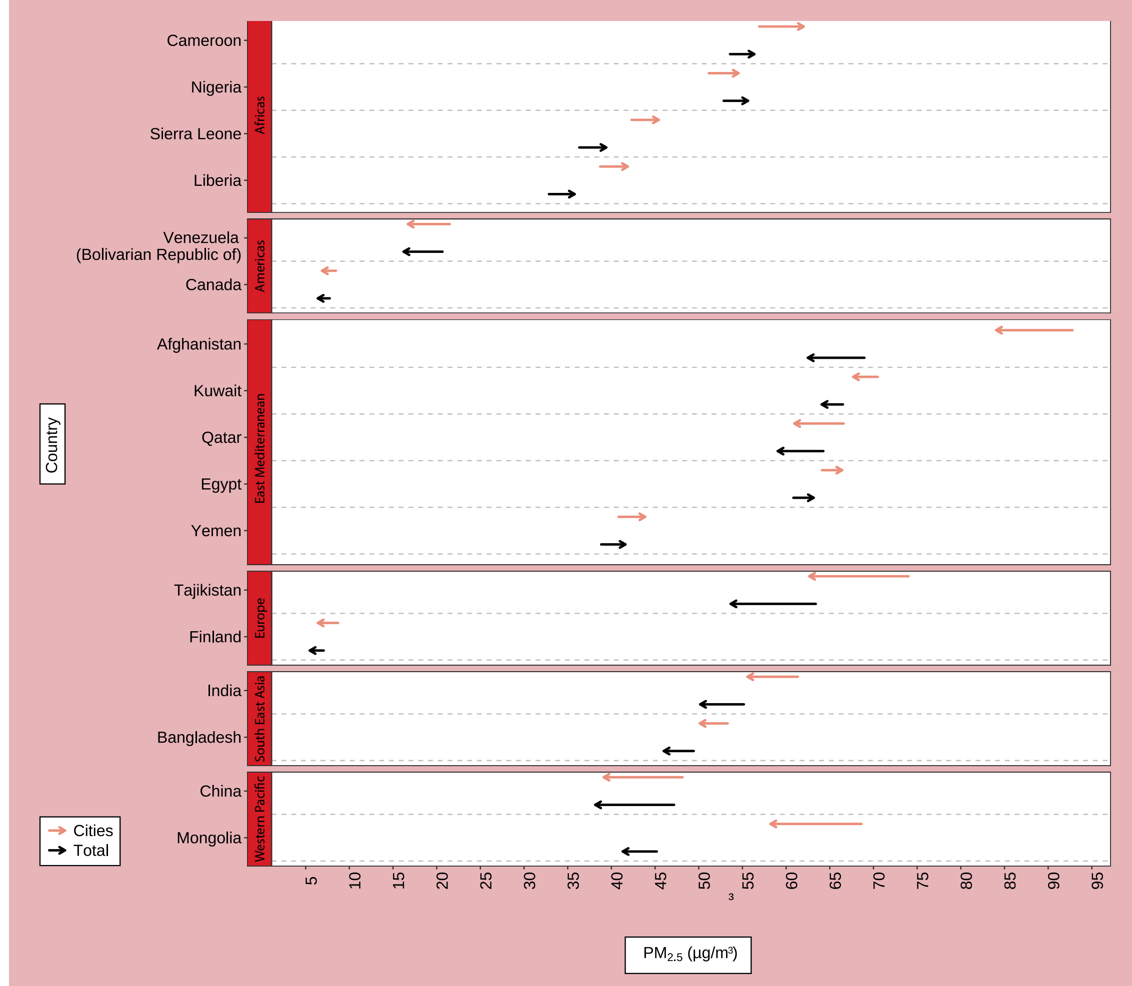


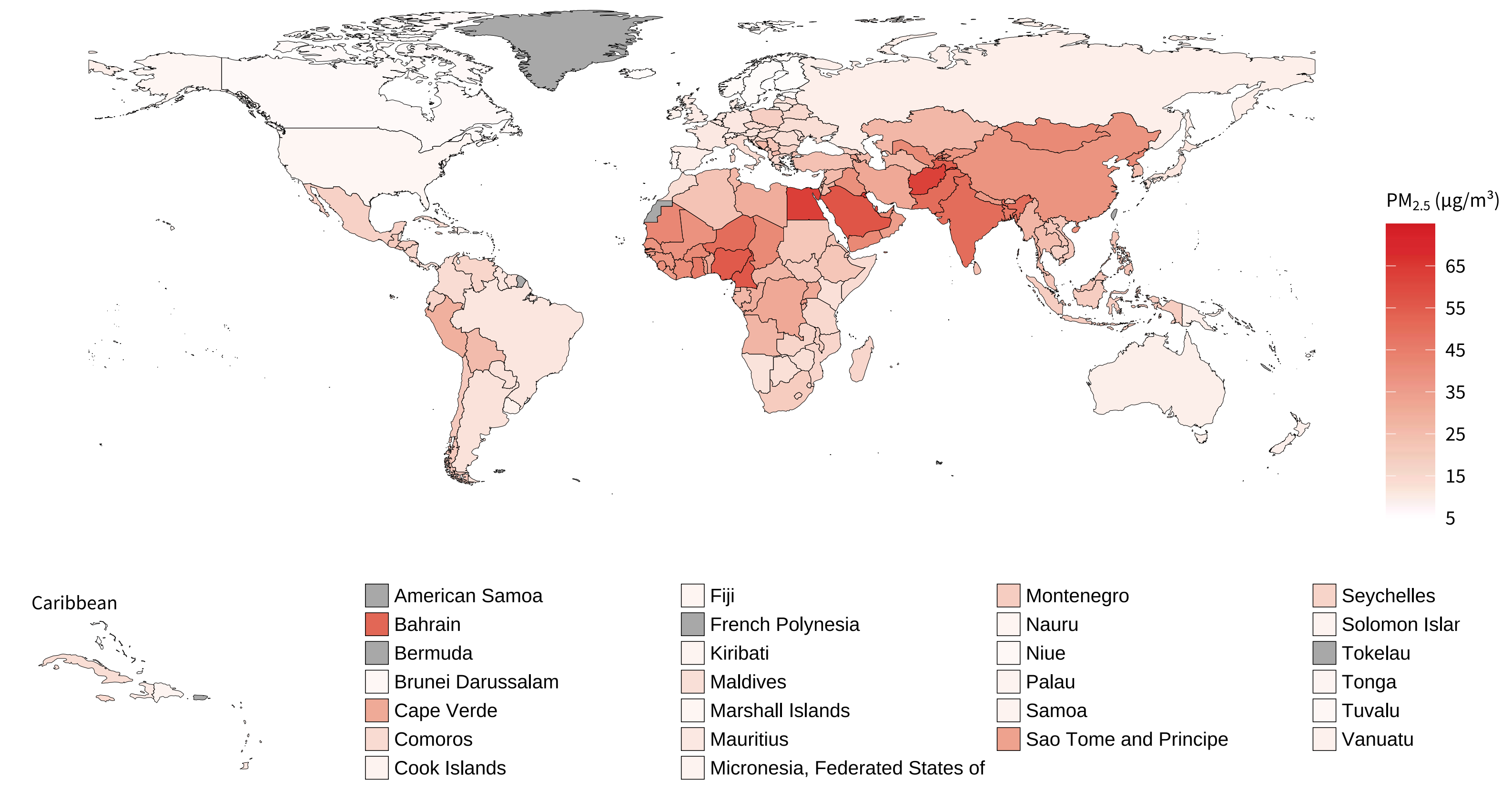

**FIGURE 3**

Changes in $PM_{2.5}$ concentrations between 2010 and 2019 (selected countries; overall and city-level)

Source: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/concentrations-of-fine-particulate-matter-(pm2-5)

Note: See Online Appendix for the full set of countries.

FIGURE 4



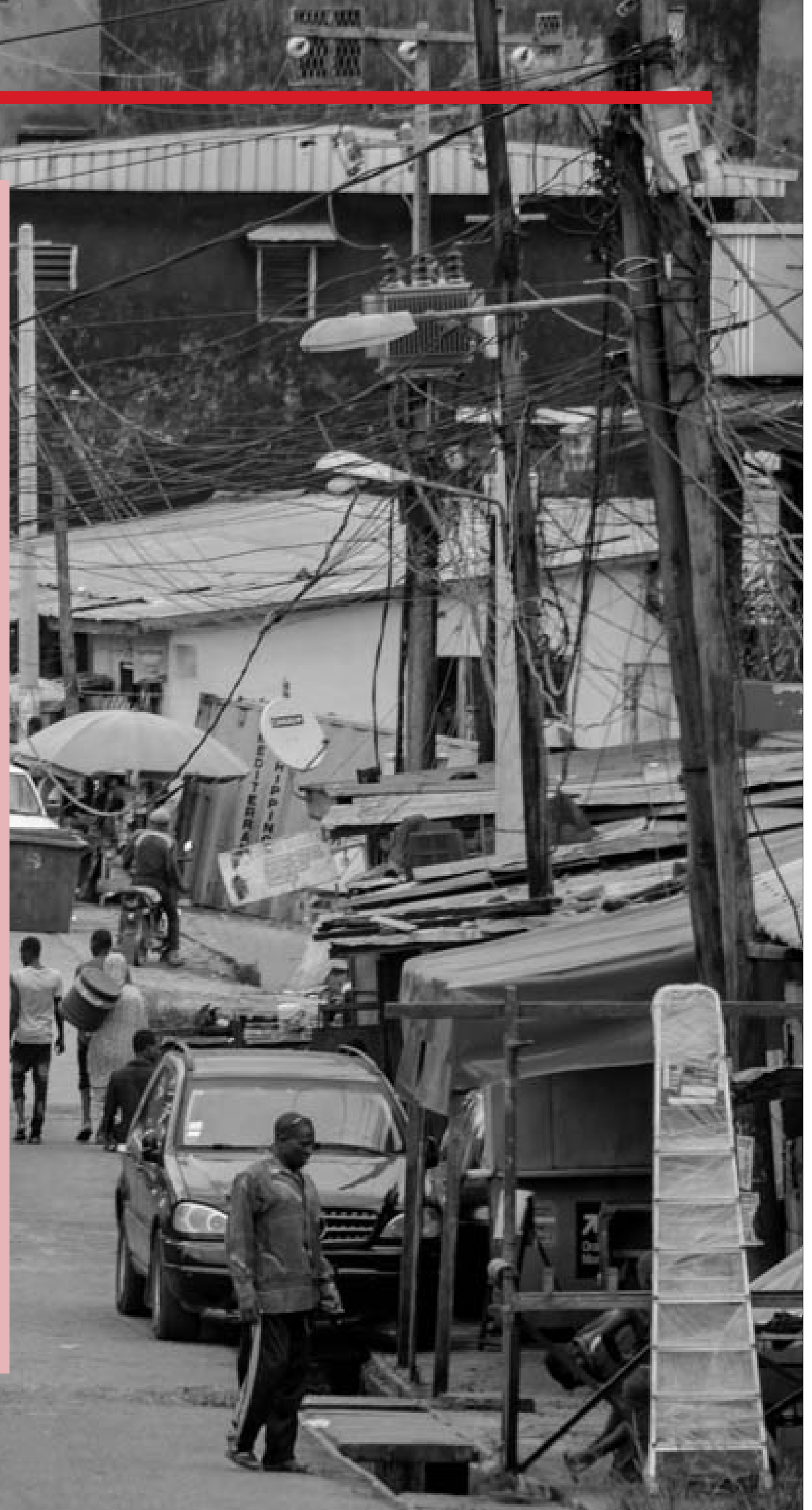

Source: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/concentrations-of-fine-particulate-matter-(pm2-5)

## NO COUNTRIES IN THE AFRICA, EASTERN MEDITERRANEAN, OR SOUTH-EAST ASIA REGIONS RECORDED AN AVERAGE ANNUAL $PM_{2.5}$ CONCENTRATION BELOW 10 µG/M³.

The top three countries in the Africa and Eastern Mediterranean regions recorded values up to three times higher than the top three countries in the Americas region (Table 1).

Most Pacific island countries in the Western Pacific region had relatively low levels of average annual $PM_{2.5}$ concentration (below 10 µg/m³).

**FIGURE 4**
Mean annual $PM_{2.5}$, 2019 (See Online Appendix for methodology)



# BOX 1 – AFRICA: THE NEED TO IMPROVE AIR POLLUTANT MONITORING

With a population exceeding 1 billion and increasing urbanization in many countries, Africa faces a growing threat of air pollution and its resulting health impacts. By 2035, half of Africa's population is expected to live in urban settings, and Sub-Saharan Africa is in a position to host five of the world's 41 megacities by 2030 [9].

Africa faces significant challenges in addressing the consequences of air pollution, with distinct vulnerabilities at both population and individual levels, including socio-economic risk factors, limited access to quality healthcare, and the coexistence of chronic and infectious diseases. Exacerbating this challenge is a scarcity of robust air quality monitoring data, with the partial data available revealing elevated air pollution levels in certain urban areas in Africa.

As highlighted in IQAir's 2023 World Air Quality Report, which looked at $PM_{2.5}$ air quality data across 7,812 cities globally, only 24 of 54 African countries have the ability to monitor air quality in some capacity, with most of the existing stations concentrated in the western and southern regions of the continent, (Figure 5) [10]. Where monitors exist in Africa, they do not always measure all air pollutants that are considered key to health. While satellite estimates provide valuable data on key air pollutants such as $PM_{2.5}$ and $NO_2$ in areas lacking ground monitors, these estimates have limitations, such as spatial resolution and assumptions that ground-level pollutants will reflect the column of air.

There is an urgent need to improve the quality of air pollution monitoring and data gathering in Africa, as is needed for every region and country. Enhanced air quality monitoring is essential to comprehensively understand the issue, design public health interventions, and implement sustainable practices to combat air pollution for protecting people's health.

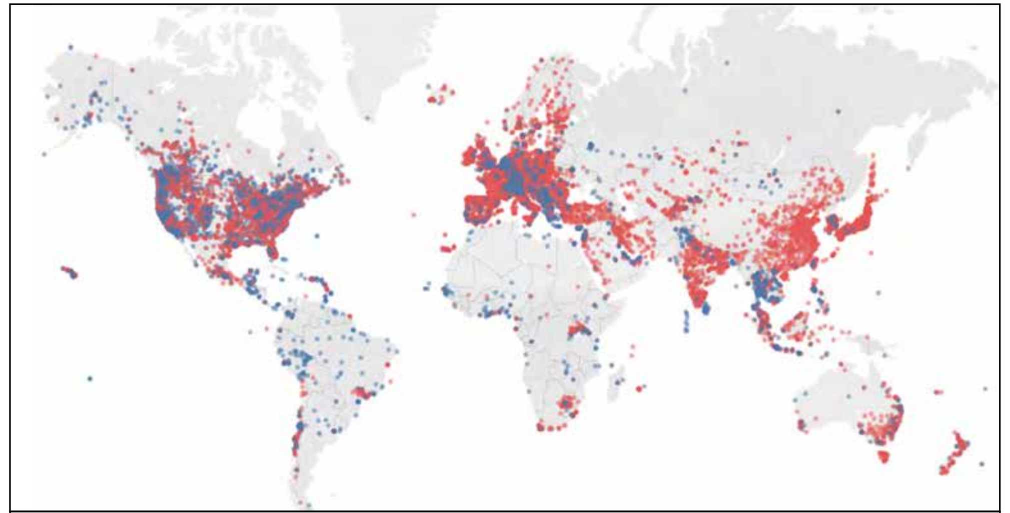
In 2019, over 1 million deaths in Sub-Saharan Africa were attributed to CVDs. Addressing air pollution monitoring gaps is a critical step to mitigating the future impact of pollution on cardiovascular health in the region.

| WHO Region | Lowest µg/m³ | | Highest µg/m³ | |
|---|---|---|---|---|
| | | Mean (95% CI) | | Mean (95% CI) |
| Africa | Mauritius | 10.48 [8.25 -12.84] | Niger | 50.15 [21.92 - 99.90] |
| | Namibia | 11.81 [6.32 -18.88] | Nigeria | 55.64 [37.64 - 76.88] |
| | Kenya | 12.52 [7.80 -17.78] | Cameroon | 56.37 [39.06 - 79.81] |
| Americas | Bahamas | 5.20 [3.77 - 7.05] | El Salvador | 22.15 [14.49 - 31.82] |
| | Canada | 6.39 [6.21 - 6.59] | Bolivia (Plurinational State of) | 25.23 [16.41 - 36.37] |
| | USA | 7.18 [7.07 - 7.28] | Peru | 29.07 [22.20 - 38.42] |
| Eastern Mediterranean | Morocco | 13.44 [11.03 - 16.52] | Afghanistan | 62.49 [45.04 - 86.46] |
| | Somalia | 14.28 [7.65 - 24.25] | Egypt | 63.16 [40.38 - 92.33] |
| | Djibouti | 19.98 [7.70 - 41.73] | Kuwait | 64.08 [55.65 - 72.49] |
| Europe | Finland | 5.47 [5.16 - 5.76] | Kyrgyzstan | 37.58 [26.16 - 52.31] |
| | Iceland | 5.79 [5.11 - 6.46] | Uzbekistan | 40.98 [29.83 - 57.12] |
| | Sweden | 5.96 [5.70 - 6.22] | Tajikistan | 53.65 [38.18 - 76.75] |
| South-East Asia | Maldives | 13.00 [10.33 -16.7] | Democratic People's Republic of Korea | 41.46 [31.42 - 53.61] |
| | Indonesia | 19.34 [16.76 - 23.72] | Bangladesh | 45.99 [41.65 - 51.00] |
| | Timor-Leste | 20.47 [9.02 - 42.19] | India | 50.17 [47.87 - 52.43] |
| Western Pacific | Niue | 6.74 [3.15 - 13.16] | Republic of Korea | 24.04 [23.39 - 24.75] |
| | Tuvalu | 6.81 [2.59 - 13.49] | China | 38.15 [36.69 - 39.42] |
| | Brunei Darussalam | 6.86 [5.76 - 8.32] | Mongolia | 41.30 [30.68 - 53.50] |

**TABLE 1**

$PM_{2.5}$ levels: Lowest and highest 3 countries by WHO regions (2019)

Source: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/concentrations-of-fine-particulate-matter-(pm2-5)



GOVERNMENT- OPERATED STATIONS
INDEPENDENTLY OPERATED MONITORING STATIONS

**FIGURE 5**

Global distribution of $PM_{2.5}$ monitoring stations

Source: https://www.iqair.com/us/newsroom/waqr-2023-pr

# AMBIENT AIR POLLUTION AND HEALTH

Ambient air pollution is currently the sixth biggest risk factor for mortality globally, the seventh for DALYs, and the number one environmental risk factor [1].

In 2019, ambient air pollution caused 4.2 million deaths and over 100.4 million DALYs. The number of deaths was almost 140,000 more than the number recorded in 2010, a rise mostly driven by the South-East Asia (152,000 more deaths), Western Pacific (64,000 more deaths) and Eastern Mediterranean (47,000 more deaths) regions. Europe recorded over 135,000 *fewer* deaths in 2019 compared to 2010.

While the number of deaths increased globally, the five-cause (IHD, stroke, chronic obstructive pulmonary disease, acute lower respiratory infections, and lung cancer) age-standardized death rate attributable to air pollution declined globally from 70.7 deaths per 100,000 people to 59.7 deaths per 100,000 people, with all regions experiencing an average annual decline between 1% and 3% (Figure 6).

As evidenced by the high number of deaths and morbidity, the complex make-up of air pollutants means that their health impacts are far reaching and connected to myriad diseases. Air pollution has strong links to the burden of respiratory diseases, such as asthma and chronic obstructive respiratory disease (COPD), and research over the last decade has found associations between air pollutants and conditions of most organs of the body [11] (Figure 7).

Some estimates suggest the number of annual deaths from air pollution could be as high as 8.9 million [12]. Nearly all existing estimates are likely to be conservative, as they only quantify the impact of long-term exposures to $PM_{2.5}$, rather than all air pollutants, and for only a limited number of disease categories.

# EXPANDING RESEARCH ON AIR POLLUTION AND MULTIMORBIDITY

With the growing awareness that air pollution has deleterious effects on most organ systems, regard should be given to the consequences of air pollution where there is multimorbidity.

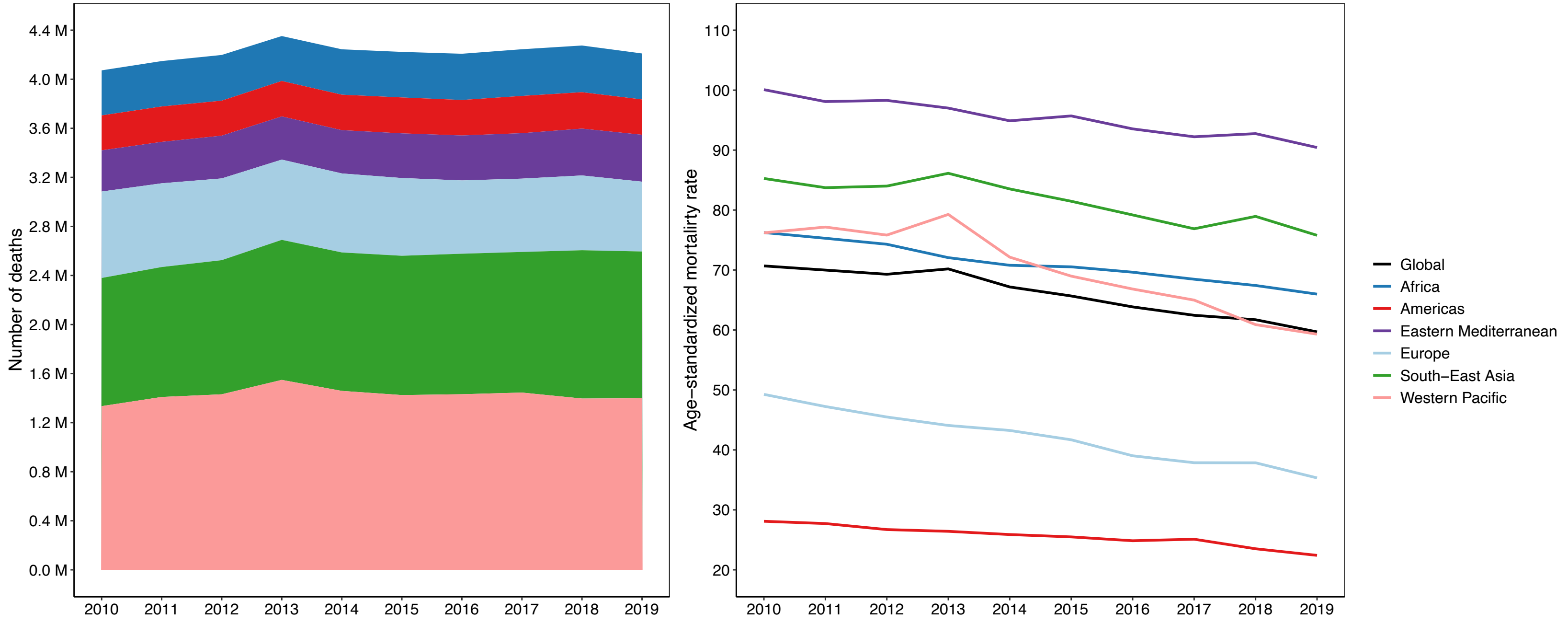
This is especially important given that life expectancy is increasing, and with an older population, it is more likely that people will suffer from more than one condition as they become elderly. The cardiovascular system plays an integral role in the function and regulation of multiple organ systems.

Therefore, different biomedical specialities must work with cardiovascular researchers to understand the role of the cardiovascular system in disease of other organs. Areas of potential interest include diabetes, dementia, kidney disease, cancer, and pregnancy.

**FIGURE 6**

Number of deaths (left panel) and age-standardized mortality rates (deaths per 100,000 people) (right panel) attributable to ambient air pollution for both sexes and WHO regions

Source: WHO Global Health Observatory



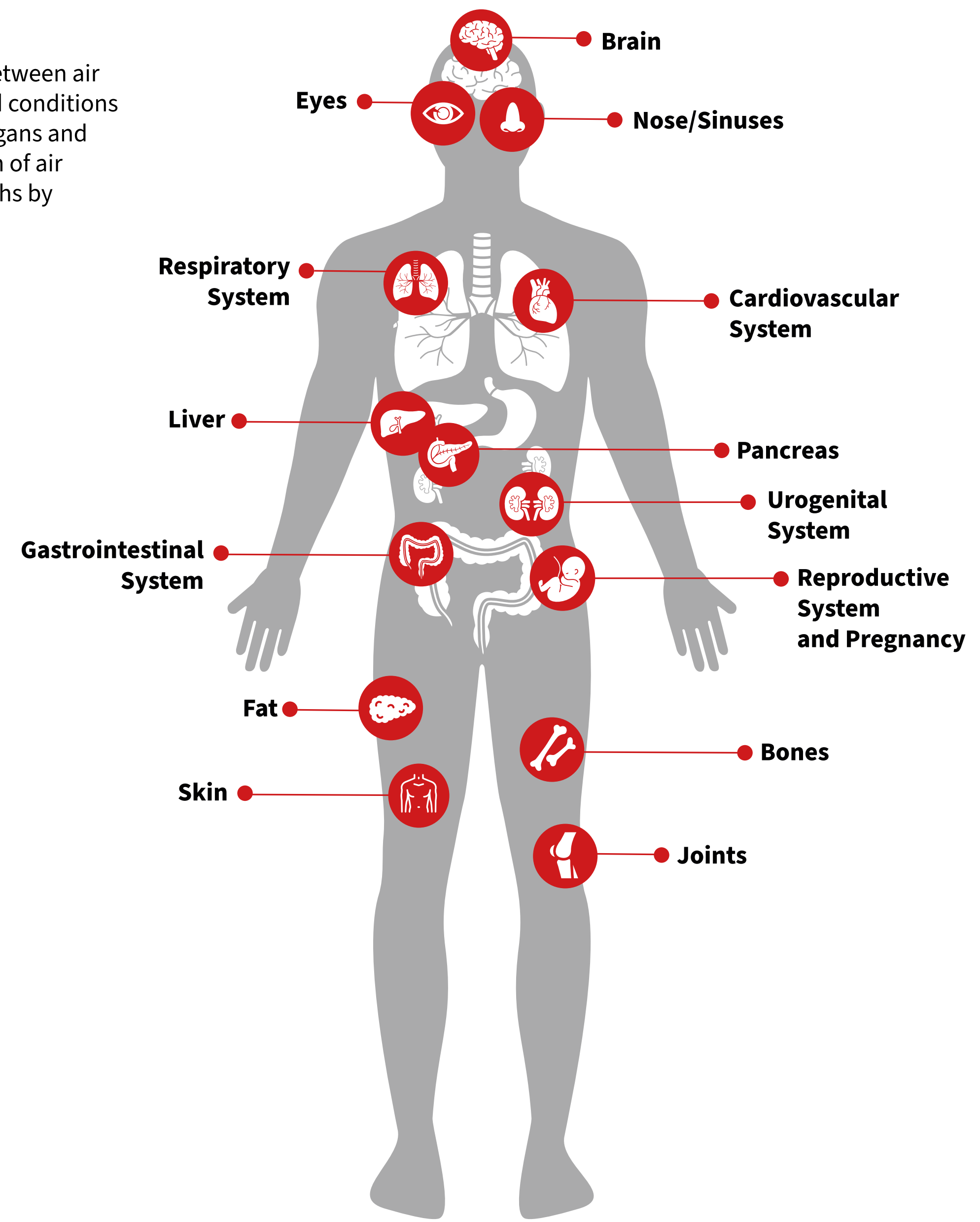
# AMBIENT AIR POLLUTION AND CARDIOVASCULAR HEALTH

There is expansive literature linking air pollution to most cardiovascular conditions, with most studies run in high-income countries [13]. Limited data exists from LMICS.

Cardiovascular conditions linked to air pollution include:

- IHD/Coronary artery disease
- Cerebrovascular disease
- Stroke
- Heart failure
- Cardiac arrhythmia and arrest
- Venous thromboembolism and peripheral artery disease such as pulmonary hypertension
- Dilated cardiomyopathy
- Congenital heart disease
- Pulmonary hypertension

**FIGURE 7**
Association between air pollutants and conditions of different organs and the proportion of air pollution deaths by specific cause

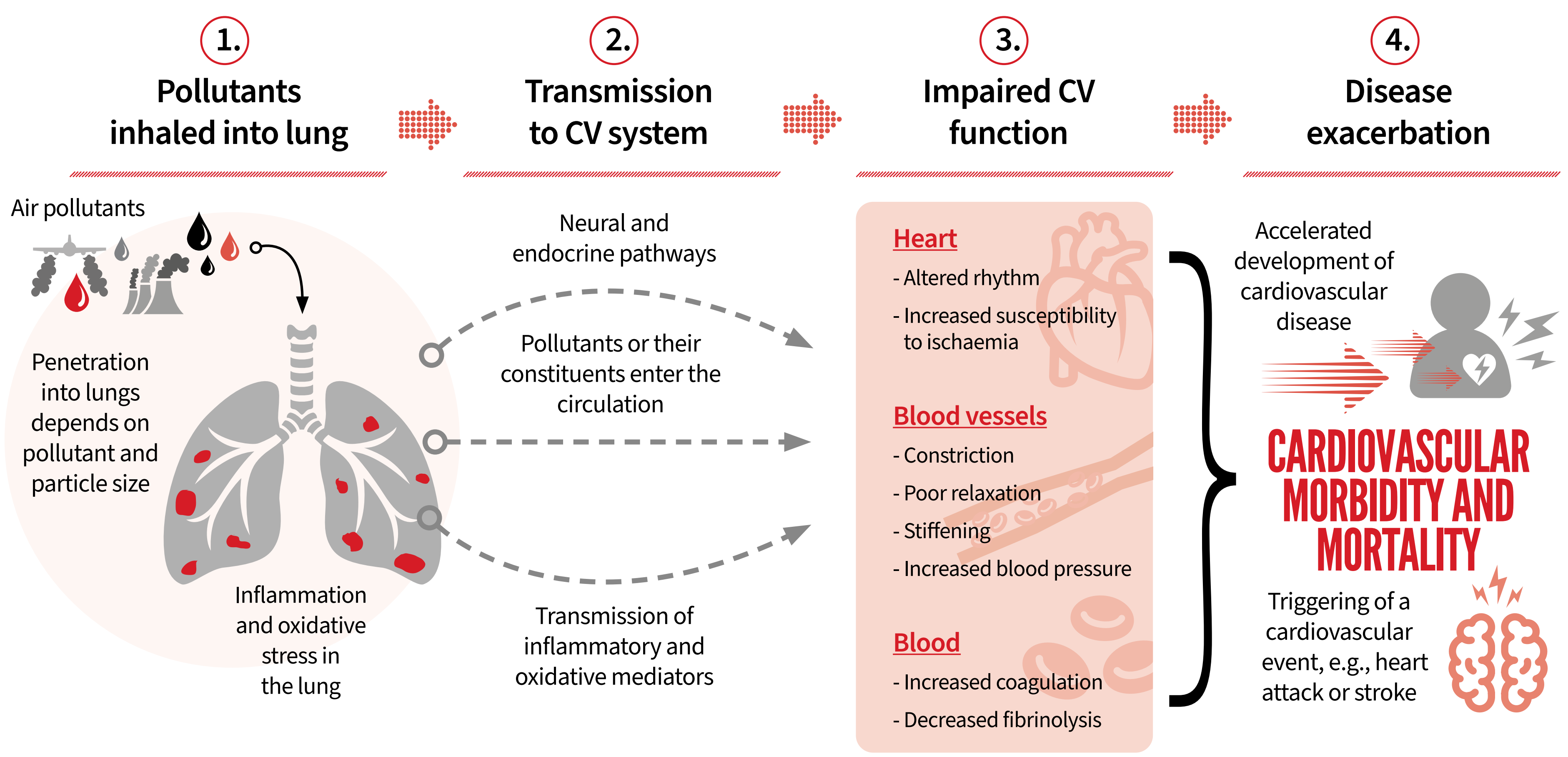



## CONSIDERABLE PROGRESS HAS BEEN MADE IN ESTABLISHING HOW AIR POLLUTION NEGATIVELY IMPACTS THE CARDIOVASCULAR SYSTEM [14] (FIGURE 8), WITH THE EFFECTS INCLUDING:

- Endothelial dysfunction
- The generation of oxidative stress
- Loss of endothelial-derived nitric oxide bioavailability
- Increases in circulating vasoconstrictive mediators
- Platelet activation
- Impaired fibrinolysis
- Endothelial cell inflammation
- Promotion of inflammatory pathways in endothelial cells
- Emerging evidence for pathways such as epigenetic modification, circulating microRNA and changes to circulating stem cell populations

Long-term exposure to air pollution has also been shown to accelerate atherosclerosis (narrowing of the arteries) and promote plaque instability [13,15].

**FIGURE 8**
Pathway by which air pollution leads to cardiovascular morbidity and mortality




## MOST LARGE-SCALE META-ANALYSES SHOW CLEAR ASSOCIATIONS BETWEEN EXPOSURE TO BOTH SHORT-TERM (FIGURE 9) AND LONG-TERM (FIGURE 10) AIR POLLUTANTS AND THE INCREASED RISK OF CVDs.

In many cases, various CVDs are associated with more than one pollutant. While there will be some overlap in risk estimates from closely related pollutants, combined air pollutant mixtures will compound risks. Regardless, the risk estimates for even single pollutants are substantial and especially concerning given the prevalence of CVDs globally.

**FIGURE 9**
Short-term percentage increase in the risk of cardiovascular diseases (selected outcomes) by type of air pollutant

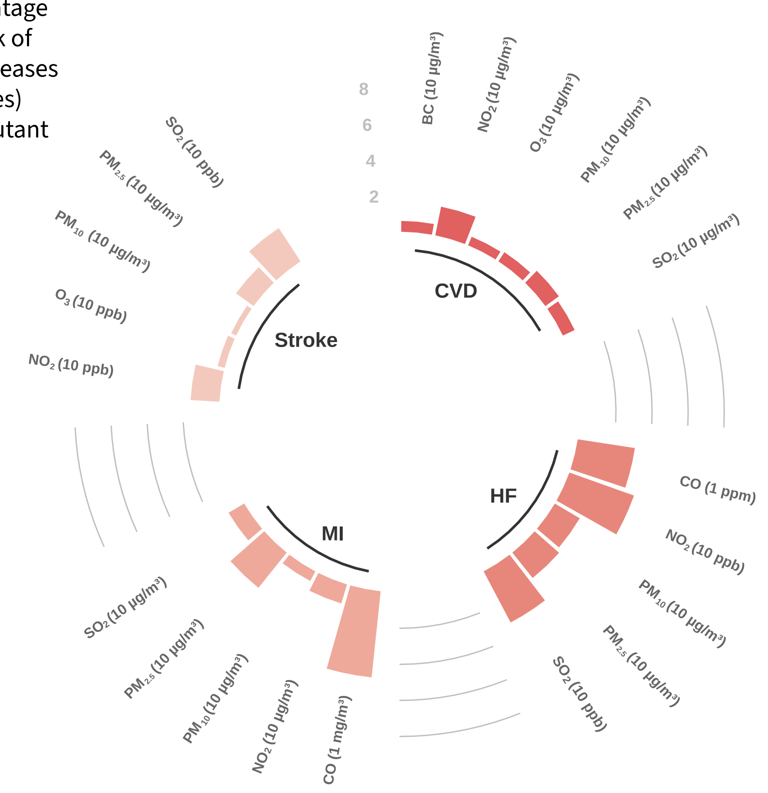
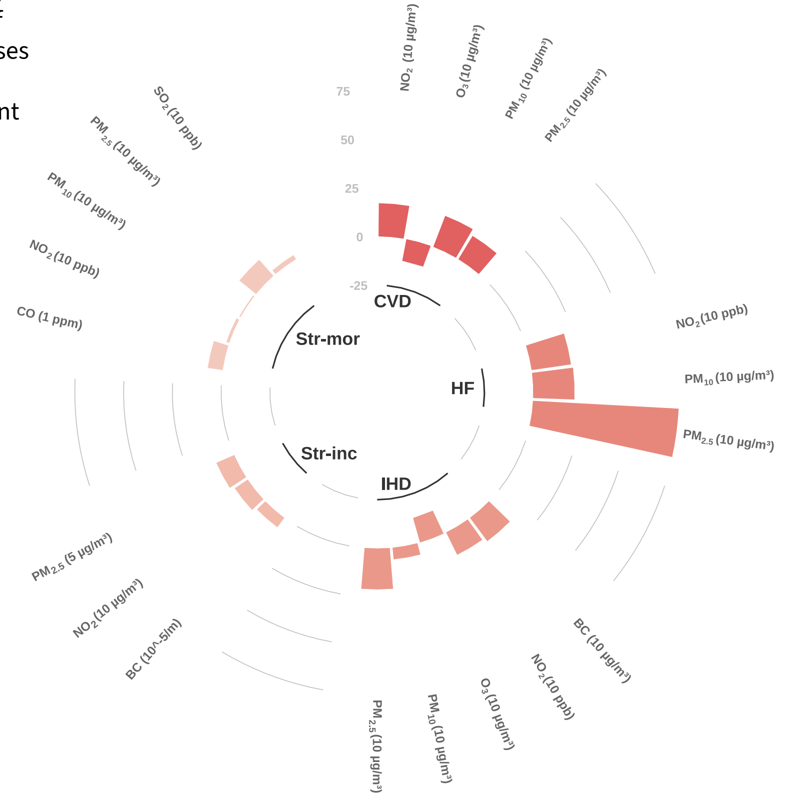



**FIGURE 10**
Long-term percentage increase in the risk of cardiovascular diseases (selected outcomes) by type of air pollutant




Source: See Online Appendix for the full set of data

Figure 9 note: Each bar represents the percentage increase in the risk of developing the condition due to short-term exposure to specific pollutants (increase unit in pollutant provided in brackets in figure). CVD - Cardiovascular disease mortality; HF - Overall risk of heart failure incidence, mortality, and hospitalization; MI - Myocardial infarction incidence; Stroke - Stroke mortality; BC - Black carbon.

Figure 10 Note: Each bar represents the percentage increase in the risk of developing the condition due to long-term exposure to specific pollutants (increase unit in pollutant provided in brackets in figure). AF - Atrial fibrillation incidence; CVD - Cardiovascular disease mortality; HF - Overall risk of heart failure incidence, mortality, and hospitalization; IHD - Ischaemic heart disease mortality; Str-inc - Stroke incidence; Str-mor - Stroke mortality; BC - Black carbon.

The developed biological understanding of the complex interplay between air pollution and cardiovascular health is helping to determine which pollutants may be most harmful and who may be particularly susceptible. This offers the promise that effective interventions—including health and policy-based measures—could be implemented to mitigate the health effects of air pollution for people who live in areas with unavoidably high air pollution.

# CARDIOVASCULAR MORTALITY AND MORBIDITY ATTRIBUTABLE TO AMBIENT AIR POLLUTION

Of the 4.2 million deaths globally attributed to ambient air pollution in 2019, almost 70% were caused by cardiovascular conditions, notably IHD (1.9 million deaths) and stroke (900,000 deaths) (Figure 13).

## REGIONAL ANALYSIS AND TRENDS

In 2019, the number of air pollution attributable deaths from IHD and stroke combined was highest in the Western Pacific (957,000 deaths) and South-East Asia (762,000 deaths) regions. China and India, respectively, belong to these regions. Overall, nearly 30% of all global ambient air pollution IHD deaths were recorded in the Western Pacific region (for both males and females). The lowest percentages were observed in Africa and the Americas for both males and females. Between 15% (in the Americas) and 25% (in the South-East Asia and Eastern Mediterranean regions) of deaths due to IHD were attributable to ambient air pollution. For stroke between 9% (in the Americas and Europe regions) and 18% (in the Eastern Mediterranean region) of deaths were attributable to air pollution.

The global number of IHD deaths attributable to air pollution increased by almost 200,000 from 2010 to 2019. Most regions experienced an increase in IHD deaths of 20-27% in this period, except for the Americas and Europe, where the number of IHD deaths attributable to air pollution increased 2.4% and decreased 19.2%, respectively. The levels of age-standardized IHD mortality rates (deaths per 100,000 people) attributable to air pollution remained mostly stable or showed a very limited decline from 2010 to 2019 across regions, except for Europe, which experienced a decline of 28% over the entire period.

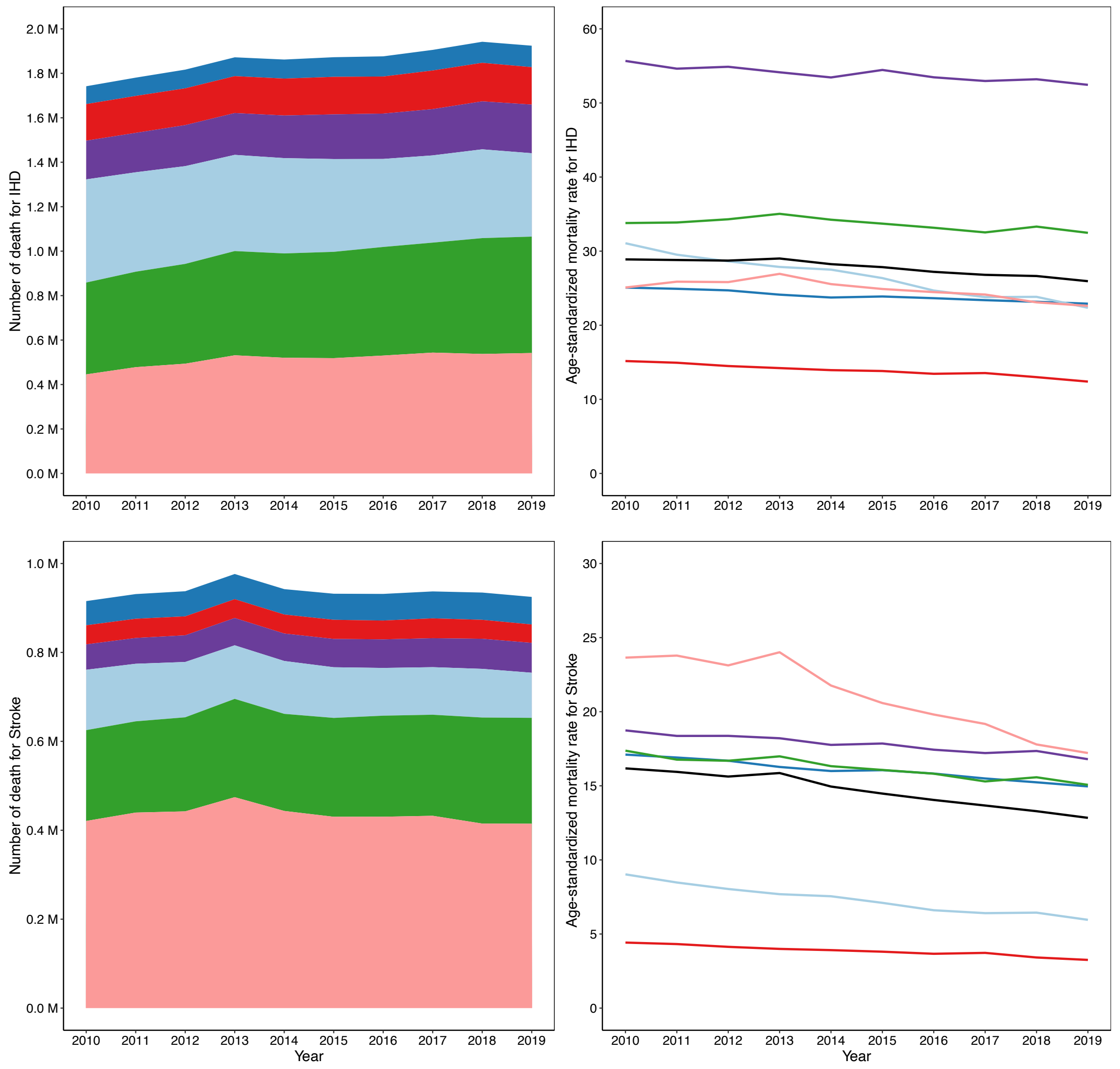
The global number of deaths from stroke attributable to air pollution increased only 1% from 2010 to 2019, though with significant regional variation. Increases were observed in the Africa, South-East Asia, and Eastern Mediterranean regions in this period, while Europe experienced a 25.3% decline, and the Americas and Western Pacific regions saw lesser reductions. Levels of age-standardized stroke mortality rates attributable to air pollution declined in all regions from 2010 to 2019, with the Eastern Mediterranean, Africa, and South-East Asia regions recording an average annual reduction of around 1%. The remaining regions experienced annual average reductions of 2.6-3.3% (Figure 11).

It is important to remember that the greater number of deaths in one region over another is down to different factors, including air pollution exposure and population size. For example, Africa and the Western Pacific had similar levels of air pollution exposure in 2019 (Figure 2), yet the latter had a higher number of deaths due to a larger population.

There is no significant difference between males and females in the regional distribution of IHD deaths attributable to air pollution, except in the Europe region, where the proportion of female IHD deaths was higher (22.5%) than male deaths (17%) (Figure 12).

Regarding deaths from stroke attributable to air pollution, almost 50% of total global male deaths occurred in the Western Pacific, compared to 40% of total global female deaths. As with IHD, the proportion of female stroke mortality attributable to air pollution in the Europe region was higher than males (13.4% compared to 8.8%)*.

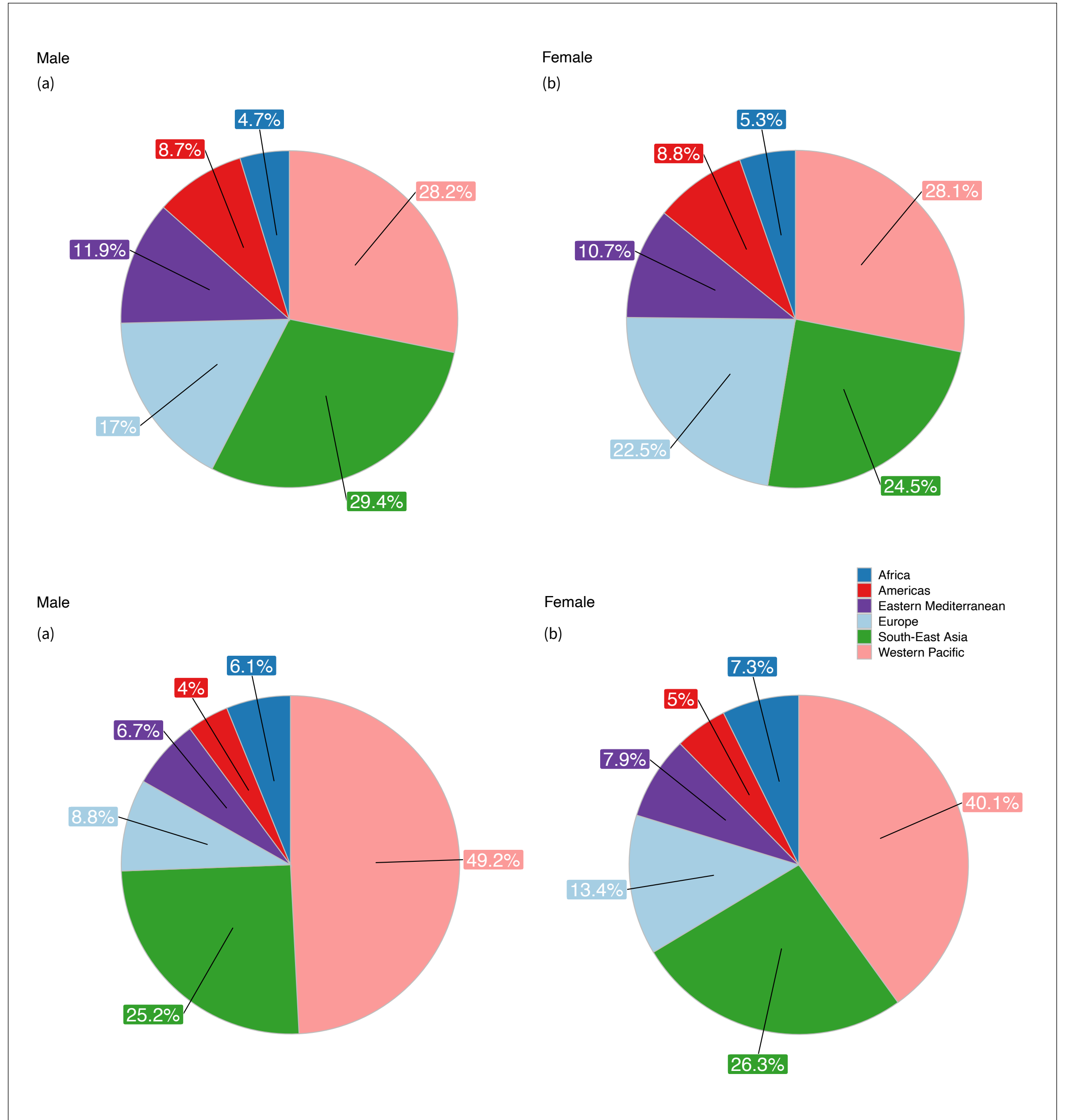
*Note that these burden estimates from an ecological study level would not capture differences in exposure to air pollution between genders arising from differences in behaviour and location throughout the day (i.e., air pollution exposure would be the same for males and females).




## FIGURE 11

Number of IHD and stroke deaths (left panels) and age-standardized mortality rates (per 100,000 people) (right panels) attributable to ambient air pollution for both sexes and WHO regions

Source: WHO Global Health Observatory




Source: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/concentrations-of-fine-particulate-matter-(pm2-5)

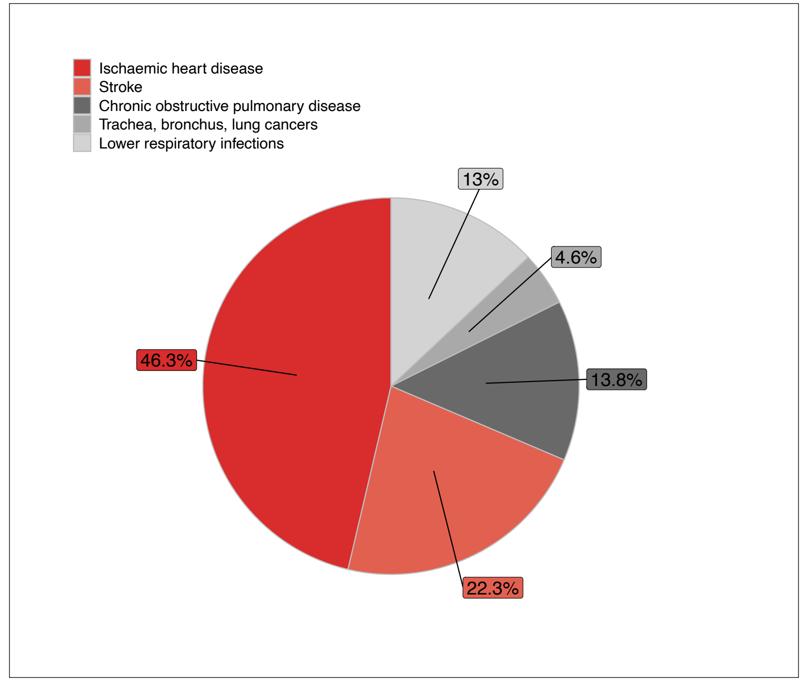
## FIGURE 12

Percentage of a) ischaemic heart disease and b) stroke mortality attributable to ambient air pollution by sex and WHO regions, 2019

Note: Data for DALYs is available in Online Appendix.

## FIGURE 13

Proportion of ambient air pollution deaths attributable to different causes



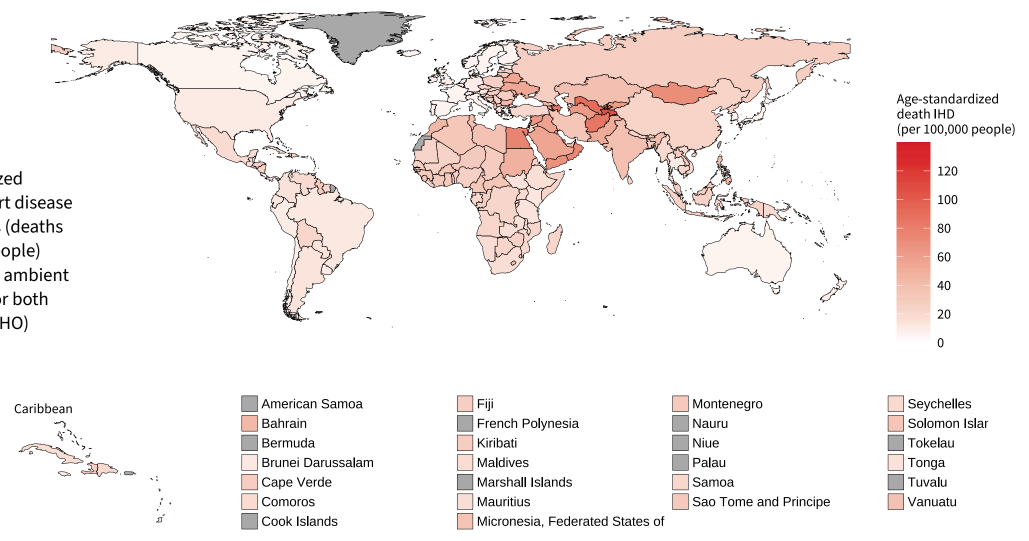



**FIGURE 14**

Age-standardized ischaemic heart disease mortality rates (deaths per 100,000 people) attributable to ambient air pollution for both sexes, 2019 (WHO)

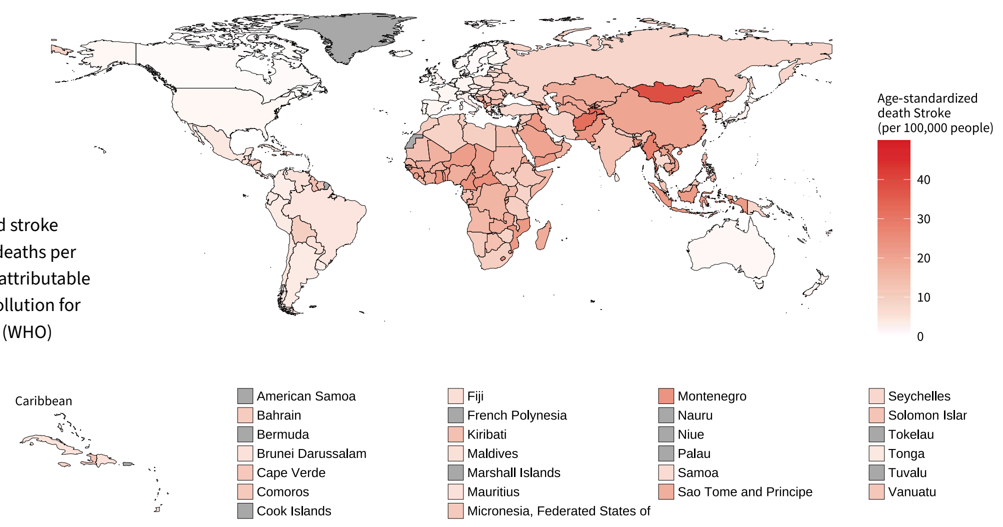



**FIGURE 15**

Age-standardized stroke mortality rates (deaths per 100,000 people) attributable to ambient air pollution for both sexes, 2019 (WHO)

# COUNTRY ANALYSIS

In 2019, the three countries with the highest age-standardized IHD mortality attributable to air pollution (deaths per 100,000 people) were Tajikistan (106 deaths; CI 74-134), Uzbekistan (90 deaths; CI 61-116) and Afghanistan (84 deaths; CI 60-106).

The lowest levels were recorded in Norway (4.8 deaths; CI 2.4-7.0), Portugal (5.2 deaths; CI 2.8-7.4) and France (5.4 deaths; CI 3.1-7.3) (Figure 14).

In the same year, the three countries with the highest age-standardized stroke mortality attributable to air pollution were Mongolia (38 deaths; CI 21-58), Tajikistan (33 deaths; CI 18-52) and Afghanistan (32 deaths; CI 17-50). Canada (0.86 deaths; CI 0.24-1.84), Iceland (0.87 deaths; CI 0.21-2.00) and Norway (0.99 deaths; CI 0.28-2.10) recorded the lowest levels (Figure 15).

In 2019, 1,973 IHD air pollution attributable DALYs were recorded in Afghanistan (CI 1,404-2,500) and Tajikistan (CI 1,339-2,433) and almost 1,700 were recorded in Uzbekistan (CI 1,154-2,185). The lowest equivalent levels were recorded in Norway (81; CI 41-120), Sweden (91; CI 49-144) and Finland (97; CI 47-150) where the lowest concentration levels of $PM_{2.5}$ exist (See Online Appendix).

For stroke, air pollution was responsible for 927 DALYs in Mongolia (CI 510-1,410), 738 in Afghanistan (CI 399-1,172) and 689 in the Democratic People's Republic of Korea (CI 370-1,060). Iceland (17; CI 4-39), Sweden (21; CI 6-47) and Canada (21; CI 6-45) recorded the lowest levels (See Online Appendix).

Note: Data for IHD DALYs and Stroke mortality rates and DALYs available in Online Appendix.

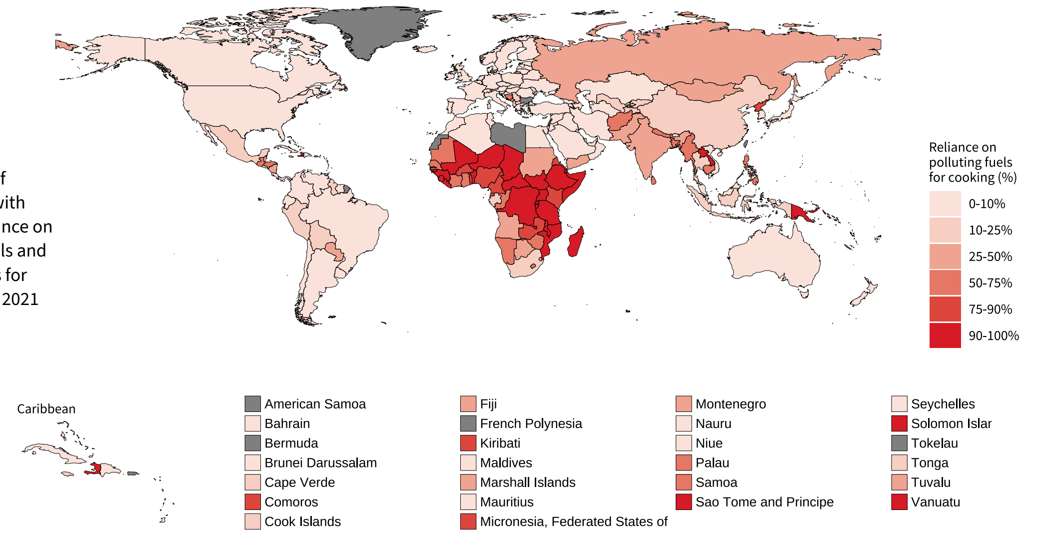



**FIGURE 16**

Proportion of population with primary reliance on polluting fuels and technologies for cooking (%), 2021

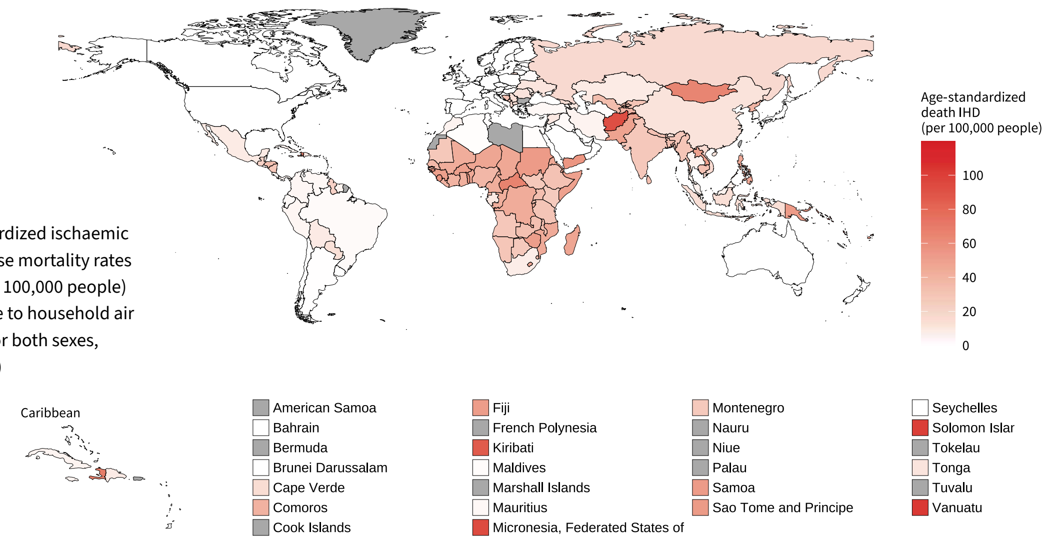



**FIGURE 17**

Age-standardized ischaemic heart disease mortality rates (deaths per 100,000 people) attributable to household air pollution for both sexes, 2019 (WHO)

All Sources: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/household-air-pollution-attributable-death-rate-(per-100-000-population-age-standardized)

# HOUSEHOLD (INDOOR) AIR POLLUTION AND CVDs

Exposure to household air pollution is among the top 10 risk factors for disease, with the poorest communities in LMICs most affected [1].

WHO estimates that over 2 billion people worldwide rely on polluting fuels such as wood, coal, crop waste, animal dung, or charcoal paired with inefficient stoves for cooking [16] (Figure 16). Considerable evidence indicates the role of household air pollution in contributing to a broad range of respiratory, cardiovascular, paediatric, and maternal conditions, among others [17].

Estimates in 2019 showed that household air pollution contributed to 3.2 million deaths annually, a similarly high level to the estimated deaths from exposure to ambient air pollution [18,19]. Over half of these 3.2 million deaths were due to cardiovascular disease, with 1 million from IHD and 700,000 from stroke.

In 2019, the three countries with the highest age-standardized IHD mortality attributable to household air pollution (deaths per 100,000 people) were Vanuatu (103 deaths; CI 79-126), Solomon Islands (100 deaths; CI 77-122) and the Federal State of Micronesia (94 deaths; CI 69-118). The lowest levels, outside of the high-income countries where no burden for household air pollution is estimated, were recorded in Argentina (0.3 deaths; CI 0.0-2.6), Jordan (0.4 deaths; CI 0.0-3.2) and Tunisia (0.8 deaths; CI 0.0-5.0) (Figure 17).

The burden of disease (including CVDs) attributable to household air pollution has declined globally over the past two decades; however, there is clear geographical variation [20]. LMICs experience most of the burden, due to comparatively limited access to electricity or gas cooking.

In 2021, the proportion of the population with primary reliance on polluting fuels and technologies for cooking was highest in Africa (Sub-Saharan region), with South Sudan (100% of the population; CI 96.1-100), Burundi (99.8%; CI 94.6-100), and Liberia (99.6%; CI 94.6-100) recording the highest values.

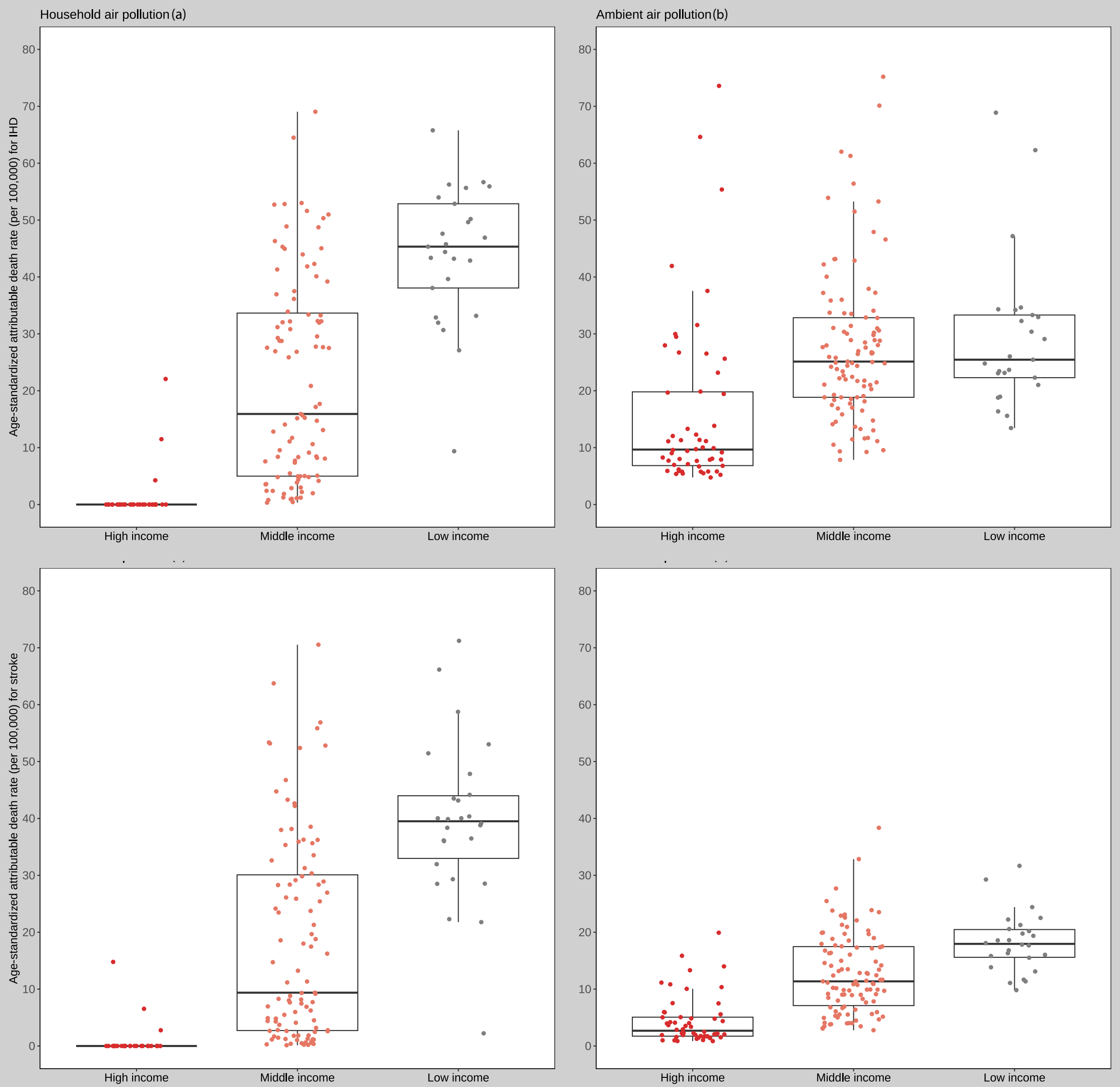
## GOVERNMENT INTERVENTION VIA POLICY AND TARGETED INVESTMENTS CAN ACCELERATE THE ADOPTION OF CLEAN COOKING SOLUTIONS AND HAS BEEN SUCCESSFUL IN COUNTRIES SUCH AS CHINA, INDIA, AND INDONESIA [21].

However, in many regions, particularly across LMICs, progress remains slow. Acknowledging these challenges, WHO guidelines recommend expansion of the use of clean fuels and technologies including solar, electricity, biogas, liquefied petroleum gas (LPG), natural gas and alcohol fuels.

It should be noted that while the longer-term goal should be a transition away from non-renewable fuels, in the short term the use of LPG should be promoted as a scalable, transitional clean household energy solution. Where access to clean fuels remains limited, more advanced combustion cookstoves that meet the emission targets in the WHO Guidelines may be prioritized in the transition to clean cooking solutions.

**FIGURE 18**

Ischaemic heart disease and stroke age-standardized mortality rates (deaths per 100,000 people) attributable to household air pollution(a) and ambient air pollution(b), by income level for both sexes, 2019




Source: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/ambient-air-pollution-attributable-death-rate-(per-100-000-population-age-standardized)

# THE DISPROPORTIONATE IMPACT OF AMBIENT AND HOUSEHOLD AIR POLLUTION ON LOWER-INCOME COUNTRIES

When countries are grouped by income level, the impacts of ambient (outdoor) and household (indoor) air pollution on people's health differ significantly (Figure 18).

Countries in the low-income group experience higher levels of age-standardized stroke and IHD mortality attributable to both household and ambient air pollution than those in the middle- and high-income groups, with the exception of IHD mortality attributable to ambient air pollution. A larger gap is observed in levels of stroke and IHD mortality attributable to household air pollution, with most of the countries in the high-income group having no deaths attributable to household air pollution (except for Guyana, Panama, and Romania).

Note: Each dot represents a country. Countries are classified as high-, middle-, and low-income based on the World Bank classification. Countries in the lower-middle-income and upper-middle-income economies have been grouped under "middle-income" economies*.

*See World Bank Country and Lending Groups – World Bank Data Help Desk. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-group

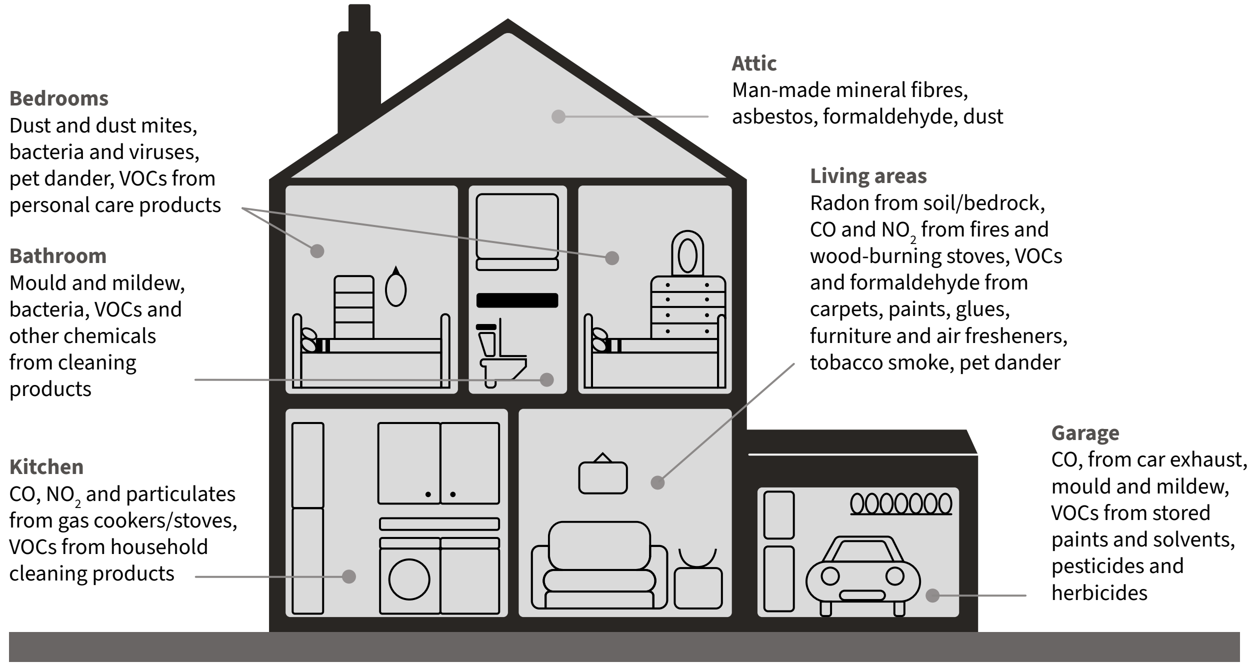
# UNDERSTANDING INDOOR AIR POLLUTION IN MODERN BUILDINGS

Indoor air pollution still poses an issue in more affluent areas/countries and modern buildings.

Cooking and heating can produce high levels of pollutants (with spikes in pollution often orders of magnitude higher than ambient levels), while there is a plethora of indoor sources of pollution such as house dust, volatile organic carbon compounds from chemically treated surfaces, cleaning products and body-care products, and bioaerosols from mould and pets (Figure 19).

At present, there is a notable absence in our understanding of the cardiovascular effects of indoor-derived air pollution in modern buildings. As the world transitions towards net-zero, a concern is that energy efficiency measures will make buildings more air-tight, reducing the egress of pollutants via ventilation and increasing the build-up of pollutants from indoor sources. Research into indoor air pollution in domestic housing, schools, workplaces, and social care is gaining momentum. However, the complexity of indoor air pollutants, buildings and user behaviour is vast, making it vital to learn from scientific knowledge of outdoor air pollution to understand modern indoor settings.

**FIGURE 19**
Sources and types of indoor pollution in homes




**Please note that these lists are not exhaustive and that the actual pollutants present, and their amounts, will vary from household to household.**

Figure reproduced from: Royal College of Physicians. https://archive-rcplondon.zedcloud.co.uk/file/every-breath-we-take-lifelong-impact-air-pollution-full-report

COOKING AND HEATING CAN PRODUCE **HIGH LEVELS OF POLLUTANTS** WITH SPIKES IN POLLUTION OFTEN ORDERS OF MAGNITUDE HIGHER THAN **AMBIENT LEVELS.**

# AIR POLLUTION INTERACTIONS WITH OTHER RISK FACTORS AND CONDITIONS

Certain groups and individuals are more susceptible to air pollution's negative health impacts, including pregnant people, those with lung or heart conditions, and those with obesity, hypertension, or diabetes. Some of these interactions are outlined in the following pages, in addition to air pollution's interaction with other pollutants (noise, light) and lifestyle factors.

Further research is needed into the cardiovascular conditions that result in elevated risk for the effects of air pollution, so that tailored guidance and interventions can be provided to these individuals and groups

## PREGNANCY

Exposure to air pollution during pregnancy is linked with effects on the mother [22], including hypertensive disorders in pregnancy and gestational diabetes, and is associated with adverse birth outcomes such as pre-term birth, low birth weight and, in some settings, still-birth [23].

Meta-analyses show that associations with adverse birth outcomes are strongest for $PM_{2.5}$, although gaseous pollutants, such as NOx, $SO_2$ and VOCs, also contribute to the burden [24].

The negative impacts of air pollution on birth outcomes are particularly prominent in low-income regions where household air pollution from solid fuel use is a major risk and contributor.

In utero exposure to air pollution has been linked to health effects in the child in later life, including the risk of developing CVDs [25].

## OBESITY & DIABETES

There is growing evidence that air pollution is linked with both obesity and diabetes, including that people living with these conditions are more susceptible to air pollution.

In human studies [26], exposure to air pollution is associated with impaired glucose handling, insulin resistance, as well as increased prevalence of diabetes and risk of death from diabetes due to long-term exposure to pollution.

Studies[26] show that $PM_{2.5}$ can increase fasting glucose levels, impair insulin signalling at multiple levels, promote changes to the build-up of fat inside our body, and cause inflammation in internal fat.

Given the prevalence of cardiovascular conditions in patients with diabetes and obesity, the effects of air pollution in obese and diabetic individuals are likely to indirectly cause significant levels of morbidity and mortality.

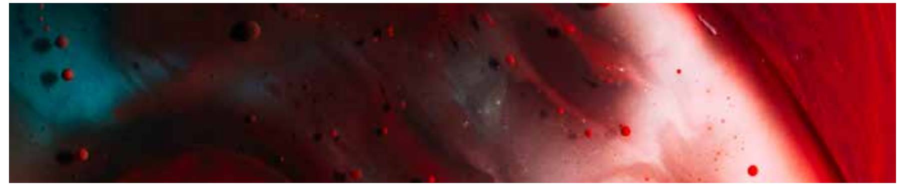
## HYPERTENSION

There is robust evidence that both short- and long-term exposure to air pollution increases blood pressure, the incidence and prevalence of hypertension, as well as hypertensive clinical events [27].

The increases in blood pressure linked to air pollution are relatively small (e.g., ~1-3 mmHg per interquartile range of air pollutant at an individual level) [27]. However, given the ubiquitous exposure to air pollution, increases of this magnitude across a population would be associated with substantial increases in cardiovascular events.

The hypertensive effects of air pollution may contribute to associations between air pollution and other cardiovascular (and non-cardiovascular) conditions and events.

The WHF Roadmap on Hypertension (2021 update) [28] calls for measures to control ambient and household air pollution to be included in comprehensive population-level programmes to reduce the burden of hypertension.



## TOBACCO SMOKING

Air pollution is the second leading cause of death from non-communicable diseases (NCDs) after tobacco smoking, according to WHO [29].

Studies suggest that air pollution and smoking build on one another to have combined cardiovascular effects [30], though further research is needed to clarify this.

Air pollution and cigarette smoke are closely related in how they impair cardiovascular function, including endothelial dysfunction, oxidative stress, inflammation, vasoconstriction, impaired fibrinolysis, and deregulation of heart rhythm [31].

There are similarities between the pollutants in certain sources of air pollution (particularly those from combustion) and those emitted in tobacco smoke. These include gases such as carbon monoxide, nitrogen dioxide, and ultrafine particles. Within these constituents, there are many other noxious chemicals, including benzene, aldehydes, alkanes, polyaromatic hydrocarbons and reactive metal species [32].

A substantial reduction in cardiovascular events—including beyond people who smoke—has been observed following the ban on cigarettes in public places in many countries [33, 34]. These positive health outcomes and the broad public appreciation for these policy interventions could provide lessons for implementing policies to cut air pollution more broadly. Further information on gains in tobacco policymaking to date and ways in which these can be strengthened can be found in WHF's Roadmap for Reducing Cardiovascular Mortality Through Tobacco Control [35].

# NOISE, LIGHT, TEMPERATURE AND MICROPLASTICS

It is estimated that 113 million people live in settings with levels of traffic noise that are harmful to health [36].

Exposure to noise has been associated with increases in the risk of cardiovascular mortality and morbidity, including IHD, heart failure, and stroke. Exposure to noise also has interactions with other conditions, such as diabetes and mental health conditions, that have known cardiovascular morbidity [37].

There is an increasing recognition of the cardiovascular health benefits of sunlight, but artificial light pollution, particularly at night, has detrimental effects on health. Studies have shown that light pollution is associated with coronary heart disease hospitalization and death [38].

The relationship between temperature and CVD mortality and morbidity usually follows an inverse bell-shaped curve (U-shaped), with extremes of either or both cold and hot temperatures associated with increased risk of cardiovascular events [39, 40, 41].* See the Air Pollution and Climate Change section of this report for a discussion on the interactions between temperature and air pollution.

As well as being found in water and the food chain, micro-/nano-plastics have also been found in the air [42]. A recent study identified nano-plastics in atherosclerotic plaques, which was associated with a higher risk of cardiovascular events and death [43].

Air pollution interacts with the above environmental risk factors, with both noise and pollutant emissions from vehicles, and higher levels of light and air pollution in urban locations.

*Evidence suggests sex and age differences in temperature-related CVD mortality, with older females being more sensitive to heat and older males being more cold sensitive.

# MITIGATING AIR POLLUTION HARMS

## DIET

Several studies show that diets rich in fruit, vegetables, fibre and protein, as well as the antioxidant-rich Mediterranean diet* can ameliorate some of the cardiovascular effects of air pollution [44].

## SUPPLEMENTS

While there is uncertainty as to the benefits of antioxidant supplements in preventing cardiovascular morbidity and mortality, studies in preclinical models with various antioxidant compounds and omega-fatty acid supplements in humans, suggest that some antioxidants may offset the detrimental cardiovascular effects of air pollution [45].

## MEDICATIONS

While reduction of air pollution emissions should remain the key priority for the prevention of the cardiovascular effects of air pollution, there may be benefits of tailoring therapeutic treatment of patients with CVDs who have largely unavoidable high exposure to air pollution, until an effective means to reduce exposure can be implemented [45].

A stronger evidence base is needed to support the limited evidence that various pharmacological medicines (e.g., statins and beta-blockers) used for CVDs can also ameliorate the cardiovascular effects of air pollution.

*Plant-based with fish and poultry, and minimal dairy.

## PHYSICAL ACTIVITY

Research is needed to better determine the benefits and trade-offs of exercising in air pollution. Exercise increases the volume of air breathed, increasing air pollution exposure; however, the cardiovascular benefits of physical activity are well documented.

While studies [46] show that cardiovascular function can be impeded by exercise next to a busy road compared to doing so in a park, modelling studies [47] suggest that the substantial benefits of physical activity are only offset if exercising in extremely polluted environments for prolonged periods of time (many hours).

Some air pollution alert systems recommend that susceptible individuals avoid strenuous exercise in episodes of high air pollution [48]. Nuance is needed in this messaging to ensure that this advice does not discourage individuals from physical activity.

Greater effort is needed to encourage active travel (walking, running, cycling or scooting, rather than using motorized vehicles) as this will generate health gains both by promoting regular physical activity and reducing the harmful emissions from vehicles. Providing pedestrian and cycle routes away from roads and reallocating road space to separate walking and cycling infrastructure can reduce vehicle traffic. Urban design practices that promote integrated accessible walking and cycling infrastructure, mixed-use destinations in neighbourhoods as well as co-located community facilities can also facilitate increases in walking and cycling and reduction in air pollution. Provision of public open spaces and green spaces can help meet physical, recreational, and social needs.

WHF has published a Policy Brief on Physical Activity [49] that provides guidance to different age groups and those with health conditions on physical activity and outlines the strategies to promote healthy physical activity that can be activated by different stakeholders.

# AIR POLLUTION AND CLIMATE CHANGE

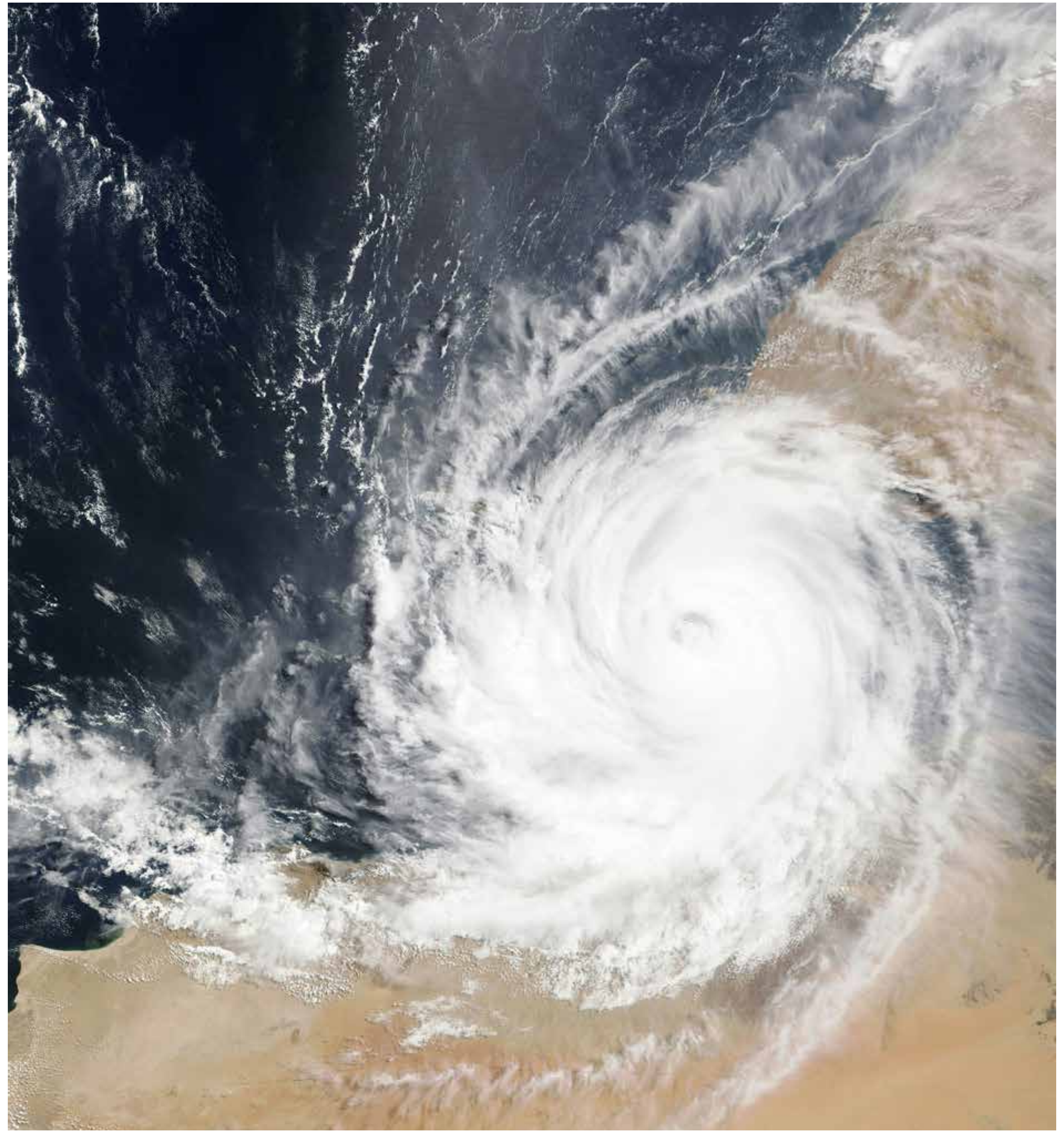
Climate change and air pollution are interlinked. Most of the major drivers of air pollution, such as fossil fuel combustion and other anthropogenic activities, are also sources of greenhouse gas emissions, thereby driving climate change, while major environmental events caused by climate change increase air pollution, creating a vicious cycle [50].

## AIR POLLUTION'S CONTRIBUTIONS TO CLIMATE CHANGE

In addition to contributing to greenhouse gas emissions, fossil fuels lead to the generation of black carbon particles, which can absorb heat, with a higher global warming potential than carbon dioxide. This is not the case for all particulate matter, as some absorb heat and some reflect it, meaning that the net warming/cooling effect on the planet will depend on the source and composition of PM, as well as atmospheric conditions and co-pollutants [51]. Further evidence is needed to understand the complexity of the science and establish effects on health.

## CLIMATE CHANGE'S CONTRIBUTIONS TO AIR POLLUTION

Climate change leads to an increase in the intensity, frequency, and duration of extreme weather events, including storms, floods, droughts and extreme temperatures, ecosystem collapse, declines in global food production, and nutritional quality of major crops [52]. Climate change can exacerbate air pollution through events like wildfires, desertification and dust storms, and the longer window of warmer and drier temperatures that contribute to an increase in ozone production [53].



# THE HEALTH IMPACTS OF CLIMATE CHANGE-RELATED AIR POLLUTION ARE MYRIAD.

Wildfire smoke has been linked to IHD, heart failure, and hospitalization for acute coronary events and stroke [54]. The increase in incidence, size, and severity of wildfires in recent years has produced plumes of harmful air pollutants that can travel many kilometres from source, polluting densely populated urban areas as well as more rural communities.

Climate changes have led to longer pollen seasons, with biological exposures like pollen and mould interacting with air pollutants to exacerbate allergic diseases [55].

Heat is often accompanied by stagnant weather, reducing the dissipation of air pollutants and promoting photochemical formation of other pollutants, such as ozone. Stagnant weather from temperature inversions can also result in episodes of cold temperature and air pollution, precipitating cardiovascular stress [56].

## TEMPERATURE, AIR POLLUTION, AND CVDs

Climate change alone (i.e., non-air pollution related) impairs the cardiovascular system, both directly and indirectly, in ways that closely parallel those induced by air pollution.

CVDs can be attributed to extreme temperatures; for example, heat has been linked with endothelial dysfunction and systemic inflammation. The cardioregulatory response to increased heat involves an increased peripheral circulation and an increase in the core body temperature. Additionally, dehydration associated with extreme heat can cause low blood volume and increased blood viscosity. Heat intolerance and subsequent cardiovascular dysregulation results when the cardiac output is unable to compensate for this. Conversely, exposure to cold involves increased blood pressure, cardiac workload, and vasoconstriction, which can lead to cardiovascular dysregulation and reduced blood flow to the heart [51,57].

Temperature and air pollution have been shown to each enhance the impacts of the other [58]. Whether the health effects of temperature and air pollution—in particular their cardiovascular effects—act synergistically is yet to be determined. However, it is highly plausible that these stressors will act in concert to increase the risk of cardiovascular events.

## INDIRECT IMPACTS OF CLIMATE CHANGE

The indirect health impacts of climate change are exacerbated by certain socio-economic factors, including, poverty, access to healthcare and health inequalities, underlying susceptibilities (e.g., age or sex related), disruption of social services, and the capacity of health systems to resist and manage climate hazards.

Similarly, air pollution has health inequities both in terms of the level of exposure (with those of lower socio-economic status likely to have higher exposure) and effect (with those that are already vulnerable being more biologically susceptible to the effects of pollutant exposure). The impact of climate change will exacerbate these inequalities and compound efforts for those at greatest risk to live healthily and seek medical help [59].

It is undeniable that the environmental and social consequences of climate change will increase the prevalence and severity of CVDs over this century without strong health and socio-economic interventions. Because they are closely interconnected, mitigation and other interventions targeting and tackling air pollution have the co-benefit of acting on climate change [60].

There is a need to be cautious that policies and interventions to tackle one environmental risk do not have inadvertent consequences on another. In the early twenty-first century, some manufacturers and governments pushed the adoption of diesel cars to reduce greenhouse gases; however, this overlooked the greater levels of ultrafine particles produced by these vehicles compared to other fuel types. The focus on reducing the reliance on fossil fuels is likely to have mutual benefits in slowing climate change and improving air quality [61]. Understanding the science behind these crucial environmental risk factors, and how they impact NCDs like CVDs, will maximize these gains.

# AIR QUALITY GUIDELINES AND POLICIES

National and local governments have a critical role to play in reducing air pollution through policy implementation. The 2021 WHO Global Air Quality Guidelines provide policymakers with recommended levels for air pollutants based on the evidence of their impact on health, along with interim targets to guide progress towards recommended levels.

A range of evidence-based policies to reduce air pollution in line with these targets exist in many countries. At the city level, these include steps to reduce emissions from vehicles through traffic charging and parking policies, improved public transport and infrastructure for cycling and walking, zoning laws to prevent residential zones being near areas with industrial and traffic activity, updated building codes to require indoor air filtration and reduce penetration of ambient air pollution, advisory and prevention monitoring to notify communities if pollutants are exceeding safe levels, fossil fuel taxes, and penalties for excessive air pollution [62]. The following section presents several case studies of the successful implementation of such policies.

At the national level, governments can provide policy support and legal frameworks for the implementation of more local policies. This includes national legislation and engagement with global mechanisms related to setting and monitoring air pollution standards and commitments, such as the 2015 Paris Climate Agreement and the annual World Health Assembly.

The 2021 UN Environment Programme (UNEP) report 'Regulating Air Quality: The first global assessment of air pollution legislation' assessed national air quality legislation in 194 countries and in the European Union. The study found that 122 countries plus the EU (64%) have legislation or policy/guideline documents empowered under law, which contain ambient air quality standards (AAQS) [63]. Most countries without AAQS legislation are in the Africa region (Figure 20).

**FIGURE 20**
Countries with legal instruments containing Ambient Air Quality Standards

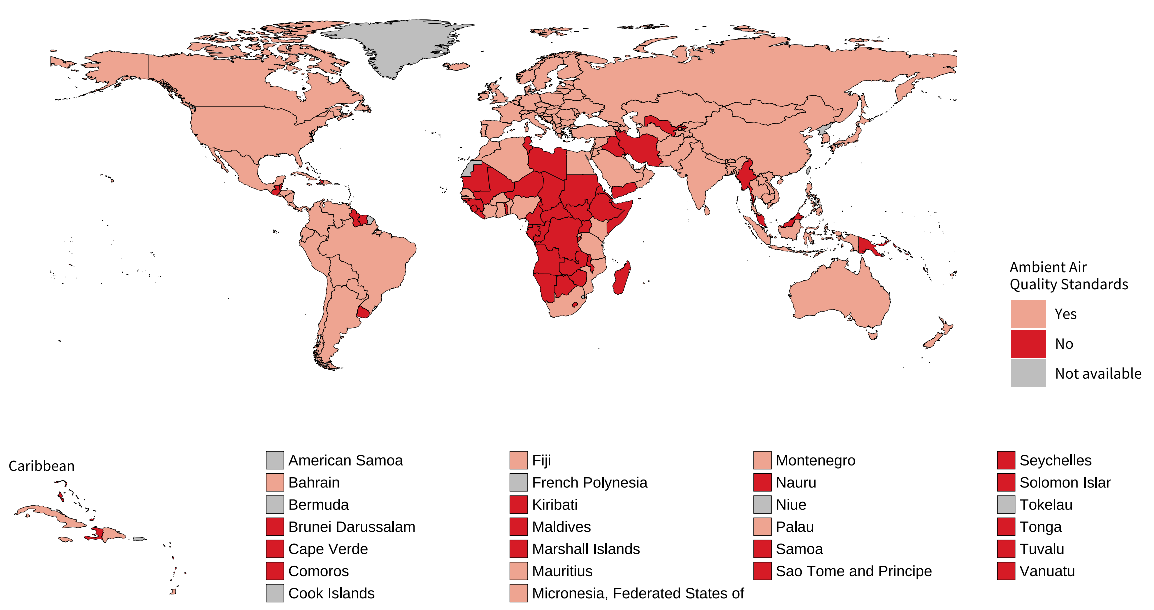



Figure reproduced from: https://www.unep.org/resources/report/regulating-air-quality-first-global-assessment-air-pollution-legislation

## HOWEVER, THE STANDARDS INCLUDED IN NATIONAL AIR QUALITY POLICY AND LEGISLATION OVERWHELMINGLY DO NOT ALIGN WITH THE VALUES SET IN THE WHO GLOBAL AIR QUALITY GUIDELINES.

The WHO Health and Environment Country Scorecards [64], which evaluate 121 countries' management of air pollution and other environmental risks, show that none of the included countries have legal standards that align with the 5 µg/m$^3$ annual mean of $PM_{2.5}$ recommended by WHO guidelines [65].

UNEP also reports that 55% of countries allow routine exceedances of their legal standards, which can mask non-compliance if the exceedances are set broadly. The proportion of countries with legal requirements to monitor air quality is similarly limited at only 57%. Europe is the only region where a notable majority of countries have a requirement to monitor air quality incorporated into law (95%). The Americas (53%) and Eastern Mediterranean (50%) are the only other regions with half or more of countries having such legislation, with Africa (30%) having the lowest proportion of countries with a legal requirement for monitoring (See Online Appendix).

The right for civil society and citizens to access such information on air quality is important for awareness raising and public participation in efforts to mitigate the harms of air pollution. While 61% of countries have a public right to access air quality data, in many instances this requires the public to specifically request this information. In only 39% of cases does the state have a duty to disseminate such information, with the majority being in Europe where 82% have legislation outlining such an obligation for the state. Around a third of states have such legislation in the Americas (33%) and Western Pacific (32%), whereas the proportion is less than a fifth of states in Africa (18%), Eastern Mediterranean (14%), and South-East Asia (10%) (See Online Appendix).

Countries that are signatories to the Paris Climate Agreement regularly report their commitments and planned policies for reducing greenhouse gas emissions through Nationally Determined Contributions (NDCs). Many policies and measures contained within NDCs relate to or overlap with efforts to mitigate air pollution, given the links between air pollution and climate change (discussed in the preceding section). The Global Climate and Health Alliance published a scorecard in 2023, which assessed the extent to which countries' NDCs integrate air quality and health considerations, including their mention of health impacts, air pollution source sectors, monitoring targets for specific pollutants, and discussion of the cost of air pollution or budget for improvement actions [66]. Notably, 14 of the 15 countries with the greatest consideration of health in their NDCs were LMICs. Overall, less than a third of analysed NDCs referred to the health impacts of air pollution.

There is also a need for stronger policies and commitments from governments and multilateral bodies to increase funding for research, technical innovations, and implementation projects to tackle air pollution. The Clean Air Fund's analysis of the funding allocated to air pollution research [67] shows that while funding for air pollution is increasing, less than 2% of international development funds, philanthropic foundation funding and international public climate finance went to tackle air pollution between 2015 and 2021.

## WHO RESOURCES ON AIR POLLUTION INTERVENTIONS

Interventions to reduce emissions and exposure to air pollution exist. However, it is important to identify those that are most efficient, assess the logistics of implementation, and decide how the success of the intervention will be assessed in terms of pollutant reduction, health impact and socio-economic gains. WHO has launched a repository of systematic reviews evaluating interventions in several environment, climate change and health topics, including air pollution [68].

This repository can serve as a tool not just for researchers, but also for decision makers, to identify and assess available evidence on effectiveness of interventions. Additionally, WHO has published a compendium of guidance on health and environment, including guidance on air pollution policies and actions, awareness building and capacity strengthening [69]. Continued funding will be important to ensure these important resources are kept up-to-date with the scientific evidence.

# EVOLVING AIR POLLUTION GUIDELINES

### WHO "BEST PRACTICE" GUIDELINES:

As well as making more stringent requirements for the key air pollutants, in its 2021 Global Air Quality Guidelines, WHO makes recommendations for black carbon (a constituent of PM commonly associated with combustion sources), ultrafine particles (UFPs), and sand and dust storms [65]. Specific targets were not set for these pollutants because of the lack of systematic monitoring and a smaller body of evidence on their health effects. Nonetheless, there is sufficient evidence to suggest these pollutants are likely to have toxicity, directly or indirectly. Highlighting these pollutants of concern is forward looking and should help direct future research and policy. In particular, UFPs are relevant for CVDs, as particles of this size can cross from the lung into the blood to directly interact with the cardiovascular system and have been shown to accumulate in areas of vascular disease [70].

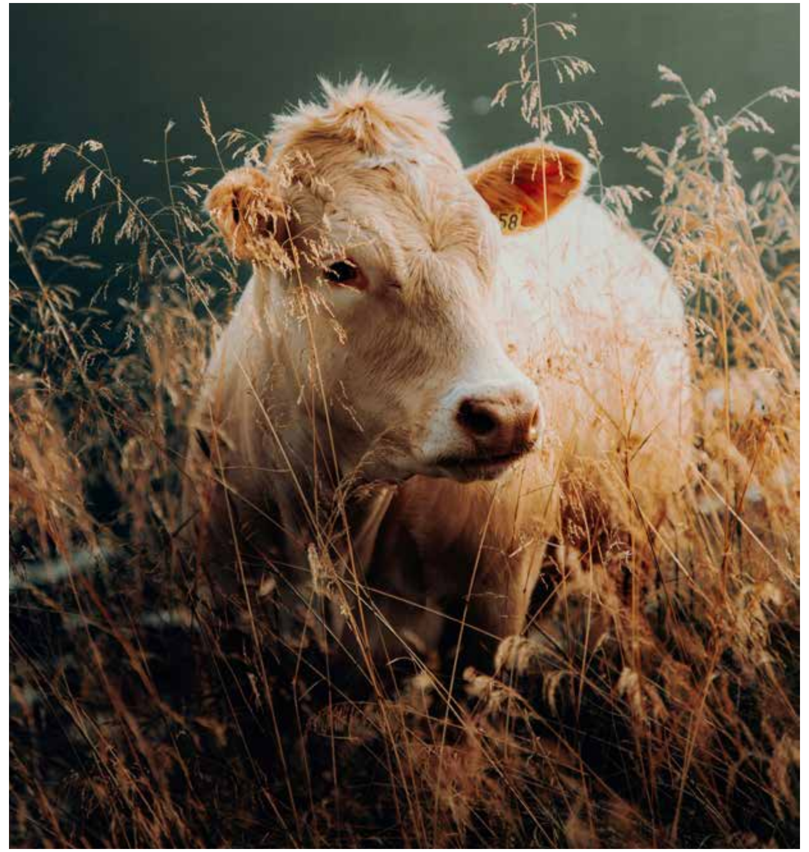
### AGRICULTURE POLICIES

Agriculture is a significant source of air pollution.

The gas ammonia is emitted into the air from livestock waste and fertilizer use. Ammonia then reacts with acidic sulphate and nitrates in the atmosphere to form secondary ammonium particulates. These secondary particulates can travel hundreds of kilometres and even in European cities, 20-40% of $PM_{2.5}$ can be derived from ammonium compounds [71]. Methods to reduce ammonia emissions from agricultural practices already exist (e.g., urease inhibitors in fertilizer, slurry store covers, fertilizer injection, and lower protein animal feeds).

However, farmers across the world already increasingly work on narrow economic margins and pressures from bureaucratic administration. Future agricultural policies are needed to tackle the relatively limited progress in reducing ammonia emissions over the last few decades, but should balance flexibility and enforcement, and consider financial support to implement technological innovations. Fostering vegetable production with an agroecological focus, and the promotion of composting would result in the reduction of the use of chemicals and synthetic fertilisers. Moreover, this could relieve the pollution related to incineration of organic waste and GHG production by landfills [72].

Another source of agricultural-derived emissions, especially in LMICs, is from crop and stubble burning. Plumes from agricultural biomass burning are significant and can travel long distances, contributing to the PM levels in neighbouring countries [73]. Committees and agreements on transboundary pollution exist, although cross-border pollution remains a politically contentious issue, and there is the risk that the need to meet more stringent air quality measures may heighten these disagreements and political "blame-games". International co-operation and policies based on international multidisciplinary science will be vital in demonstrating the gains that can be made when countries work together to improve air quality. Finally, we note the cardiovascular effects of agriculture-derived emissions, especially secondary PM from ammonia, are yet to be established. An understanding of the contribution of agricultural PM to CVDs would provide scientific support to accelerate policy change.



### VEHICLE STANDARDS

Many countries have legislation and annual checking for vehicle standards to ensure safety, and the inclusion and extent of emission testing is growing.

Progress has been made in reducing tailpipe emissions from new vehicles, both in terms of $NO_2$ and particulates, even in modern diesel engines where emissions are becoming comparable to that of gasoline engines. However, there is a need to avoid complacency. Even acute exposure to vehicle exhaust has multiple detrimental effects on facets of cardiovascular function, with a magnitude that is comparable to long-term smoking (74,75). And while modern vehicle engines are substantially cleaner than their counterparts a decade ago, the average vehicle age is around 10 years old in European nations, considerably older in LMICs. The installation of "particle filters" on vehicle exhaust has been a factor in reducing PM emissions from newer vehicles, yet compliance to maintain (or even retain) these filters is mixed [76]. Vehicle exhaust is also the major source of harmful ultrafine particles in urban areas (though these smaller particles are not adequately captured by mass metrics such as $PM_{2.5}$). Experts in vehicle emissions are advocating for legislation for the inclusion of particle number counts (a surrogate for UFP concentrations) in annual vehicle standard checks.

Pending formal approval from the European Council, the new Euro 7 standards for vehicles will enter into force in the European Union in 2024 [77]. The notable addition to these standards is the inclusion of limits for brake and tyre wear particles. As the world slowly moves away from the combustion engine to cleaner technologies such as electric vehicles, the proportion of non-exhaust emissions from traffic will increase. The European Council estimates that 90% of all particulate matter emitted by road transport in the EU will come from non-exhaust emissions such as brake and tyre emissions by 2050. Due to the heavier weight of electric vehicles, levels of brake and tyre wear PM may be greater than comparative combustion engine vehicles (although developments in regenerative braking and lighter batteries are off-setting this to some extent). Developing the legislation on non-exhaust emissions will be important over the forthcoming decades, and the passion for technological innovation in this area is reassuring. Ultimately, though, cardiovascular effects remain woefully under-explored, and research could further drive progress in this area.

### PROVISION OF CLEAN DOMESTIC FUELS

Indoor air pollution is associated with significant levels of morbidity and mortality, including through CVDs (see section on Household Pollution and CVDs). Solid-fuel use drives this burden in LMICs, with domestic exposure to combustion-derived PM and gases especially high during cooking and home heating [78]. In low-income regions, single-room housing may lead to prolonged exposure to pollutants where ventilation is not considered, especially for women who tend to have greater exposure to cooking fumes in LMICs. A move from solid fuel combustion to the use of LPG and solar panels is urgently needed in LMICs, with use of clean stove combustion advisable where clean fuel options are not available. As poverty may make individuals are unable to make this transition themselves, provision of cleaner fuels from both local and external bodies is essential. There are examples of clean fuel initiatives in many countries, such as the World Bank-supported Bangladesh Improved Cookstove Programme. This used a market model to help 3.4 million people gain access to improved cooking solutions while creating 3,000 jobs and saving 3.54 million tons of biomass fuel annually [79]. Successful programmes such as the one in Bangladesh will be helpful in guiding and expanding other programmes. It is important that governments, local bodies, and international partners provide the necessary support, financially, logistically and through legislation, to make clean fuel provision universal.

### URBAN PLANNING AND INFRASTRUCTURE

Over 50% of the world's population lives in cities [80].

While cities can provide greater access to amenities and healthcare, they are also likely to have higher levels of harmful air pollutants. Innovative city design and development can help reduce both emission of air pollution and exposure to it. Better housing may reduce the ingress of ambient air pollution into indoor spaces, and ventilation can be optimized to reduce egress of indoor air pollutants out of the home [81]. Reducing the reliance on vehicles for transport would also have significant benefits, not only in reducing vehicle emissions, but also in promoting the health gains of active travel (see section on Air Pollution Interactions with other Risk Factors and Conditions) [82].

City design can reduce car journeys by providing the necessary amenities within walking/cycling distance. Safe active travel space and improved public transport will be essential for this to be effective. The provision of parks and greenspace will provide lower air pollution areas to exercise, and a means to improve mental wellbeing [83]. The transition to "20-minute neighbourhoods", where necessary amenities can be reached from a residence within 20 minutes without taking a private vehicle, will take considerable time and resources to achieve; however, policies are moving in this direction, with cities including Bogotá, Melbourne, Milan, Paris, and Portland cited as good practice examples [84].

The gradual move towards healthy cities will be rewarded through gains in physical and mental health, as well as economic and environmental sustainability [85].

### ENVIRONMENTAL INJUSTICE: ADDRESSING INEQUITIES THROUGH FUTURE POLICIES

Environmental injustice is the inequitable and disproportionate exposure of poor, racial and ethnic minorities, and disenfranchised populations to toxic chemicals, air and water pollution, unsafe workplaces, and other environmental hazards.

The concept of environmental injustice was first used in the 1980s by Black and Latino communities in the United States exposed to hazardous waste sites and has since developed in other areas of the world [86]. The idea of environmental injustice is correlated with the unequal exposure to pollution, and other factors linked to poverty, such as inadequate access to medical and preventive care and other conditions like malnutrition or the lack of pollution healthcare in the workplace [87]. In LMICs, heating and cooking by biomass and the relocation of polluting industries from high-income countries are emblematic of the disparities in air pollution exposure [88].

Under the coordination of the Autonomous University of Barcelona, the Environmental Justice Global Atlas collates almost 4,000 environmental "conflicts" around the world, whereby civil society actors have mobilized against a socio-environmental issue [89]. Conflict projects include ammonia-coal co-firing in efforts to prolong coal plant lifespans in Asia, a waste incinerator close to populated areas in North America, the development of industrial areas with high environmental impact in South America, and the creation or expansion of airports and motorways. These are examples of environmental justice conflicts involving air pollution that can be found on every continent, with the majority most likely to have a greater impact on vulnerable populations with little capacity to enforce their rights.

# CASE STUDIES OF AIR QUALITY INTERVENTIONS

## BARCELONA, SPAIN: GREENING URBAN SPACES

In the initial eight years since 2013 when targeted policies were introduced in Barcelona to "green" urban zones, reduce vehicle congestion, and combat air pollution, the city saw a 30% decrease in $NO_2$ emissions. Measures introduced to achieve this result include the employment of new air quality monitoring stations, the creation of a new bus network, and the expansion of the metro and bicycle lane networks, resulting in 56% more bicycle journeys. The changes to the urban environment have also helped incentivize journeys on foot, with more pedestrian-friendly streets and spaces. The activation of the Low Emission Zone (LEZ) in 2017 also resulted in a reduction in the initial measurement period of 600,000 journeys by vehicles that pollute the most, while the gradual switch to electric vehicles for the municipal fleet of the City Police and cleaning and waste collection vehicles has helped cut pollutant emissions [90].

## ULAANBAATAR, MONGOLIA: PHASING OUT RAW COAL

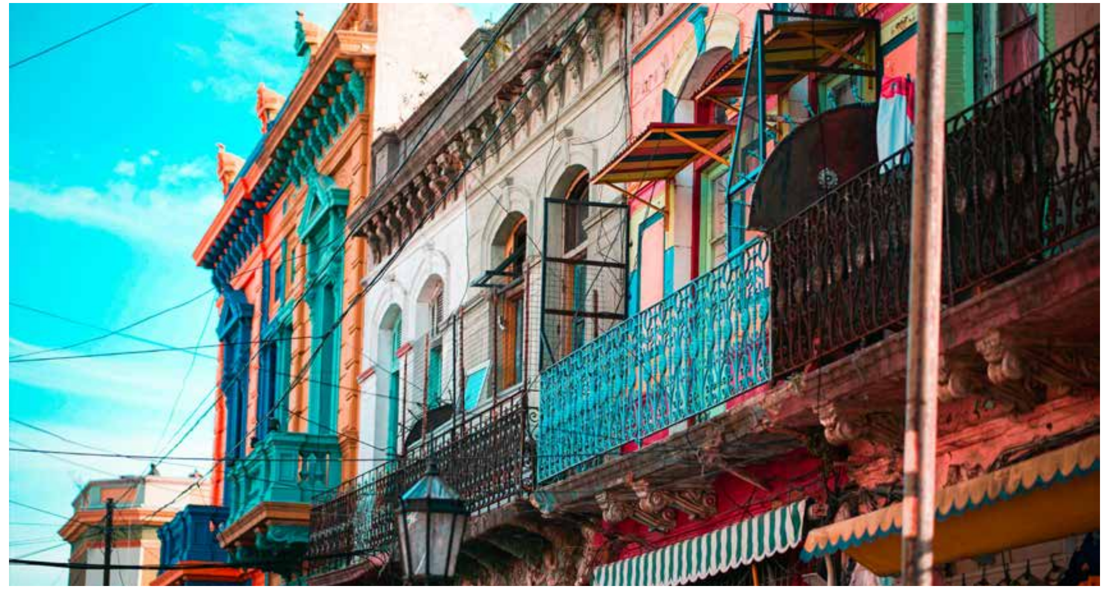
Ulaanbaatar is recognized as both the coldest and most polluted capital city in the world. Multiple projects have helped shift heating and energy production from the burning of raw coal to other, cleaner sources. A recent two-phase investment by the Asian Development Bank focused on 1) the piloting of coal briquettes and establishing technical standards for vehicle pollution; and 2) implementing the policies supported in phase 1 with a loan. The average ambient $PM_{2.5}$ concentrations in the winter of 2019–2020 were 51% lower compared to the winter levels of 2016–2017, 46% lower compared to 2017–2018, and 40% lower compared to 2018–2019, exceeding the targeted 30% reduction compared with 2016 levels [91].

## CAMEROON, AFRICA: GRASSROOTS ADVOCACY FOR CLEAN AIR AND DISEASE PREVENTION

In 2020, the Global State of the Air Report ranked Cameroon eighth among the top 10 countries with the highest population weighted annual average $PM_{2.5}$ concentration level (65 µg/m³). In 2019, the World Organization of Family Doctors (WONCA) conducted a comprehensive air pollution and health train-the-trainer programme for healthcare professionals with active participation of experts in Yaoundé and Douala, the political and economic capitals, respectively. Following training, the Association for the Promotion of Youth Leadership, Advocacy and Volunteerism Cameroon (APYLAV) undertook advocacy visits to the Ministry of Public Health. This resulted in a collaboration agreement between the Ministry of Public Health and APYLAV, with the objective of promoting health and preventing diseases by raising awareness about environmental health, particularly focusing on air pollution and air quality among youth. Over 2,000 students were trained through various activities, including two UN International Day of Clean Air for Blue Skies events in 2022 and 2023. These were funded by the European Lung Foundation's Healthy Lungs for Life grant and advocacy campaigns, such as the Global Action Plan and UK Freedom to Breathe campaign. With support from the CLEAN-Air (Africa) project, APYLAV trained over 500 medical students from different universities in Cameroon. The Cameroon government has acknowledged the Global Youth Strategy on Air Pollution and Climate Health as an organization in 2022 to help curb the burden of air pollution on the health of youths in Cameroon and beyond [92].

## BUENOS AIRES, ARGENTINA: COMPREHENSIVE PLANNING FOR INCLUSIVE REDUCTION OF AIR POLLUTION

According to the 2022 IQAir report, Buenos Aires ranked sixth among capitals with the highest levels of air pollution, despite Argentina having relatively low levels of air pollution when compared with other countries. Buenos Aires City has generated a Climate Action Plan—currently in its third phase—to be recognized as a carbon neutral, resilient and inclusive city by the year 2050. This programme, which seeks to reduce greenhouse gases by 53% by the year 2030 and 84% by the year 2050, includes efforts to become a prepared city (infrastructure and green space development), a nearby city (promote non-motorized transportation by a pedestrian-friendly polycentric city), an innovative and low-carbon city (rational and more efficient use of energy, fostering the circular economy), and, an inclusive city (equitable distribution of the benefits of climate action). If this effort is implemented in full, it could reduce CVDs related to air pollution in the coming years [94].



## BEIJING, CHINA: MAJOR ACTION AND INVESTMENT FOR RAPID AIR POLLUTION REDUCTION

In the early 2000s, Beijing faced a rise in air pollution, prompting temporary measures during the 2008 Olympic Games. However, severe pollution episodes persisted in the winter of 2012, leading the government to recognize air pollution as a critical issue. In response, Beijing introduced a comprehensive five-year action plan in 2013, acknowledging the severity of air pollution and aiming for substantial improvements in public health and sustainable growth. The plan included specific targets, stringent emissions standards, and measures to address loopholes in enforcement, with a notable focus on the transport sector. Initiatives such as a city-wide licence plate lottery for fossil fuel-burning cars and incentives for electric vehicles aimed to reduce vehicular pollution. Additionally, efforts to control truck traffic through the city were implemented. Beijing, once known as the "Kingdom of the Bicycle", reintroduced bike-sharing schemes to promote cleaner modes of transportation. Beyond transport, initiatives to promote the use of cleaner household fuels, restructure industry, close urban centre power stations, and repair neighbouring ecosystems to prevent dust pollution were all implemented. Following significant financial investment, with the budget to combat air pollution soaring from 3 billion yuan (approximately, US$480 million) in 2013 to over 18 billion yuan (approximately, US$2.7 billion) in 2017, the improvements in air quality were significant. By the end of 2017, the annual average $PM_{2.5}$ concentration in Beijing had decreased by 35%, sulphur dioxide by over 93%, and nitrous dioxide by nearly 38%. Heavy pollution episodes became less frequent and less intense, showcasing the success of Beijing's comprehensive action plan [94].

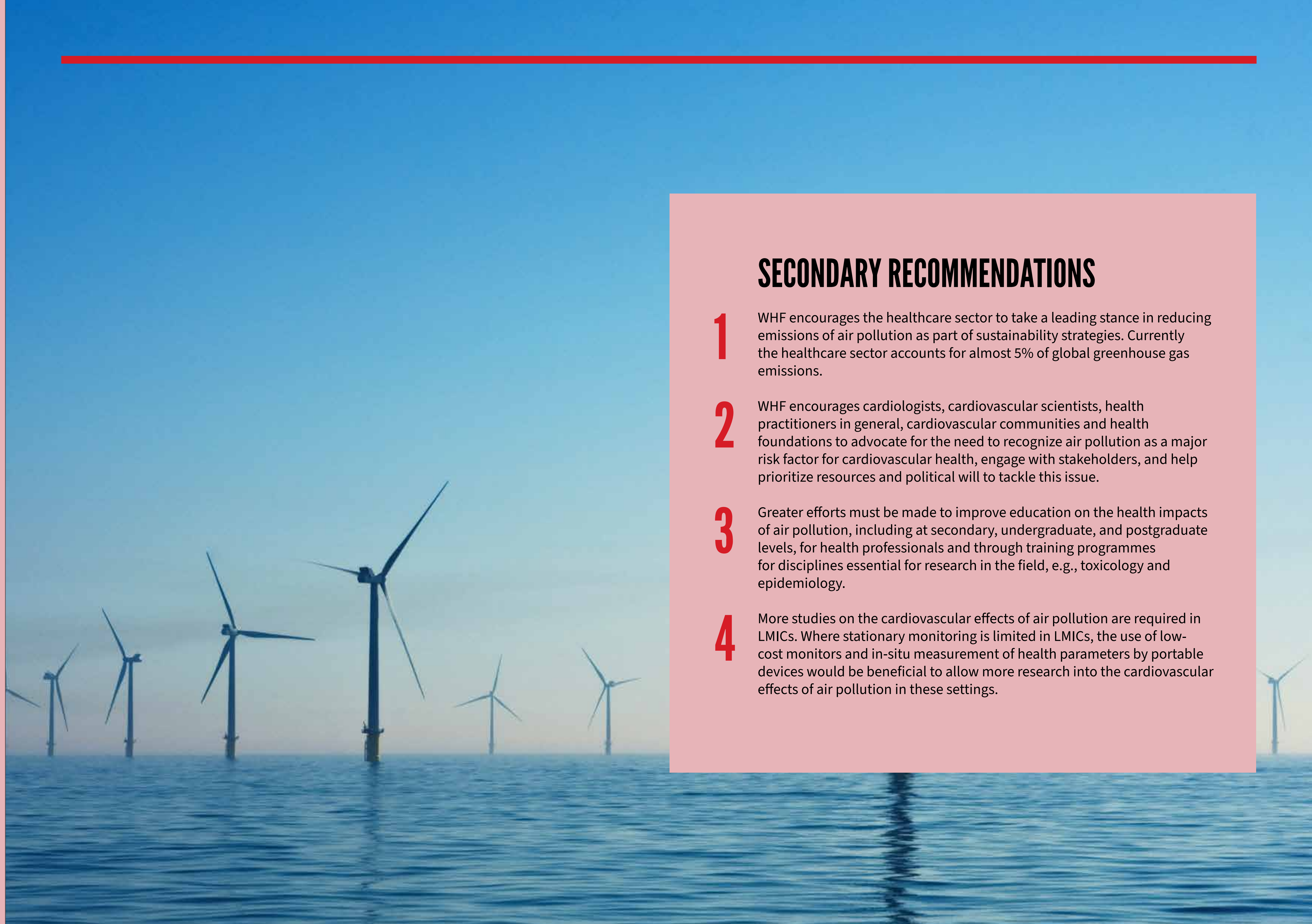
# KEY RECOMMENDATIONS

All countries and stakeholders must urgently work together to accelerate efforts to curb air pollution levels and implement policy and health interventions to protect people from its most harmful effects. These actions will be critical to achieving Sustainable Development Goals related to cutting non-communicable disease mortality, as well as having broader benefits with regard to tackling the climate crisis.

To help promote urgent action against air pollution and its impacts on cardiovascular disease and health more broadly, the World Heart Federation recommends the following:

## PRIMARY RECOMMENDATIONS

1. All countries must adopt the new WHO global guidelines on air quality. This includes making a roadmap of strategies to meet the interim targets outlined by WHO whilst progressing to the overall guideline level. Policies should be multifaceted and multi-sectoral, encompassing, among others, health, housing, city design, transport, and agriculture.
2. WHF supports the implementation of a global fossil fuel non-proliferation treaty. Country commitments to these treaties must be maintained, ideally through legally binding agreements, and suitable implementation strategies must be employed to rapidly reduce the use of fossil fuels.
3. Countries and technical bodies, particularly in LMICs, should urgently improve air pollution monitoring and modelling where there are gaps. This includes expansion of the stationary monitoring network in both rural and urban areas that will help provide more accurate estimates of air pollution levels and trends.
4. Countries, multilaterals, and philanthropies must increase funding into multidisciplinary air pollution research and technological innovations to improve air quality and strategies to implement interventions for reducing air pollution.
5. Health and research agencies at country, regional, and global levels should conduct additional studies into the cardiovascular effects of air pollution and CVDs linked to ambient and household air pollution, in addition to the role of the cardiovascular system in the disease of other organs. This should include the study of the cardiovascular effects of less-well-researched air pollutants, so that policies and interventions can target the air pollutants that are most harmful. This will support the design and implementation of health interventions.



## SECONDARY RECOMMENDATIONS

1. WHF encourages the healthcare sector to take a leading stance in reducing emissions of air pollution as part of sustainability strategies. Currently the healthcare sector accounts for almost 5% of global greenhouse gas emissions.
2. WHF encourages cardiologists, cardiovascular scientists, health practitioners in general, cardiovascular communities and health foundations to advocate for the need to recognize air pollution as a major risk factor for cardiovascular health, engage with stakeholders, and help prioritize resources and political will to tackle this issue.
3. Greater efforts must be made to improve education on the health impacts of air pollution, including at secondary, undergraduate, and postgraduate levels, for health professionals and through training programmes for disciplines essential for research in the field, e.g., toxicology and epidemiology.
4. More studies on the cardiovascular effects of air pollution are required in LMICs. Where stationary monitoring is limited in LMICs, the use of low-cost monitors and in-situ measurement of health parameters by portable devices would be beneficial to allow more research into the cardiovascular effects of air pollution in these settings.

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WORLD HEART FEDERATION

# WORLD HEART REPORT 2024

CLEARING THE AIR TO ADDRESS POLLUTION'S CARDIOVASCULAR HEALTH CRISIS


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