STATE OF GLOBAL AIR /2025

A Report on Air Pollution and Its Role in the World's Leading Causes of Death

HEI Health Effects Institute

IHME

in partnership with

NCD Alliance

The State of Global Air is a collaboration between the Health Effects Institute and the Institute for Health Metrics and Evaluation's Global Burden of Disease project.

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Hazy morning in São Paulo, Brazil

ABOUT STATE OF GLOBAL AIR

The State of Global Air is a research and outreach initiative to provide reliable, comprehensive, and up-to-date information about air quality status and trends around the world. A collaboration of the Health Effects Institute and the Institute for Health Metrics and Evaluation's Global Burden of Disease project, the program gives citizens, journalists, policymakers, and scientists access to high-quality, objective information about air pollution exposure and its health impacts. All data and reports are free and available to the public.

ABOUT THIS REPORT

Now in its sixth iteration, the State of Global Air report presents information on exposures to outdoor and household air pollution and associated adverse health impacts from a variety of pollutants, including fine particles or $PM_{2.5}$ (ambient and household particulate matter), nitrogen dioxide (NO_2), and ozone. For the first time, the report quantifies air pollution's impact on dementia. This report is produced in partnership with the NCD Alliance and focuses on noncommunicable diseases.

HOW CAN I EXPLORE THE DATA?

This report has a companion interactive website with tools to explore, compare, and download data and graphics. Anyone can use the website to access data for cities and countries around the world and track long-term trends for air pollutants and associated health impacts. Visit ***www.stateofglobalair.org***.

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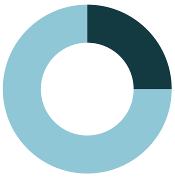
Table of Contents

Jakarta, Indonesia, obscured by smog

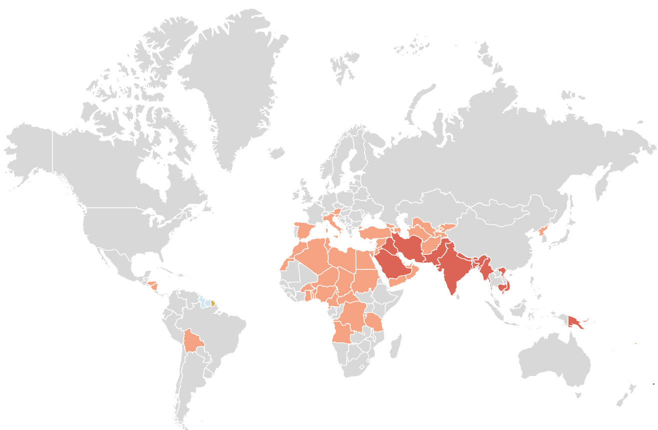
Executive Summary



36%
of the world's population is exposed to levels of $PM_{2.5}$ above the least stringent interim target of 35 μg/m³ (IT-1).

11%
of the global population lives in areas where there are no national air quality standards.

Low- and middle-income countries face the largest burden. 90% of all air pollution deaths were in these countries:



India and China each had more than **2 million deaths** attributable to air pollution in 2023.

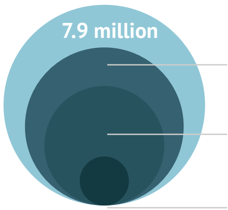
Bangladesh, Pakistan, and Nigeria each saw more than **200,000 deaths.**

Indonesia, Myanmar, and Egypt each saw more than **100,000 deaths.**

Air pollution continues to be the second leading risk factor for early death, surpassed only by high blood pressure.

7.9 million
deaths attributed to air pollution in 2023,

about **1 in 8** deaths worldwide.

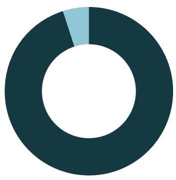


Of this total, **4.9 million deaths** were attributable to ambient $PM_{2.5}$ exposure,

2.8 million were from household air pollution, and

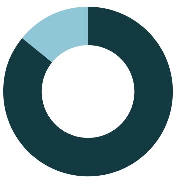
470,000 were from ozone.

In 2023, dementia attributable to air pollution resulted in 626,000 deaths and 11.6 million healthy years of life lost.



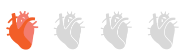
95%
of deaths in adults over the age of 60 are due to noncommunicable diseases.

Noncommunicable diseases accounted for 6.8 million deaths.



86%
of global deaths were attributable to air pollution in 2023.

1 in 2 chronic obstructive pulmonary disease (COPD) deaths



1 in 4 heart disease deaths

More than **1 in 4** dementia deaths

Nearly **1 in 6** diabetes deaths

Introduction

7.9 million

In 2023, 7.9 million deaths were attributed to exposure to air pollution worldwide.

Air pollution is a public health burden without boundaries. Drifting across borders, seasons, and societies, it makes people across all walks of life sick, with impacts that ripple through communities, countries, economies, and future generations. Severe air pollution episodes bring these threats into stark focus for millions in cities around the world. During the past year in South Asia, Central Asia, and Europe, air quality episodes—largely from agricultural burns and the burning of fossil fuels—blanketed cities in thick smog. In West Africa, the annual Harmattan dust storms shrouded communities in clouds of dust from the Sahara Desert, making navigating roads and waterways a treacherous undertaking. Across North America and Latin American countries, including Brazil, Bolivia, and Venezuela, wildfires have brought the dual hazard of devastating fire and damaging smoke.

The impacts of these pollution spikes linger long after the air has cleared. So, too, do the impacts from the day-to-day air pollution that has remained persistently high in some regions for decades. The human toll is striking: In 2023, 7.9 million (95% uncertainty interval [UI]: 6.4–9.4) deaths and 232 million healthy years of life lost worldwide were attributed to air pollution (Figure 1). This loss of healthy life by millions of individuals undermines progress toward the United Nations (UN) 2030 ***Sustainable Development Goals*** (SDGs) and other targets aimed at elevating the quality of life for all humanity.

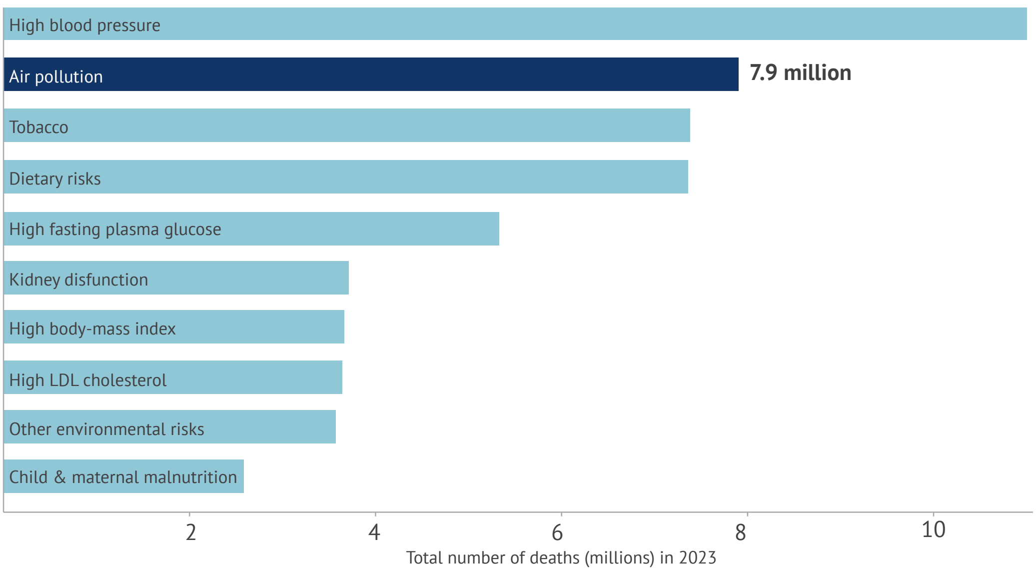


Figure 1: **Global ranking of risk factors by total number of attributable deaths from all causes in 2023.** Air pollution is the second largest risk factor for death worldwide, surpassed only by high blood pressure.

This year, the UN General Assembly renewed its focus on preventing and controlling noncommunicable diseases as an integral part of the path toward greater global well-being.

At the World Health Assembly in May 2025, Ministers of Health unanimously approved the World Health Organization's updated roadmap for an enhanced global response to the adverse health effects of air pollution; this includes a target for countries to achieve a 50% reduction in the population-attributable fraction of mortality from anthropogenic sources of air pollution by 2024, relative to 2015 baseline values.

In September 2025, the UN General Assembly renewed its focus on preventing and controlling noncommunicable diseases (NCDs) as an integral part of the path toward greater global well-being, with a High-Level Meeting of Heads of State and Government. The meeting will be followed by the consideration of a Political Declaration by the UN General Assembly, which includes a series of commitments to address air pollution. NCDs — long-lasting diseases that are not transmissible from one person to another — account for 6 of the top 10 causes of death worldwide. Many of these diseases share a common set of risk factors, including air pollution.

While public health approaches to chronic diseases have long focused on behavioral factors such as tobacco, alcohol, diet, and physical activity, environmental factors are now rising in prominence. Even as behavioral health interventions remain critical in reducing NCDs and their impacts, taking steps to curb environmental risk factors, such as air pollution, can amplify the benefits of interventions across large and broad swaths of the population. In 2018, in recognition of its significant disease burden, the Political Declaration of the previous UN High-Level Meeting on Noncommunicable Diseases recognized air pollution as a major NCD risk factor, together with tobacco and alcohol use, unhealthy diets, and physical inactivity, shifting to a 5×5 approach for the NCD agenda.

The toll of air pollution touches us all — but so do the benefits of cleaner air. The more we know about air pollution, its causes, and its health impacts, the more progressive we can be in our efforts to improve air quality. Scientific progress and improved air quality monitoring over the past several years have informed important steps toward curbing pollution. In 2024 alone, the United States, the European Union, Brazil, and Uganda announced stricter air quality standards and regulations. Each of these steps represents an act of hope for a cleaner, healthier future. Decades of research into the health impacts of pollution at lower exposures played a key role in guiding the United States' decisions to reduce the annual particulate matter ($PM_{2.5}$) standard from 12 to 9 micrograms of particulate matter per cubic meter of air, or μg/m³ (under the new US Environmental Protection Agency standards) and the European Union's decision to aim for less than 10 μg/m³ by 2030 (in the European Union's Ambient Air Quality Directive). Policies and actions to reach these standards, focused on cutting pollution emissions and population exposure, are key to reducing the health burden. For example, in China, the Combined Heat and Power Policy (CHP) launched in 2015, which banned household coal burning and provided subsidies for clean electric or gas-powered heating for millions of peri-urban and rural households, resulted in cardiovascular health benefits (Lee et al. 2024).

By quantifying the continuing burden of air pollution around the globe, this report is intended as a resource to motivate and inform further steps to build on this progress and restore healthy air for all.

What This Report Covers

This State of Global Air report presents the latest comprehensive estimates of exposures to fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), and ozone (O_3) and their impacts on human health around the world between 1990 and 2023. *Note that exposure data for ozone are reported for 2020.*

The report's main data source is the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD study) of the Institute for Health Metrics and Evaluation, a collaboration of more than 17,000 researchers worldwide that produces global estimates of the impact of 88 environmental, behavioral, and dietary risk factors on health across 204 countries and territories from 1990 to 2023. Updated regularly, this comparative risk assessment uniquely describes both the absolute and relative importance of the multiple health risk factors that contribute to the global burden of disease. Drawing upon the latest data from this unparalleled resource (GBD 2023), the State of Global Air project puts air pollution into perspective, offering a comprehensive account of exposures and impacts as a foundation to inform decisions and actions. Other global and regional datasets and studies are cited as relevant. *Key definitions are described on pages 36–38.*

This report and the State of Global Air data focus on air pollution and health impact trends at three spatial scales: globally, within the GBD Super Regions (countries grouped by similar cause-of-death patterns; see **Figure i**), and in the most populous countries. Interactive maps and figures, downloadable data, and additional resources on the State of Global Air website (*www.stateofglobalair.org*) allow deeper exploration and visualization of air pollution levels and health impacts in individual cities, countries, and regions.

This report and the associated data focus on long-term air pollution exposures rather than short-term events such as winter smog, sand and dust storms, or wildfires. Because exposures are calculated as population-weighted $PM_{2.5}$ concentrations reflecting annual averages across entire countries, they include, but do not fully represent, the considerably higher concentrations that may be observed day to day or in certain seasons, especially around cities or major pollution sources. Although they are not the focus of this report, short-term exposure spikes can also affect health and warrant further study.

Note: All GBD estimates are subject to a peer-review process, and the data reflected in this report were published in ***The Lancet*** *in October 2025. The GBD project uses global estimates based on a range of publicly available datasets that do not necessarily represent datasets submitted to UN agencies by national governments.*

What's New for This Report?

With each update, the GBD study incorporates the latest scientific evidence and methods to refine estimates of pollution exposures and impacts.

1. **Revisions to the methods used for exposure assessment and updates to relative risks**
2. **The inclusion of a new health outcome — dementia — in quantifying the burden of disease for air pollution.**

Why Are the Estimates for the Burden of Air Pollution Different from Previous Cycles?

The GBD project updates its estimates annually and, with each update, provides an analysis of the trends over time (e.g., from 1990 to 2023 for this cycle). Although these updates include improvements in data and methods that contribute to differences from previously published GBD, each GBD update recalculates the entire temporal sequence so that its trends (e.g., based on the years 1990–2023) are internally consistent. With each cycle, new data and methodological advances are taken into account to ensure that the burden of disease estimates reflect the best available data and scientific knowledge.

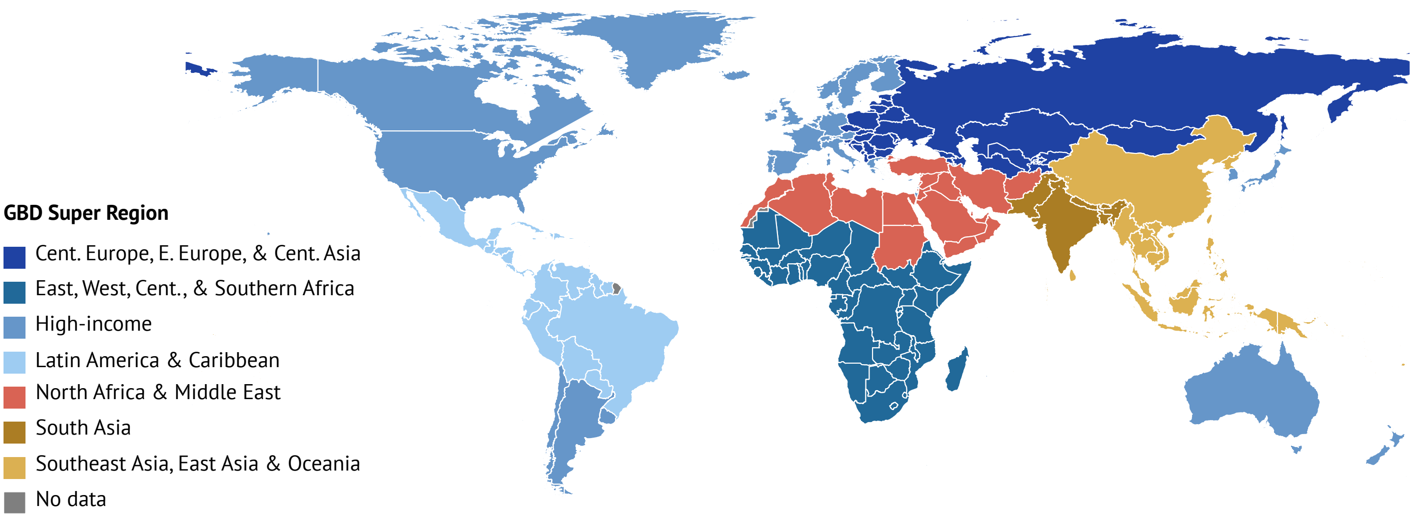


Figure i: Countries included in the seven GBD Super Regions.

Trends in Air Pollution Exposure

High levels of ambient $PM_{2.5}$ persist in many areas of the world, exposing billions of people to dangerous concentrations of fine particulate matter.

Fine particle air pollution ($PM_{2.5}$), ozone, and nitrogen dioxide (NO_2) are the three main indicators used to quantify air pollution exposures in the GBD study. One way to put global air quality into perspective is to compare the national ambient air quality levels to the health-based ***Air Quality Guidelines (AQGs)*** and the interim targets established by the World Health Organization (WHO). Taken together, the guideline values and the interim targets enable countries to set realistic goals toward clean air and make steady progress in protecting people's health against the effects of air pollution. Exceedance of the AQG levels is associated with important risks to public health. Many countries also set their own legally binding air quality standards, which may be informed by the WHO guidelines. This iteration of State of Global Air provides an overview of exposures and trends, with a focus on progress made toward meeting air quality guidelines recommended by the WHO and standards set by individual countries.

Dig Deeper

Curious about the national air quality standards in your country? ***Explore*** data for your country and region.

New York City, United States, in June 2023, smoke from the Canadian wildfires

Fine Particle Air Pollution

$PM_{2.5}$ pollution comes from vehicles, residential fuel use, coal-burning power plants, agricultural and industrial activities, waste burning, wildfires, and many other human and natural sources. Among the air pollutants that are currently measured, long-term exposure to $PM_{2.5}$ is the most consistent and accurate predictor of poor health outcomes across populations. Much of the research on $PM_{2.5}$ divides exposures into two main categories: exposures due to pollution from outdoor sources (ambient air pollution) and pollution from household solid fuel use for cooking, heating, and other domestic tasks (household air pollution). Both outdoor and household exposures pose serious problems for human health.

Individually, ambient $PM_{2.5}$ was the fourth leading risk factor for deaths worldwide, accounting for 8% of global deaths.

In 2023, regions with the highest exposures to ambient $PM_{2.5}$ pollution were South Asia; North Africa and the Middle East; and East, West, Central, and Southern Africa (**Figure 2**). In fact, the 20 countries with the highest exposure to ambient $PM_{2.5}$ in 2023 were located in these three regions. Countries with the highest exposures to ambient $PM_{2.5}$ pollution were Qatar (108 µg/m^3), Saudi Arabia (74 µg/m^3), and Bangladesh (69 µg/m$_3$) (**Figure 3**). The higher $PM_{2.5}$ concentrations in these countries can be attributed to a combination of factors, including windblown mineral dust and sources such as transport and industries (Irankunda et al. 2025; Tanaka and Chiba 2006). The lowest $PM_{2.5}$ exposures were estimated for small island nations and territories, including Greenland, the Northern Mariana Islands, Guam, and the Federated States of Micronesia. Finland and Iceland had annual average $PM_{2.5}$ concentrations below 5 µg/m^3, the annual WHO ambient air quality guideline for $PM_{2.5}$. Notably, in countries such as the United States, wildfires have resulted in declines in air quality in recent years. According to one national estimate, nearly 4 years of progress toward cleaner air have been reversed in the continental United States (Burke et al. 2023).

The current WHO Air Quality Guideline for annual average $PM_{2.5}$ is set at 5 µg/m$_3$ based on evidence of health effects from long-term exposure to $PM_{2.5}$; for regions of the world where $PM_{2.5}$ levels remain high, WHO has suggested four interim targets set at progressively lower concentrations: 35 µg/m^3, 25 µg/m^3, 15 µg/m^3, and 10 µg/m^3. 36% of the global population — 2.8 billion people — resides in areas where annual average $PM_{2.5}$ exposures exceed the least stringent interim target (IT-1, 35 µg/m^3). Less than 1% live in areas where the annual guideline value of 5 µg/m^3 is met. In 2023, annual average $PM_{2.5}$ concentrations met the IT-1 in 170 countries, similar to a decade ago. Also, in 2023, 25% of the countries met the national air quality standard for ambient $PM_{2.5}$.

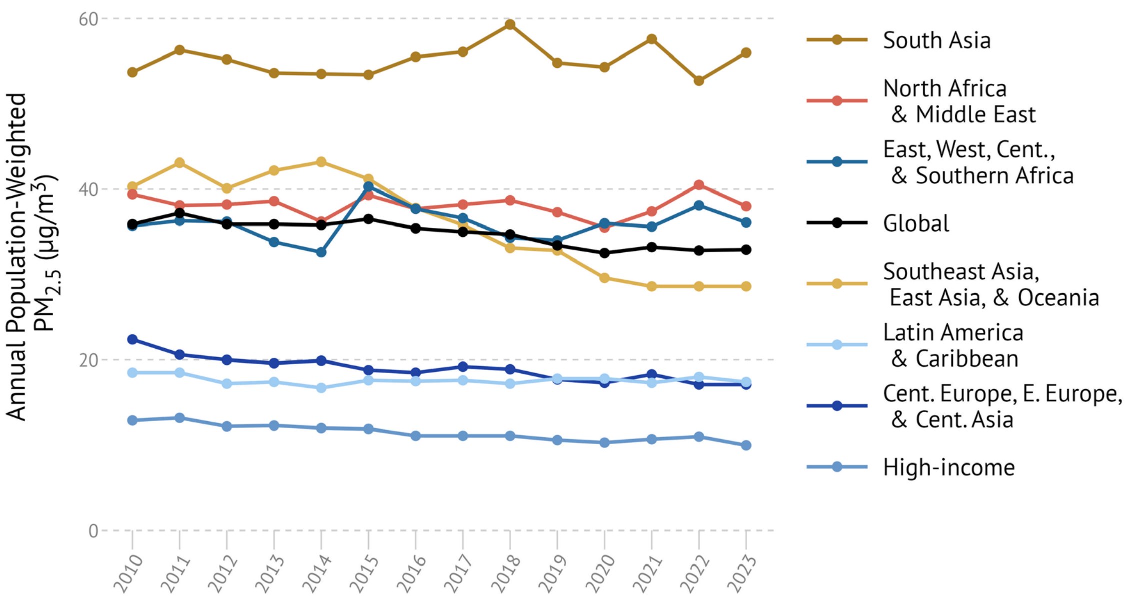


FIGURE 2: Trends in population-weighted annual average $PM_{2.5}$ concentrations globally and in the GBD Super Regions, 2010–2023.

Dig Deeper

Curious about pollution in your city, country, or region? Track trends going back to 1990 at *stateofglobalair.org*.

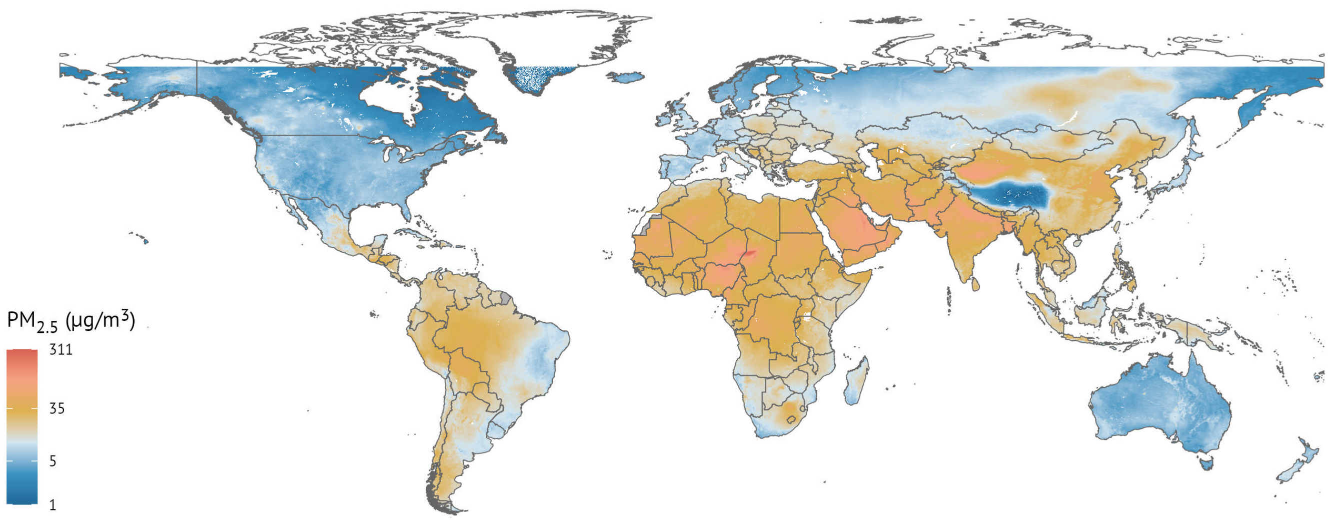


FIGURE 3: **Population-weighted annual average ambient $PM_{2.5}$ concentrations in 2023.**

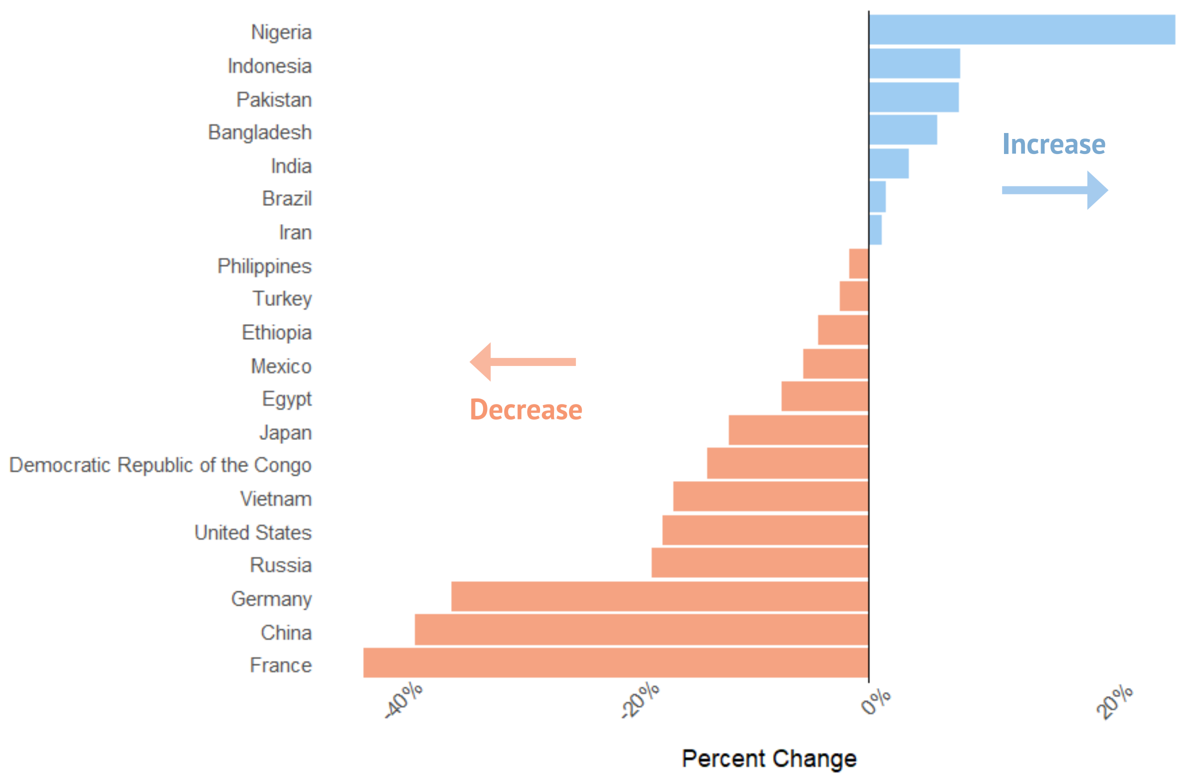


FIGURE 4: **Changes in annual average ambient $PM_{2.5}$ exposure between 2013 and 2023 among the 20 most populous countries.**

Ozone

Ground-level, or tropospheric, ozone is a pollutant that harms human health, damages plants, and contributes to climate change. Ground-level ozone is not released directly into the air but is formed through chemical reactions between nitrogen oxides and volatile organic compounds (VOCs) in the presence of sunlight. These precursor chemicals are released through the burning of fossil fuels in vehicles, power plants, factories, and homes, through industrial activities such as oil and gas extraction and processing, and from some natural sources such as trees. At the local level, ozone concentrations vary widely from place to place. Although ozone is often more concentrated around urban areas where emissions of its precursor chemicals tend to be highest, it can also travel long distances to suburban and rural areas and across national borders. Globally, ozone levels are estimated to be 30%–70% higher today than they were 100 years ago. This trend reflects rising emissions of the chemicals that form ozone as well as rising temperatures.

Tropospheric ozone has also been identified as a super pollutant. ***Super pollutants*** are warming agents that are far more potent than carbon dioxide per ton; they have significant, harmful effects on both human health and the environment. Ozone can absorb radiation and act as a strong greenhouse gas. Tropospheric ozone affects the climate beyond increased warming, having impacts on evaporation rates, cloud formation, precipitation levels, and atmospheric circulation. In addition to effects on health and climate, increasing levels of ozone can reduce crop yields, with a potential knock-on impact on nutrition. According to one estimate, yield losses of 3.6 ± 1.1% for maize, 2.6 ± 0.8% for rice, 6.7 ± 4.1% for soybean, and 7.2 ± 7.3% for wheat can be attributed to ambient ozone (Tai et al. 2021). In Europe, increases in ground-level ozone are ***estimated*** to result in a loss of 16.8 million metric tons of wheat in 2050. Despite these wide-ranging effects, ground monitoring of ozone is not yet common, and there is a need for more data to accurately monitor long-term trends and impacts on air quality, health, ecosystems, and economies.

The current WHO Air Quality Guideline for ozone is set at 60 µg/m³ for an 8-hour average concentration during peak season; for regions of the world where ozone levels remain high, WHO has suggested two interim targets set at progressively lower concentrations of 100 µg/m³ and 70 µg/m³. 42% of the global population — 3.3 billion people — resides in areas where 8-hour average ozone levels exceed the least stringent interim target (IT-1, 100 µg/m³) (**Figure 5**). 7% live in areas where the guideline value of 60 µg/m³ for an 8-hour average during peak season is met. In 2023, 8-hour average concentrations during peak season met the IT-1 in 164 countries, compared to 179 countries a decade ago. Overall, 28 out of 204 countries had population-weighted mean concentrations below the WHO AQG for ozone.

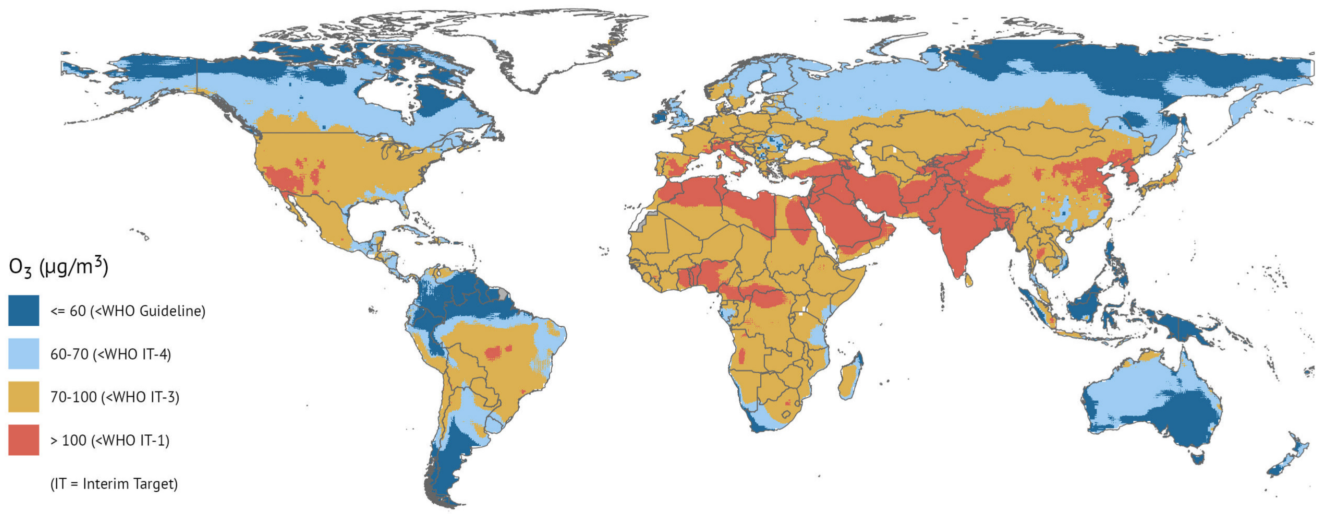


FIGURE 5: Global map of national population-weighted average seasonal 8-hour daily maximum ozone concentrations in 2020 relative to the WHO Guideline and Interim Targets.

Hazy air over the skyline in Addis Ababa, Ethiopia

The global average exposure to ambient ozone pollution has steadily increased since 1990, with the average exposure in 2020 reaching 49.8 ppb. South Asia (66.7 ppb) faces the highest exposure to ambient ozone, followed by North Africa and the Middle East (53.6 ppb); East, West, Central, and Southern Africa (46.2 ppb); and Southeast Asia, East Asia, and Oceania (44.7 ppb) (**Figure 6**). Various studies using satellite data or modeling approaches have also reported increases in ozone levels, especially in East and South Asia, in the last two decades (Lu et al. 2025; Rathore et al. 2023). The increases are attributed to increases in anthropogenic emissions, as well as rising temperatures, or the so-called *ozone-climate penalty*.

At the country level, Qatar (67.6 ppb) had the highest exposure to ozone pollution, with Nepal (67.5 ppb), India (67.2 ppb), Bangladesh (65.4 ppb), and Bahrain (64.3 ppb) making up the remaining top five countries with the highest exposure. The Marshall Islands (11.4 ppb), Micronesia (14.7 ppb), Nauru (14.7 ppb), Papua New Guinea (15.7 ppb), and the Solomon Islands (15.8 ppb) had the lowest exposures to ozone in 2020.

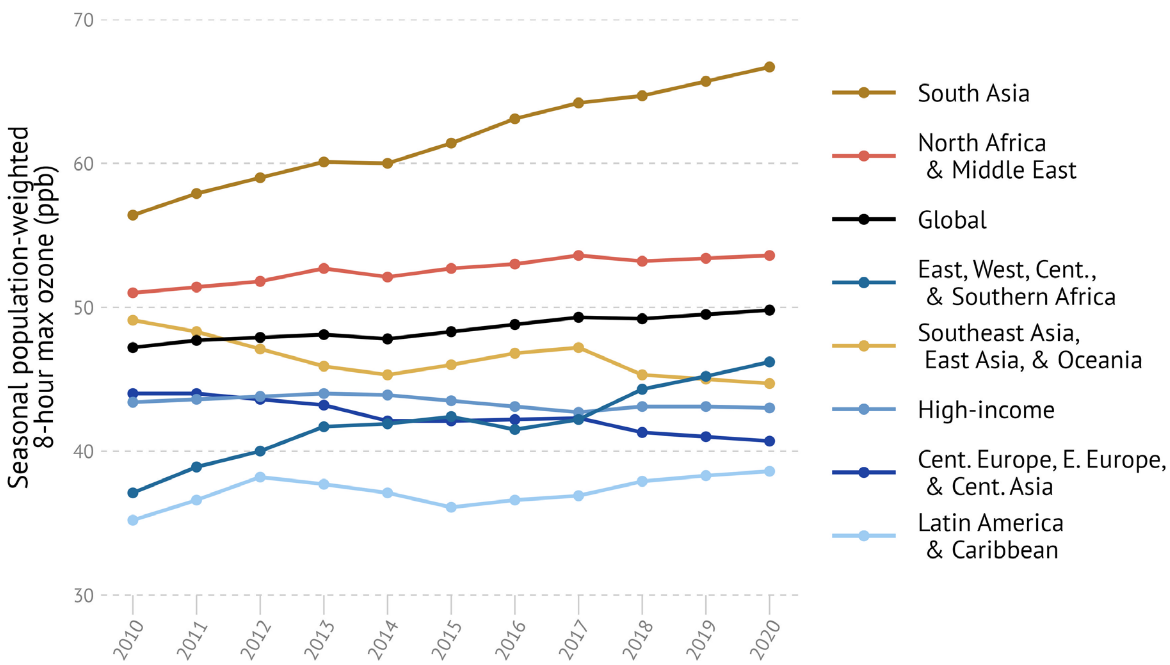


FIGURE 6: Trends in population-weighted average seasonal 8-hour maximum ozone concentration globally and in the GBD Super Regions, 2010–2020.

Nitrogen Dioxide

In 2023, regions with the highest exposures to NO_2 pollution were the High-income region (9.6 ppb), North Africa and the Middle East (9 ppb), and Southeast Asia, East Asia, and Oceania (8.2 ppb) (**Figure 7**). The region with the lowest exposure to NO_2 pollution was East, West, Central, and Southern Africa (3.9 ppb).

Countries with the highest exposures to NO_2 pollution were Singapore (22 ppb), Monaco (17 ppb), and Bahrain (15 ppb). Seven of the top 20 countries with the highest NO_2 average annual exposures are in the Middle East, including Bahrain, Kuwait, Qatar, the United Arab Emirates, Lebanon, and Jordan. The high NO_2 concentrations in these countries are linked to industrial activities, including oil production and refining, energy production, and transportation (Rey-Pommier et al. 2023; Yarragunta et al. 2025).

The average exposure to NO_2 is higher in wealthier countries than in low- and middle-income countries, largely reflecting vehicular emissions (**Figure 8**).

Furthermore, the largest sources of NO_2 include transportation, power generation, and industrial activities. In 2022, for instance, nitrogen oxide emissions (encompassing NO and NO_2) were highest from both road and nonroad transport (52 million tons), other industrial combustion (24 million tons), and the power industry (20 million tons) (Joint Research Centre 2024). Broadly, high-income countries are experiencing a rapid decline in NO_2 exposures over time as a result of sustained policy action and technological advancements, while levels are increasing in some low- and middle-income countries (**Figure 9**).

Because NO_2 reacts with other pollutants and dissipates more quickly than $PM_{2.5}$, NO_2 levels can vary dramatically hour by hour and across different neighborhoods within a city. Pinpointing the traffic patterns and other factors that lead to spikes in NO_2 pollution can help cities identify effective ways to control NO_2 and reduce exposures.

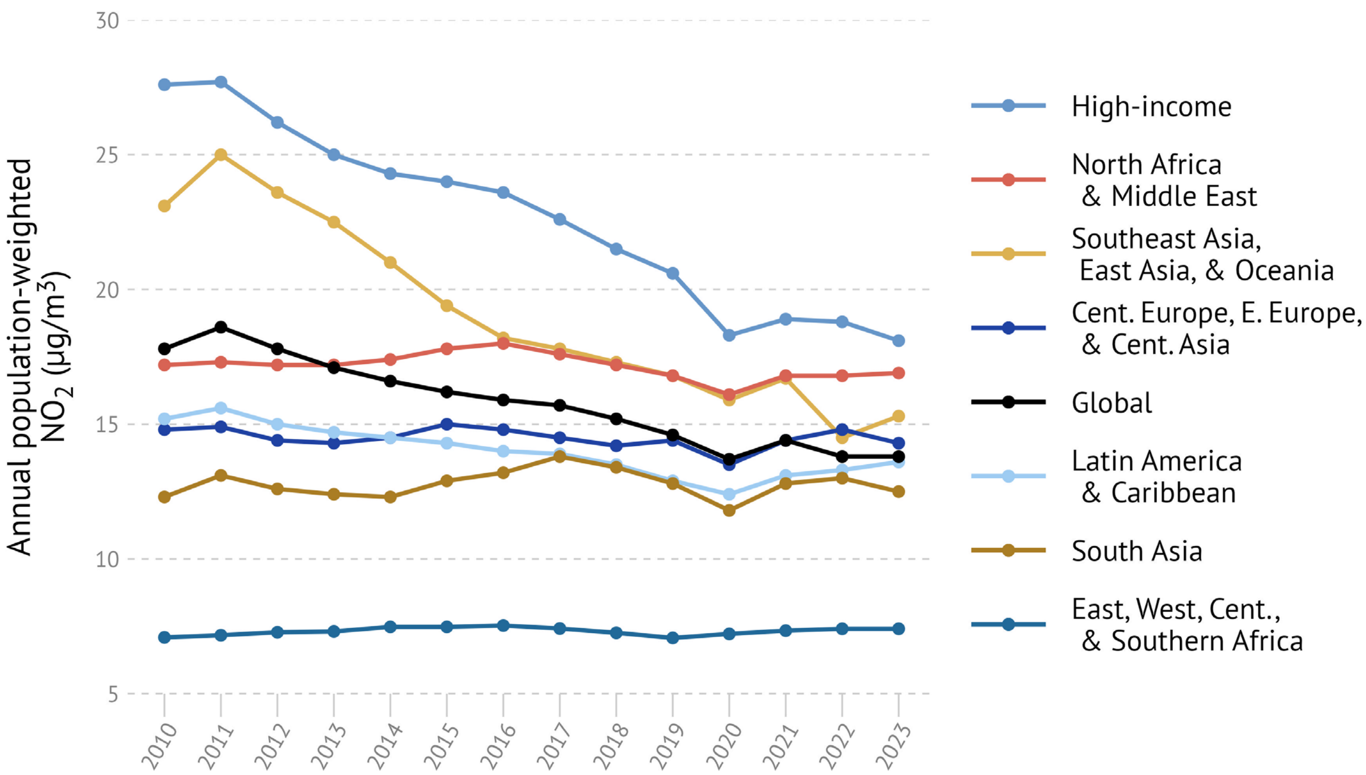


FIGURE 7: Trends in population-weighted annual average NO_2 concentrations globally and in the GBD Super Regions, 2010–2023.

The current WHO annual Air Quality Guideline for NO_2 is set at 10 µg/m³; for regions of the world where NO_2 levels remain high, WHO has suggested two interim targets set at progressively lower concentrations of 40 µg/m³, 30 µg/m³, and 20 µg/m³. 4% of the global population — 300 million people — resides in areas where annual NO_2 levels exceed the least stringent interim target (IT-1, 40 µg/m³). 50% live in areas where the guideline value of 10 µg/m³ is met. In 2023, annual average NO_2 concentrations met the IT-1 in 193 countries, compared to 176 countries a decade ago. Overall, 30 out of 204 countries meet the WHO AQG for NO_2.

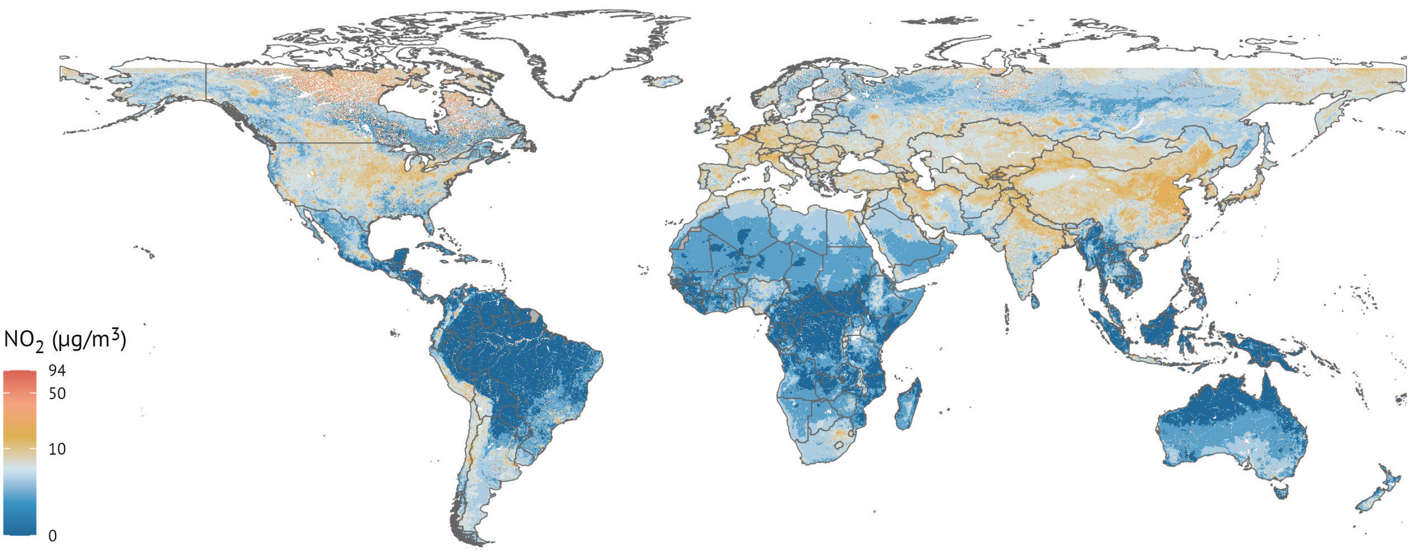


FIGURE 8: **Global map of population-weighted annual average NO_2 concentrations in 2023.**

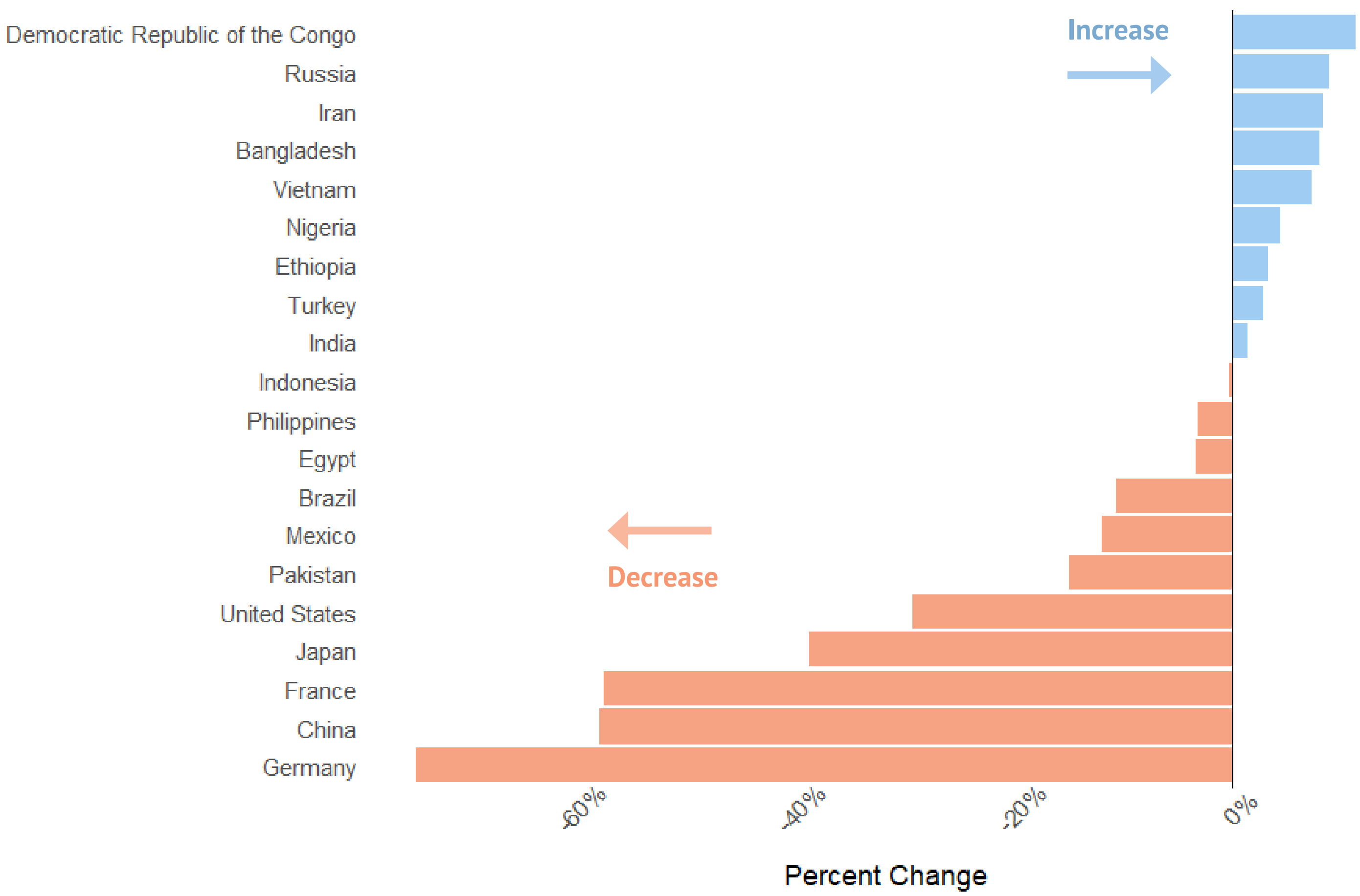


FIGURE 9: **Changes in annual average NO_2 between 2013 and 2023 among the 20 most populous countries.**

The Continuing Burden of Household Air Pollution

2.6 billion

About one-third of the world's population — almost 2.6 billion people — are exposed to pollution from burning solid fuels for cooking at home.

On a global scale, the number of households that report primarily cooking with solid fuels (e.g., coal, wood, and charcoal) has steadily dropped over the past several decades. There is strong evidence that access to cleaner cooking fuels can not only reduce exposure to harmful air pollution but also improve people's health and quality of life. However, despite some encouraging success stories and an overall steady decline globally, progress toward reducing household air pollution (HAP) exposure has been uneven in Asia and Africa.

Exposure to household air pollution is dangerous at any age. Exposure to HAP increases a person's risk of lower respiratory infections, lung cancer, stroke, COPD, cataracts, dementia, and cardiovascular disease, and may also increase the risk of ear infections, upper respiratory infections, and tuberculosis (HEI 2018, WHO 2025). When pregnant women are exposed to HAP, their newborns are at a higher risk of being born early (premature birth) or too small for their age (low birthweight). Children who are exposed to HAP have a higher risk of pneumonia. The International Agency for Research on Cancer classifies indoor burning of coal as a known human carcinogen and indoor burning of biomass as a probable human carcinogen (Straif et al. 2013).

Woman cooking food on an open fire

Household air pollution is also a major contributor to ambient $PM_{2.5}$. It has been estimated that nearly 20% of the global ambient $PM_{2.5}$ is attributed to household air pollution reaching outdoor air (Chowdhury et al. 2023; McDuffie et al. 2021).

Africa sees the largest burden from HAP. The region with the highest HAP exposure is East, West, Central, and Southern Africa, where more than three-quarters of households primarily burn solid fuels for cooking (**Figure 10**). Of the top 20 countries with the highest exposure to HAP, 19 are in Africa. In 24 African countries, over 90% of the population is exposed to HAP, with the Central African Republic, Madagascar, Somalia, Burundi, and Mali experiencing the highest exposures. In the Central African Republic, over 99% of the population is exposed to HAP from cooking with solid fuels. Furthermore, across East, West, Central, and Southern Africa, the number of people lacking access to clean cooking solutions continues to grow at a rate of 14 million people annually, largely due to rapid population growth (IEA et al. 2025). In good news, Cote d'Ivoire, Kenya, Lesotho, Nigeria, and the Republic of the Congo saw the fastest rates of progress toward clean cooking, accounting for two-thirds of all new clean cooking access in East, West, Central, and Southern Africa between 2018 and 2023 (IEA 2025).

HAP has a major impact on public health in low- and middle-income countries. Overall, about 4.6% of deaths globally can be attributed to HAP, which currently ranks ninth among the top 20 modifiable risk factors in terms of attributable deaths (**Figure 11**). Although this is a major improvement over its ranking as the third leading risk factor in 2000, HAP continues to be an important contributor to deaths globally alongside other modifiable factors such as diet and tobacco use. In some of the world's most populous countries — such as India, China, Indonesia, Nigeria, and Pakistan — on average, over 10% of the population is exposed to HAP. As a result, many millions of people are exposed, even in countries where the proportion of people cooking with solid fuels is relatively low.

Cleaner energy alternatives can save lives. In many places, the continued reliance on burning solid fuels for cooking stems from people's lack of access to affordable alternatives. Accelerating efforts to transition communities to cleaner household energy sources — such as electric stoves, solar energy, biogas, natural gas, and liquified petroleum gas — can promote sustainable development and improve health and quality of life for millions of people. Recent research on LPG interventions has shown that near-exclusive LPG can result in more than 80% reductions in personal $PM_{2.5}$ exposures for pregnant women (Johnson et al. 2022) and positive exposure-response associations with birth weight (Balakrishnan et al. 2023). Helping more households move away from solid fuel cookstoves aligns with two targets under the UN Sustainable Development Goals — target 3.9 to reduce morbidity and mortality from environmental pollution, and target 7.1 calling for universal access to cleaner fuels by 2030 — and will significantly contribute to target 3.4 to reduce premature mortality from NCDs.

In the last two decades, there has been considerable progress in moving people toward cleaner household energy sources such as gas, electricity, and, to some extent, solar energy, especially in East, Central, and South Asia. Below, we present a few examples.

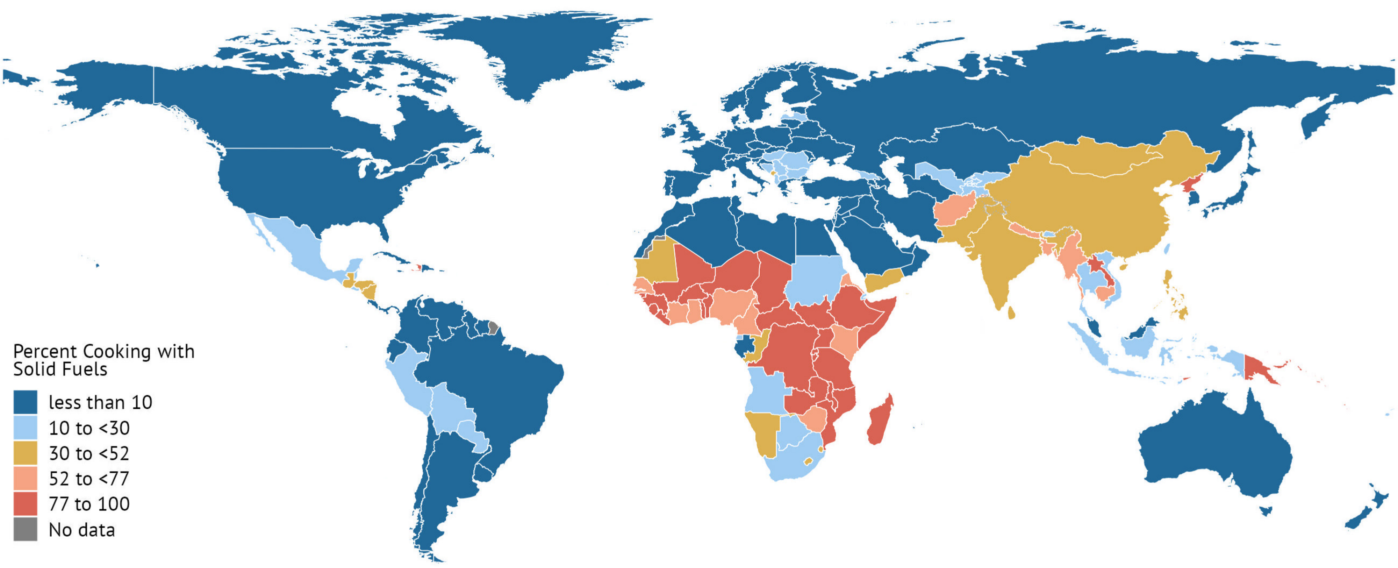


Figure 10: **Percentages of the global population cooking with solid fuels in 2023.**

India

The Pradhan Mantri Ujjwala Yojana (PMUY) has transformed the discourse on household air pollution, clean energy, and gender equity at scale in India. The program was launched in 2016 as a flagship effort to scale clean household energy use among poor populations. PMUY increased access to Liquefied Petroleum Gas (LPG) through a combination of social marketing and subsidies for both up-front and recurrent costs. By 2023, the program enrolled over 100 million households and provided direct and targeted subsidies to women as primary beneficiaries. This combination of an efficient subsidy structure and investments in the expansion of LPG distribution resulted in greater than 95% LPG coverage and a threefold increase in the use of LPG as primary fuel among rural households (Patnaik and Mani 2019). The challenge of achieving exclusive use of LPG persists, however. Modeling studies estimate that transitioning all PMUY households to such exclusive LPG use would avert more than 150,000 deaths annually, with the largest health gains resulting from preventing infant mortality due to low birth weight and resulting in high cost-effectiveness (Mehta and Kushwaha 2024). Emissions from solid cook-fuels also contribute to nearly 30% of ambient $PM_{2.5}$ concentrations in India (Chatterjee et al. 2023). Elimination of household air pollution through PMUY can thus also accelerate progress toward meeting national ambient standards for $PM_{2.5}$ and toward attainment of the WHO Interim Target Air Quality Guideline values across most states in India (Chowdhury et al. 2019). Overall, PMUY is well poised to achieve triple benefits for air quality, energy parity, and gender equity at an unprecedented scale, with a focus on addressing the most vulnerable populations. Attaining such goals requires continued investment in improving access and affordability of LPG to ensure an equitable and complete transition to cleaner cooking for all.

Ecuador

Nationwide subsidy programs have resulted in widespread LPG adoption in Ecuador. Nationwide subsidy programs have resulted in widespread LPG adoption in Ecuador: Starting in the 1970s, the national government has subsidized the use of LPG as a cooking fuel, resulting in widespread adoption of LPG as the primary cooking fuel (Gould et al. 2018). Approximately 90% of the market cost of LPG cylinder refills for consumers is subsidized, and more than 95% of the country's population cooks with LPG (IEA et al. 2025). This transition has been associated with a stark decline in lower respiratory infection mortality in children under 5 years of age over time (Gould et al. 2023). To promote uptake of electricity for cooking, the government launched La Programa de Eficiencia Energética para la Cocción (Energy Efficiency Programme for Cooking) in 2014; the program incentivizes acquisition of induction stoves and is coupled with an electricity subsidy (Valarezo et al. 2023).

China

China's Rural Clean Heating Program has resulted in air quality and cardiovascular benefits. Launched in 2015, China's Clean Heating Program (CHP) banned residential coal use and subsidized electric or gas heating in rural villages. By 2021, an estimated 36 million households were enrolled in the CHP (Dispersed Coal Management Group 2023). Studies found greater reductions in outdoor $PM_{2.5}$ (2.4–7 μg/m³) in CHP-covered regions compared with nearby areas without the program (Song et al. 2023; Yu et al. 2021). Quasi-experimental studies in Beijing showed that heart attacks fell by 6.6% in townships with high CHP coverage (Lee et al. 2024), and a separate study found small reductions in blood pressure (1–2 mmHg) among residents of CHP villages that were mediated by lower indoor $PM_{2.5}$ and warmer indoor temperatures (Baumgartner and Harper in press). Overall, these findings show that the CHP delivered measurable air quality and health benefits in northern China.

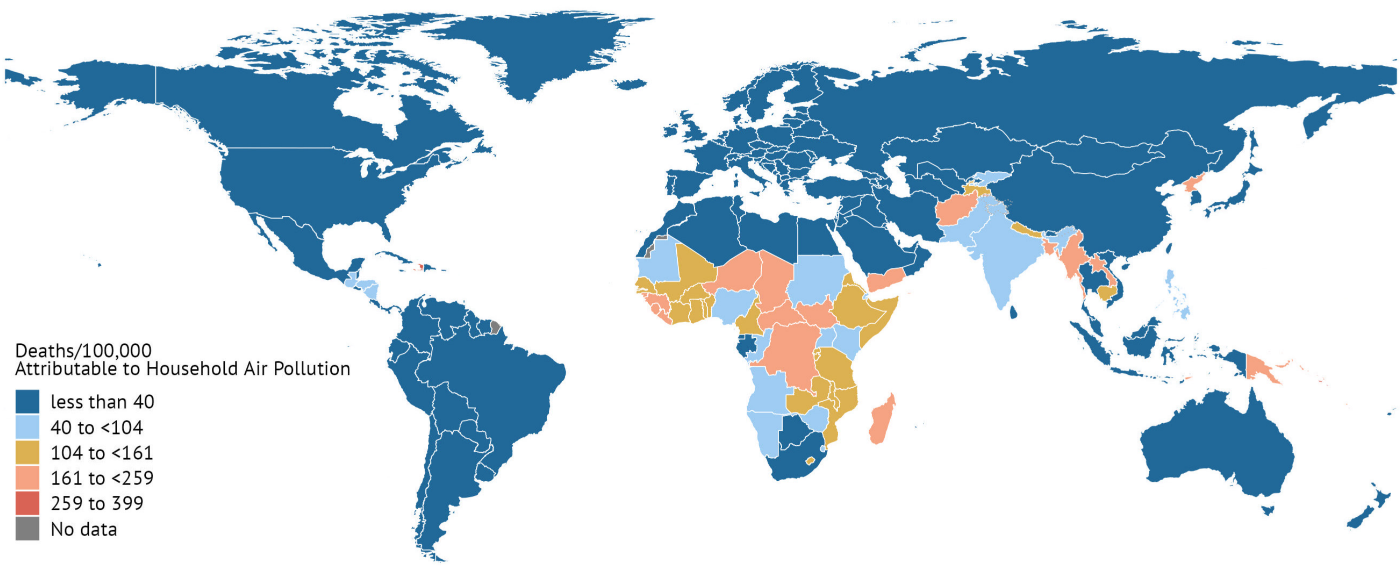


Figure 11: Global map of age-standardized rates of death attributable to household air pollution in 2023. *Note: Because they are drawn primarily from data on the proportion of the population that burn solid fuels for cooking, GBD estimates of HAP likely understate the total exposure and disease burden in some locations because they do not account for exposures related to the use of solid fuels for household purposes other than cooking (e.g., for heating), or exposures from household burning of liquid fuels such as kerosene.*

The Health Effects of Air Pollution

62%

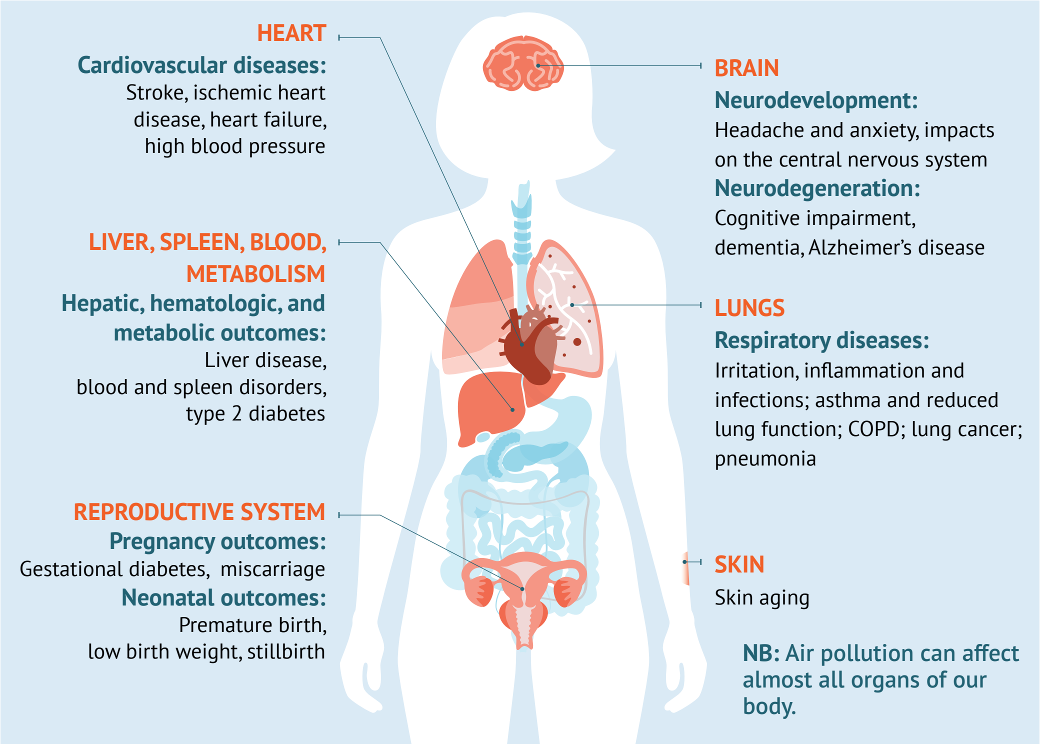
Ambient $PM_{2.5}$ is the largest driver of air pollution's burden of disease worldwide, accounting for 62% of all global air pollution deaths.

Air pollution is a complex mixture of particles and gases that can enter our bodies and harm our health. Understanding the health effects of air pollution — including the risks faced by particular groups, the impacts of different pollutants, and the changes over time — is key to informing air quality interventions and saving lives.

Scientists have conducted thousands of studies over many decades that show how air pollution can have harmful effects on human health throughout the lifespan. These include epidemiology studies, which assess associations of pollution exposures with adverse health outcomes at a population level. They also include toxicology and mechanistic studies, which use chemicals, tissue samples, and cell and animal models to understand how pollutants interact with the body and affect health. Based on the evidence to date, air pollution is thought to cause oxidative stress and inflammation within our bodies, which gives rise to chronic diseases.

Ambient $PM_{2.5}$ is the most well-studied pollutant and is considered the largest driver of air pollution's burden of disease worldwide. Long-term exposure to $PM_{2.5}$ pollution is associated with illness and early death from a variety of diseases, including, but not limited to, respiratory diseases, cardiovascular diseases, type 2 diabetes, adverse reproductive outcomes, cancers, neurodegeneration and problems with brain development, and skin aging. Some of these outcomes are discussed in more detail below.

Health Effects Associated with Exposure to Air Pollution



In 2023, air pollution was the #1 risk factor for deaths due to chronic respiratory diseases worldwide.

Respiratory Diseases

Our lungs are the primary entry point for air pollution into the body. Of all the health impacts of air pollution, respiratory diseases are the most well studied. Breathing polluted air is associated with an increased risk of respiratory infections, including pneumonia and coronavirus/COVID-19, asthma, chronic obstructive pulmonary disorder (COPD), accelerated decline in lung function, and lung cancer.

Air pollution contributes to the development of asthma and COPD by causing airway inflammation and oxidative stress in the bronchial epithelial cells that line our lungs. People with smaller airways might be most susceptible to these effects, and being exposed to air pollution in childhood can also impair lung development and lead to COPD later in life. In people who have asthma, air pollution can cause flare-ups and make symptoms worse. In people who have COPD, air pollution can increase the risk of pneumonia and other respiratory infections.

Dig Deeper

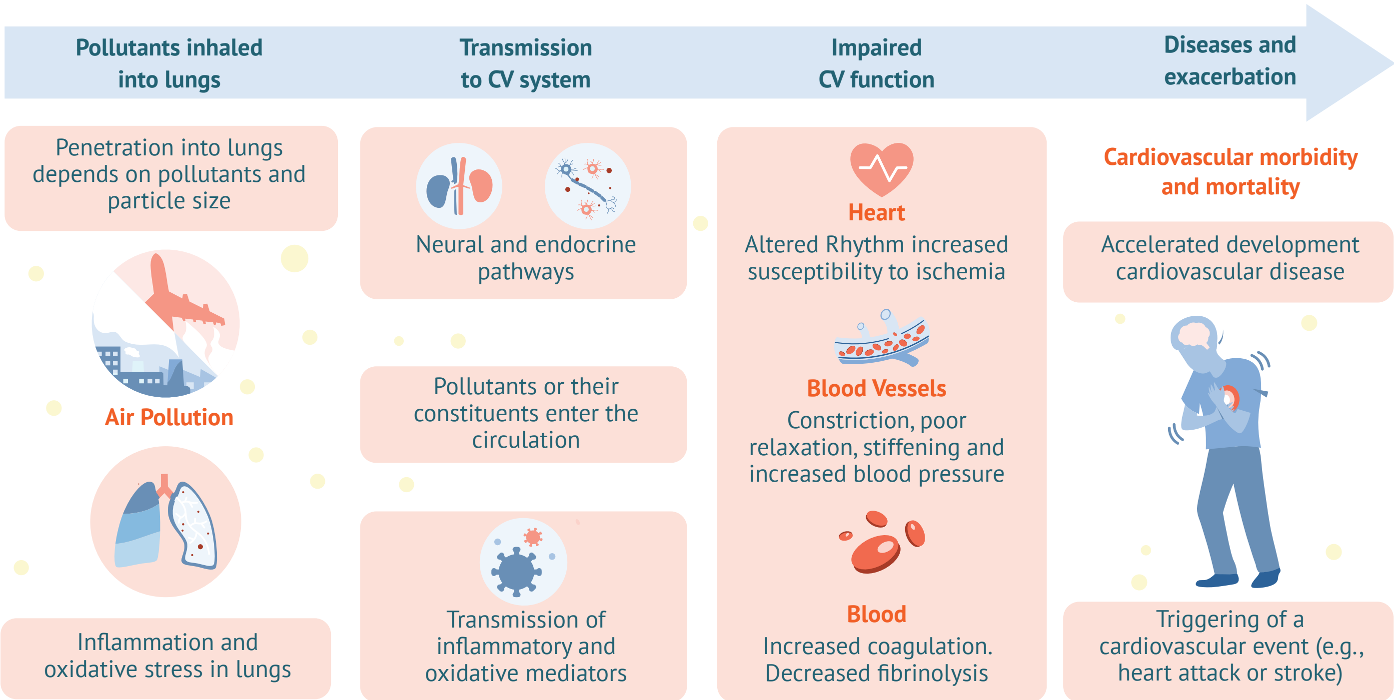
Find more information about the health effects of air pollution in our factsheet, ***Air Pollution and Your Health***.

Cardiovascular Diseases

Air pollution contributes to the development and exacerbation of cardiovascular diseases, the leading cause of death worldwide. In many low- and middle-income countries, the proportion of deaths from cardiovascular disease that are attributable to air pollution is much higher than the proportion of cardiovascular deaths due to smoking and other well-established behavioral and metabolic risk factors.

Pollutants can enter the bloodstream directly through the lungs and contribute to cardiovascular problems through inflammation, oxidative stress, or neural and endocrine pathways. Long-term exposure to air pollution over many years can increase the risk of heart attacks, strokes, hospitalization for heart failure, and early death from cardiovascular disease. It is also linked to high blood pressure, congenital heart disease, and the buildup of plaque in the heart's arteries. Short-term exposures over days to weeks can increase the likelihood of heart attacks, strokes, heart failure, and heart rhythm problems, especially in older people.

In 2023, particulate matter (i.e., ambient $PM_{2.5}$ and household air pollution) was the second largest risk factor for deaths due to stroke and ischemic heart disease worldwide.



Credit: World Heart Report 2024, World Heart Federation.
CV = cardiovascular.

Diabetes

Diabetes is a disorder affecting how the body processes food, which leads to a buildup of glucose, or sugar, in the blood. It can cause serious problems, including heart disease, blindness, kidney failure, and lower-extremity amputations. In addition to long-recognized risk factors, including high blood sugar, high body mass index, poor diet, and smoking, exposure to air pollution can also increase the risk for type 2 diabetes, the type of diabetes that generally occurs during adulthood. Multiple studies have reported an association between exposure to ambient and household $PM_{2.5}$ and type 2 diabetes incidence and mortality (Burkart et al. 2022). In 2023, air pollution was the fourth-largest risk factor for deaths linked to diabetes, behind high glucose, high body mass index, and poor diet.

Air Pollution and Brain Health

Recent epidemiology studies, research on human brain images, and studies in animal models have strengthened the evidence linking air pollution to neurodegeneration — gradual damage to the nerve cells that make up our brain and central nervous system. As a result, this iteration of the State of Global Air is the first to track air pollution's impacts on brain health or neurodegeneration.

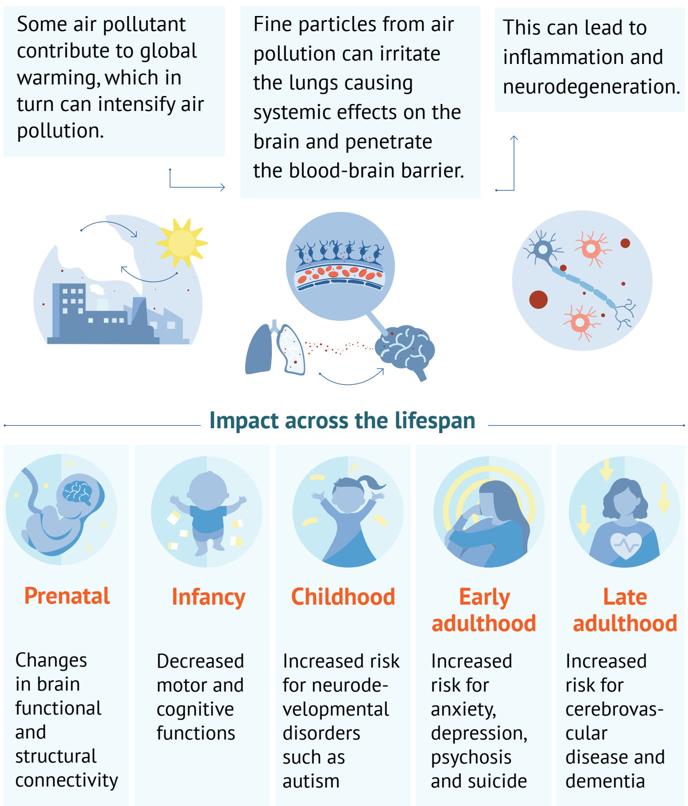
$PM_{2.5}$ contributes to neurodegeneration by entering the lungs, circulating in the blood, and flowing to the brain, where it causes inflammation and can damage brain tissue. Exposure to air pollution also increases the risk of heart disease, which can lead to dementia. Exposure to $PM_{2.5}$ is associated with Alzheimer's disease, other forms of dementia (e.g., vascular dementia), and mild cognitive impairment in older adults. These disorders can cause problems with thinking, memory, and decision-making, and typically worsen over time.

Risk factors such as smoking and lower educational attainment are thought to play a bigger role than air pollution in contributing to the individual risk of neurodegenerative diseases. However, because air pollution affects such a broad swath of the population in heavily polluted areas, even a small increase in neurodegeneration can have major effects at the societal scale. An estimated 60 million people were living with dementia worldwide in 2021, and scientists estimate that about 10 million people develop dementia each year, causing an overall rise in cases as the global population ages. Because people with dementia require help with their daily care, a high prevalence of this disease has rippling effects on economic productivity for families and caregivers, with an estimated economic impact of over a trillion dollars a year. Women bear the largest burden, being both more likely to provide care for people with dementia and more likely to develop dementia themselves.

Air pollution exposure may also impact brain development and functioning in younger people, including an increased risk for neurodevelopmental disorders such as autism and psychological disorders such as anxiety and depression.

In 2023, dementia attributable to air pollution resulted in 626,000 deaths and 11.6 million healthy years of life lost.

Effects of Air Pollutants on Brain Health



Credit: Michaiel A et al. (2025). Climate Change and Brain Health: Current Insights and Emerging Evidence.

Impacts on Children's Health

Exposure to air pollution during pregnancy has also been linked to miscarriage, stillbirths, and congenital disorders and anomalies. Being exposed to air pollution in the womb increases the likelihood that a baby will be born too small (low birth weight) or too early (preterm birth). Babies born prematurely or with low birth weight are more susceptible to lower respiratory infections and other serious infections, diarrheal diseases, inflammation, blood disorders, jaundice, and impacts on brain development. If affected babies survive infancy, they remain at a higher risk for lower respiratory tract infections, other infectious diseases, and major chronic diseases throughout life.

Breathing polluted air early in life can have both immediate and long-term implications for a child's health. Air pollution affects children's health through its role in increasing risk for pneumonia and other respiratory infections and allergic diseases. Such infections during childhood can also result in long-term health effects, including impaired lung growth and a higher risk for chronic diseases later in life.

Pollution also affects children's bodies differently than it affects adults. Children's lungs, brains, and other organs are immature, and their immune systems are still developing; this means that their bodies are not equipped with the same defense mechanisms as adults. Breathing even the same amount of pollution can result in worse impacts in children because children have smaller airway passages; thus, inflammation due to air pollutants creates proportionally more airway blockage than in adults. In addition, pollution can interfere with a child's growth and development, leading to lifelong impacts.

Exposure to ambient $PM_{2.5}$ resulted in 171,000 deaths in children under 5 years old.

Air Pollution's Burden of Disease

1 in 8

deaths worldwide is attributed to air pollution.

Together, an estimated 7.9 million deaths globally [95% UI: 6.4–9.4] were attributed to ambient and household $PM_{2.5}$ and ground-level ozone pollution— about 13% of the total deaths — in 2023. Of this total, 4.9 million deaths [95% UI: 3.9–6.1] were attributed to ambient $PM_{2.5}$ exposure, 2.8 million [95% UI: 2.1–3.7] were from household air pollution, and 470,000 [95% UI: 108,000–800,000] were from ozone (**Figure 12**). Of note, for NO_2, only DALYs for childhood asthma are calculated; the total number of deaths are not estimated.

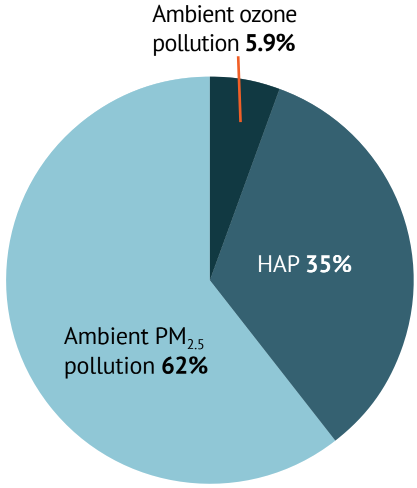


FIGURE 12: Percentage of global deaths attributable to individual pollutants in 2023.

Children playing soccer in South Africa

The past decade has seen some progress toward reducing the toll of air pollution. Overall, the age-standardized death rate attributable to air pollution decreased by 21% from 2013 to 2023. This improvement has been largely driven by a decline in HAP exposures and associated disease burden, while the rates of death linked to $PM_{2.5}$ and ozone have increased.

Air pollution's burden of disease does not fall evenly across age groups. Throughout the world, children and older people are most severely affected (Figure 13). In 2023, nearly 5 million deaths (95% UI: 3.8–5.7) among people over age 70 were linked to air pollution, with about 3 million (95% UI: 2.6–4.1) related to ambient $PM_{2.5}$, 1 million (95% UI: 900,000–2 million) to HAP, and 300,000 (95% UI: 81,000–588,000) to ozone. The toll of air pollution is likely to increase in the coming years as populations age and much of the world continues to experience high levels of pollution.

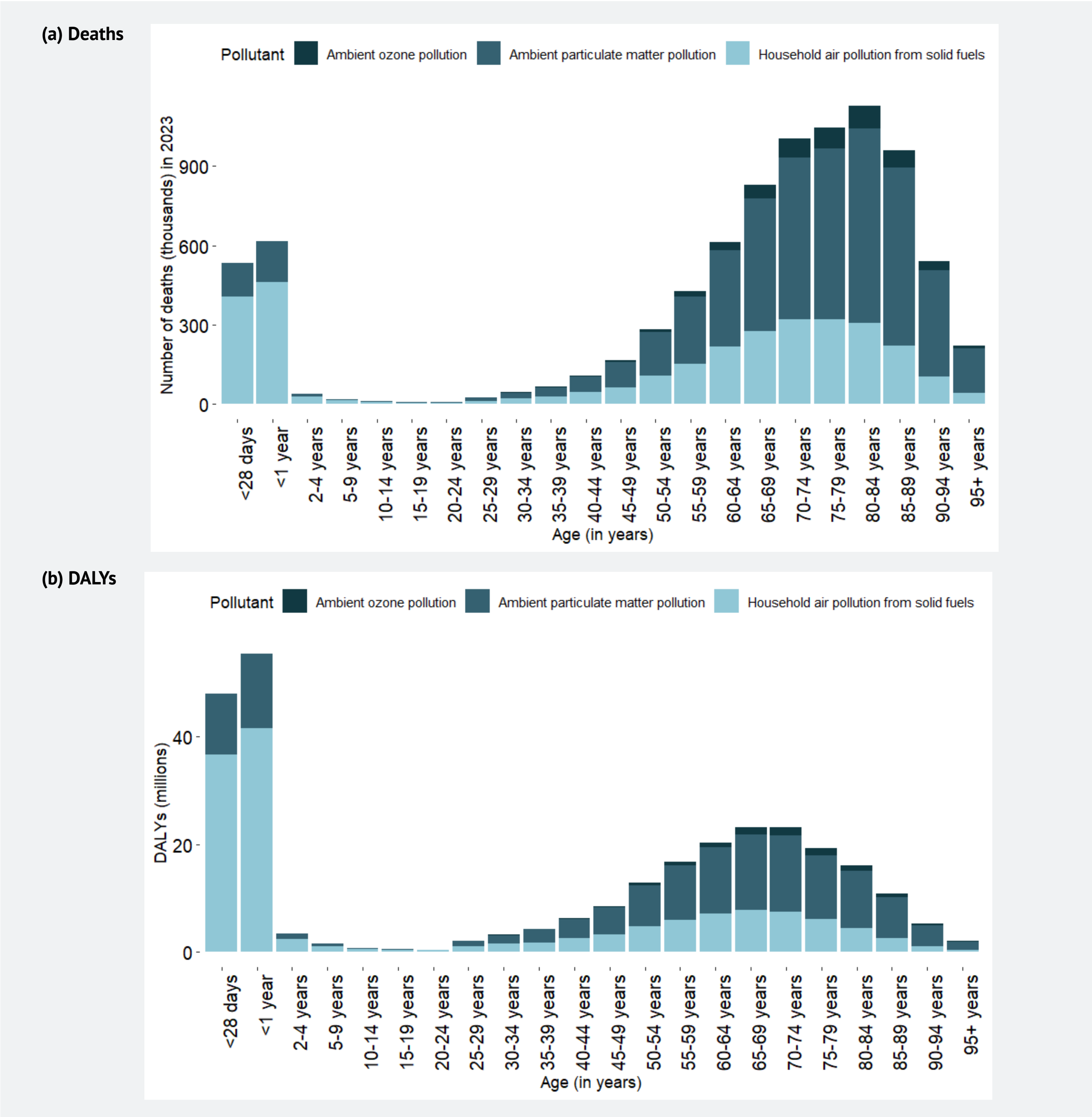


FIGURE 13: Distribution of (a) global deaths and (b) DALYs in 2023 attributable to ambient $PM_{2.5}$, HAP, and ozone, by age. Much of the disease burden of air pollution falls on older populations as a result of the role that age plays in noncommunicable diseases.

Most deaths attributable to air pollution occur in low- and middle-income countries. Overall, South Asian countries face the largest burden of disease attributed to air pollution (**Figure 14**). India and China each had more than 2 million deaths attributable to air pollution in 2023; Bangladesh, Pakistan, and Nigeria each saw more than 200,000 deaths; and Indonesia, Myanmar, and Egypt each saw more than 100,000 deaths. This disproportionate impact, illustrated also by the death rates taking into account the size of the population at risk, is also seen at a regional level. In South Asia, for example, the death rate attributable to air pollution (191 deaths/100,000 people) is more than 10 times higher compared to high-income countries (17 deaths/100,000 people) (**Table 1**). Furthermore, both in South Asia and East, West, Central, and Southern Africa, exposure to $PM_{2.5}$ (ambient and household) continues to drive the disease burden (**Figure 15**).

Table 1: Age-standardized death rate attributable to air pollution across GBD super regions in 2023.

GBD Super Region	Deaths/100,000 People
Global	92
South Asia	191
East, West, Central, and Southern Africa	145
North Africa and Middle East	120
Southeast Asia, East Asia, and Oceania	100
Central Europe, Eastern Europe, and Central Asia	56.3
Latin America and Caribbean	47
High-income	16.7
G20	***82***
EU	***21.2***

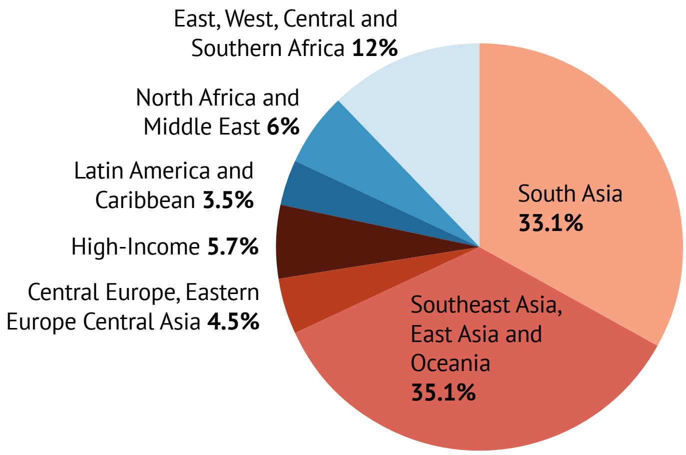


FIGURE 14: Global distribution of deaths attributed to air pollution across GBD super regions in 2023. *Note that two countries, India (South Asia) and China (East Asia), account for 52% of the total air pollution deaths.*

Traffic in Jakarta, Indonesia

Dig Deeper

For more on the health effects of air pollution, who is affected, and what the science shows, visit *stateofglobalair.org*.

Morning smog in Samanoud, Egypt

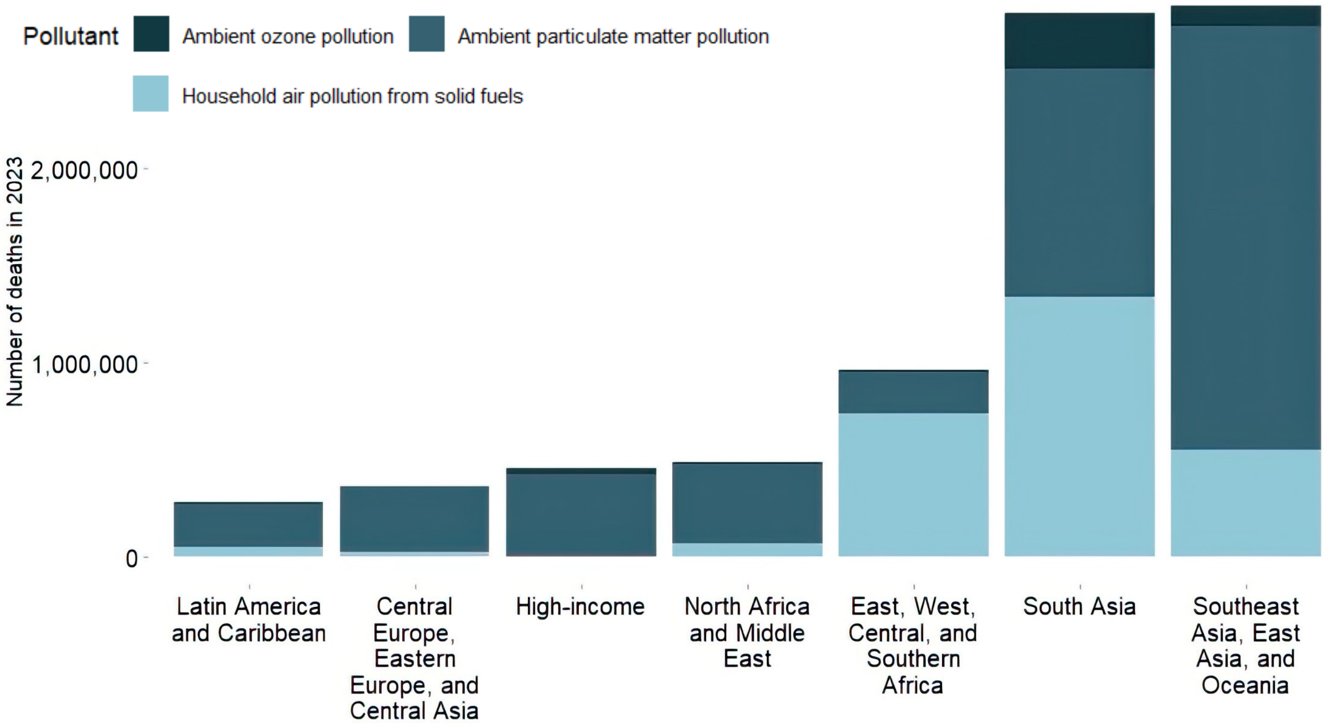


FIGURE 15: Total deaths attributable to ambient $PM_{2.5}$, HAP, and ozone in 2023, by GBD super region.

Disease Burden Attributable to Noncommunicable Diseases

Noncommunicable diseases account for 86% of global deaths attributable to air pollution.

Most deaths attributed to air pollution stem from air pollution's role in the development and exacerbation of noncommunicable diseases. These diseases, which are often long-lasting and incurable, were responsible for 86% of air pollution-attributable deaths in 2023. Overall, 6.8 million deaths (95% UI: 5.5–8.1) and 161 million (95% UI: 134–188) healthy years of life lost caused by NCDs were attributed to air pollution in 2023, with 4.5 million deaths (95% UI: 3.6–5.7) attributable to ambient $PM_{2.5}$ pollution, 2.1 million deaths (95% UI: 1.4–3) to household air pollution, and 470,000 deaths (95% UI: 108,000–801,000) to ozone. Ischemic heart disease, stroke, and COPD had the largest burden of disease attributed to air pollution in 2023 (**Figure 16**).

Between 2000 and 2023, the total number of NCD deaths attributed to air pollution increased from 5.99 million to 6.8 million — a 14% increase. During the same time, healthy years of life lost (i.e., DALYs) increased from 145 million to 161 million. Given this large and increasing burden, action on air pollution is likely to be a key contributor toward reaching SDG target 3.4 (reduce premature NCD mortality by one-third by 2030).

More than 1 in 4 dementia deaths are attributable to air pollution.

The Impact of Air Pollution on Dementia

In 2023, there were 60 million global cases, 2.2 million deaths, and 40 million DALYs or healthy years of life lost due to dementia. Of these, roughly 626,000 global deaths (95% UI: 75,000-1.8 million) and 11.6 million healthy years of life lost were attributed to air pollution, making up 29% of all global dementia deaths in 2023. The largest burdens are seen in Africa and Asia, with the lowest overall burden in high-income countries (**Figure 17**).

Note that the overall body of evidence on the association between exposure to $PM_{2.5}$ and dementia is less precise compared to other outcomes, such as stroke or COPD. This is in part because there is limited evidence from low- and middle-income countries, and because of variations in diagnoses and limited baseline health data.

Noncommunicable diseases impose a high burden on people and societies. Six of the leading 10 causes of death globally are noncommunicable diseases. Air pollution — especially $PM_{2.5}$ — is recognized as a risk factor for all of them, including various forms of heart disease, COPD and other lung diseases, dementia, and lung cancers. In addition to contributing to premature death, noncommunicable diseases can result in increased hospital admissions and need for emergency medical care (e.g., stroke, asthma); this can result in high healthcare use, economic losses, and mental health and other burdens for affected individuals and their caregivers and families. Among people living with NCDs, exposure to air pollution, including short-term exposures such as those during an air pollution episode, can result in health complications, reduce the effectiveness of treatment (e.g., for cancer), and severely impact their quality of life by restricting their ability to work, attend education, or go outdoors.

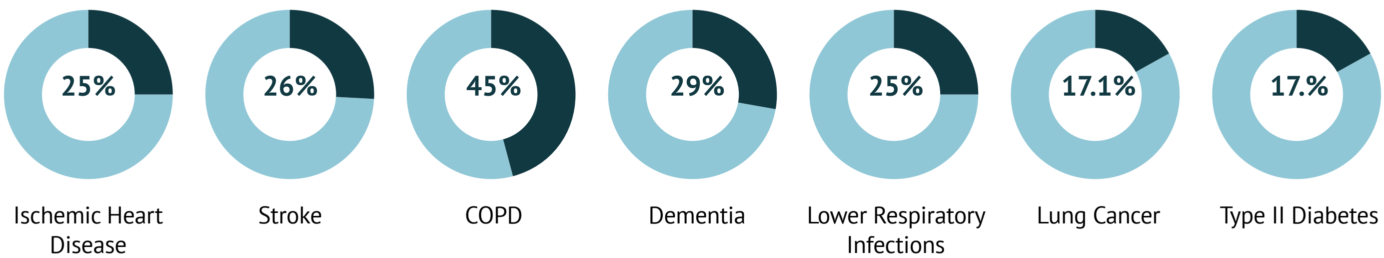


FIGURE 16: Percentage of global deaths from specific causes attributed to air pollution in 2023.

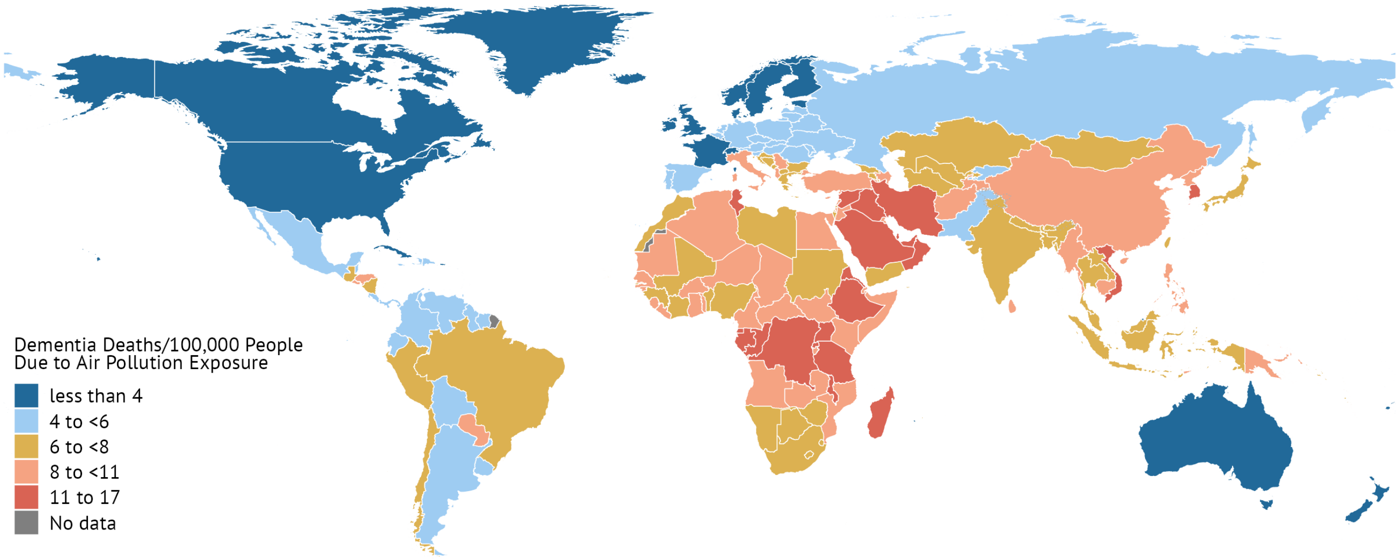


FIGURE 17: **Age-standardized rates of death due to dementia attributable to air pollution in 2023.**

People with fewer resources bear the highest burden. The toll of living with noncommunicable diseases — and the likelihood of dying early from them — varies from place to place depending on the level and types of exposures, the age distribution of the population, and other factors. Overall, people with the least resources and more limited access to healthcare experience the worst impacts (**Figure 18**). For example, while the contribution of air pollution to ischemic heart disease is 25% on average globally, that includes a range from 7% in higher income regions of the world to over 35% in regions including East, West, Central, and Southern Africa and South Asia. People who face disadvantages related to socioeconomic status, race, and ethnicity often have higher pollution exposures, more underlying health problems, and less access to healthcare, which makes them more likely to become seriously ill.

Climate change amplifies the impacts. Climate change can exacerbate the health burden of noncommunicable diseases. For example, the numbers of deaths related to heart and lung diseases tend to increase during heat waves, which are becoming more common as the planet warms. Recent studies, including one with data from 620 cities across 36 countries, have shown that the joint effects of high temperatures and air pollution can result in increased risk of deaths (Anenberg et al. 2020; Stafoggia et al. 2023). Additionally, extreme weather events can pose additional challenges, such as delays in NCD diagnosis, care, and treatment due to power outages and infrastructure damage.

Curbing air pollution can bring multiple benefits. Reducing air pollution exposures can simultaneously slow climate change, reduce pollution-related illnesses, improve economic productivity, and save on healthcare spending. For example, every dollar spent on air pollution controls in the United States has resulted in ~$30 of benefits, while in Delhi (India), the value of implementing air pollution abatements exceeds costs by 2 to 3.6 times (World Bank 2025). There is increasing evidence that reductions in air pollution can result in both health and cost savings, both in the short- and long-term. For example, in the UK, it has been estimated that compared to the business as usual scenario, air pollution reductions as a result of net zero policies can result in substantial mortality and morbidity benefits; for example, through reduction in active cases of COPD and asthma: 201,000 (150,000 – 250,000) and 192,000 (64,600–311,000), respectively (Walton et al. 2025).

Recognizing these many co-benefits, leaders at the city, national, and international levels are urging action to address air pollution as part of the strategy to reduce the toll of noncommunicable diseases. One is the inclusion of air pollution as a risk factor in the United Nations' noncommunicable diseases framework and recognition that mitigating air pollution is integral to achieving ***target 3.4*** under the Sustainable Development Goals, which aims to reduce premature mortality from noncommunicable diseases by one-third by 2030. Another example is a 2023 ***statement*** in support of stronger air quality monitoring by eight mayors from the Partnership for Healthy Cities. In May 2025, Ministers of Health endorsed a WHO global roadmap at the World Health Assembly, which requires countries to reduce the health impacts of air pollution by 50% by 2040 (vs. 2015 baseline).

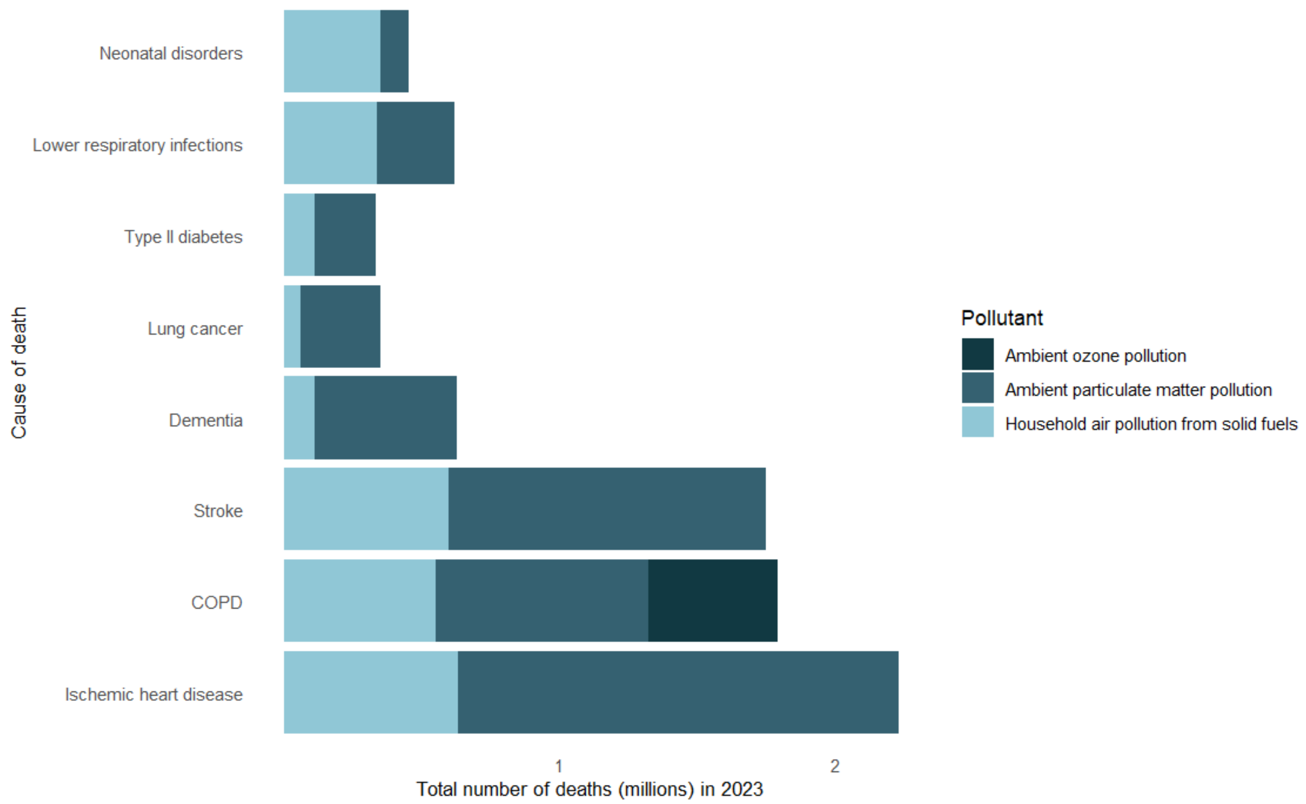


FIGURE 18: Number of air pollution attributable deaths by cause of death and pollutant type in 2023.

The Economic Cost of Air Pollution

People becoming sick or dying early because of exposure to air pollution results in high costs to society. This cost comes from healthcare use and spending, loss of economic productivity and income, and intangible economic burdens borne by families. One estimate suggests that the health impacts associated with exposure to ambient $PM_{2.5}$ resulted in economic impacts equivalent to 4.7%–6.5 % of the global GDP in 2020 (World Bank 2025). Several recent studies have quantified the impacts of air pollution's disease burden on healthcare systems, albeit using different metrics. We summarize illustrative examples of air pollution-related out-of-pocket or healthcare sector-specific costs below.

1. Air pollution-linked diseases cost the United Kingdom £5.56 billion between 2017 and 2025, including costs borne by the National Health Service and families (Pimpin et al. 2018).
2. In Leicester (UK), researchers linked neighborhood PM_{10} with increased healthcare demand, estimating that an increase of one standard deviation in PM_{10} exposure raises public healthcare costs by over £873,000 per year in that city alone (Boggiano et al. 2024).
3. In the United States, higher levels of ambient $PM_{2.5}$ have been estimated to a 13% increase in spending on asthma and COPD (Williams and Phaneuf 2019).
4. In France, researchers estimated that in 2018, nearly €13 billion could have been saved if $PM_{2.5}$ pollution were kept below a minimal threshold of 3 μg/m³ (Corso et al. 2025).
5. In Japan, researchers have highlighted that $PM_{2.5}$-related disease burden and limited availability of specialty healthcare services can result in higher economic costs for older people and exacerbate health disparities (Xu et al. 2025).
6. In China, clean air action between 2015 and 2017 is estimated to have resulted in an 8.09% decline in health expenditure across 98 cities due to air pollution-related stroke, ischemic heart disease, COPD, and LRI (Weng et al. 2023).

Disease Burden Attributable to Ambient $PM_{2.5}$

Ambient $PM_{2.5}$ is the largest driver of air pollution's burden of disease worldwide. In 2023, 4.9 million deaths (95% UI: 3.9–6.1) and 124 million healthy years of life lost (95% UI: 101–147) were attributed to long-term exposures to ambient $PM_{2.5}$ pollution, accounting for over 60% of all air pollution–attributable deaths and over 50% of DALYs, respectively. Of the total deaths, ~4.3 million deaths (87%) were in low- and middle-income countries, as defined by the World Bank.

Of the total death, 4.5 million, or 67% were due to NCDs, including 2.75 million (95% UI: 2.1–3.4) from cardiovascular diseases, 771,000 (95% UI: 582,000–997,000) from COPD, 514,000 from dementia (95% UI: 60,000–1.5), 289,000 from lung cancer (95% UI: 185,000–407,000), and 224,000 from diabetes (95% UI: 132,000–332,000).

The burden varies widely around the globe, reflecting variation in exposures, underlying prevalence of disease, and other differences in population susceptibilities. The regions that bear the highest burden from ambient $PM_{2.5}$ pollution are North Africa and the Middle East (102 deaths/100,000 people), South Asia (85 deaths/100,000 people), and Southeast Asia, East Asia, and Oceania (78 deaths/100,000 people) (**Figure 19**). Relative contributions of different sources to ambient $PM_{2.5}$ vary across the globe. Of the 4.9 million deaths, 1.34 million were due to fossil fuel use, while an additional million were due to residential use of solid fuels for cooking.

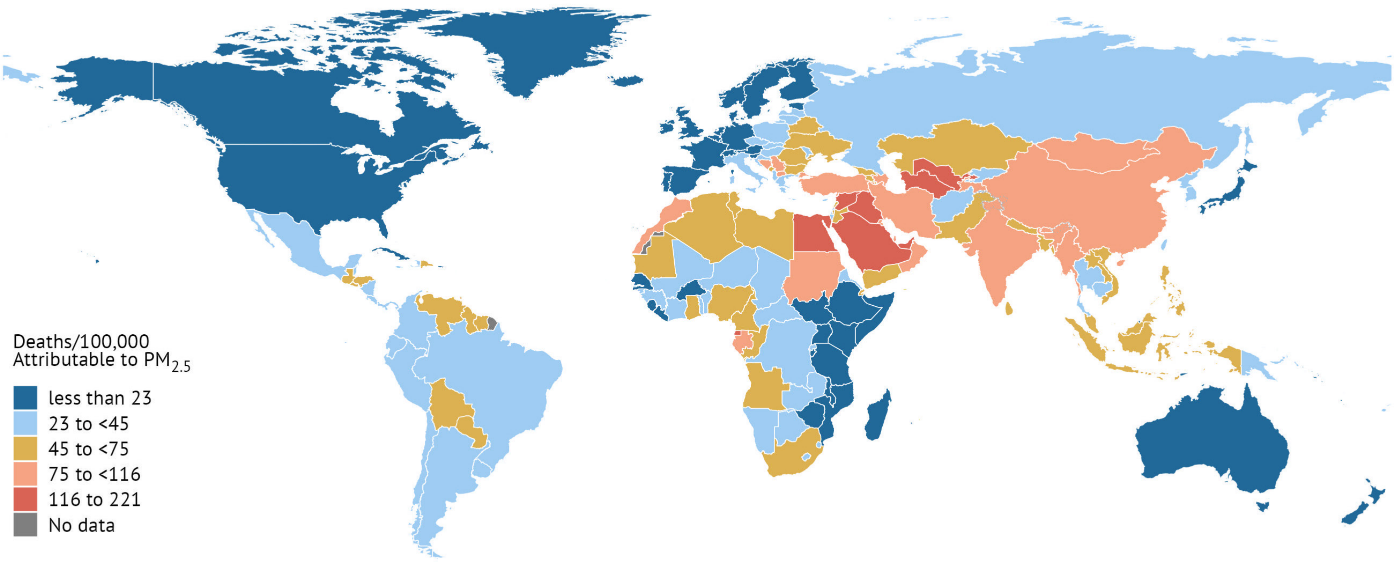


FIGURE 19: Global map of age-standardized rates of death attributable to ambient $PM_{2.5}$ in 2023. The age-standardized death rate is a useful metric for comparing the burden of disease attributable to a particular risk factor across countries or regions because it factors in population age structure and size.

Spotlight on Success: Air Quality Actions

Commitment Toward Alignment with WHO Air Quality Guidelines in Brazil

Brazil, Latin America's largest and most populous country, adopted a new National Air Quality Policy in 2024, renewing its commitment toward aligning with the WHO Air Quality Guidelines and improving public health. The policy emphasizes the urgent need to expand air quality monitoring networks and sets timelines for achieving interim air quality targets. In addition, the country launched the *VigiAr Panel*, a collaborative effort of the Ministries of Health and Environment and Climate Change to provide user-friendly information on air pollution and its impacts across the country and identify areas that require urgent attention to meet air quality goals.

Air Quality Improvements in China

China's air quality has steadily improved in the past decade since the launch of the country's *Air Pollution Prevention and Control Action Plan* in 2013, illustrating that it is possible to decouple emissions from economic growth. With a focus on measuring and reducing pollution sources, emissions, and concentrations, the country's efforts have proved effective in reducing average $PM_{2.5}$ levels in Chinese cities (YEAR) to just over 29 µg/m³ in 2024 according to local data, down 2.7% year over year. Recent studies have attributed much of this improvement to restrictions aimed at reducing coal-related emissions, which have also yielded significant health benefits. However, further progress will be needed to align with the WHO Air Quality Guideline of less than 5 µg/m³ for $PM_{2.5}$ and to address ozone pollution, which has increased in recent years. Plans to revise the country's Ambient Air Quality Standards are now underway and the Ministry of Ecology and Environment is developing an Action Plan for Continuous Air Quality Improvement for 2026–2030.

Tracking Trends in India

India's *National Programme on Climate Change & Human Health* includes a variety of actions to track air pollution's health impacts across the country and within each state. This includes a surveillance system with sentinel sites at nearly 80 hospitals across 18 states to document acute respiratory infections due to air pollution and assess trends and patterns. New training resources for community health workers and district health officers will arm public health workers to better recognize air pollution-related health impacts.

New Air Quality Standards in Uganda

Uganda, a country with 48 million people that sees about 30,000 air pollution-related deaths each year, adopted the first *National Environment (Air Quality Standards) Regulations, 2024*. The regulations were developed under the leadership of the country's National Environment Management Authority, through a highly collaborative process involving academia, international development partners, the regulated sector (i.e., and other key government agencies. The regulations establish an enforceable framework for industrial monitoring and emissions-reduction technologies, in addition to provisions for regular emissions testing for vehicles, and the phase-out of engine types that do not meet the Euro IV emission standards.

Expansion of Air Quality Monitoring in Uzbekistan

Uzbekistan has made important strides in strengthening its air quality governance and infrastructure. In 2024, the country *adopted* updated national air quality standards for $PM_{2.5}$ and PM_{10}, aligning its annual $PM_{2.5}$ limit (35 µg/m³) with the WHO Interim Target 1 — a first in Central Asia. The national monitoring network has expanded significantly since 2022, now comprising 89 monitoring points across 26 cities, including 23 modern automatic stations and one mobile unit, with plans to add over 347 additional mini stations. All provincial centers are now covered, enabling hourly data updates and integration into public platforms. Uzbekistan is also developing its first-ever comprehensive National Atmospheric Air Protection Strategy (2035), expected by the end of 2025. This strategy aims to unify current fragmented efforts and strengthen air quality management in high-impact sectors such as industry and transport.

Comprehensive Air Quality Management in Ghana

The Environmental Protection (Air Quality Management) Regulations, 2025, Legislative Instrument (LI) 2507 — developed by the Ghana Environmental Protection Authority — was passed into law in June 2025 and entered into force in July 2025. The LI 2507 seeks to improve air quality and marks a significant milestone for air quality management in the country. The regulations, among others, seek to control air emissions from mobile, diffuse, stationary and point sources including motor vehicles, industrial, commercial, domestic, construction, agricultural and waste disposal, and facilitate enforcement of the Ghana Standard for Environment and Health Protection-Requirements for Ambient Air Quality and Point source/Stack Emissions (GS 1236) and the Ghana Standard for Environment and Health Protection-Requirements for Motor Vehicle Emissions (GS 1219). For effective air quality management in the country, the regulations further mandate the development and implementation of a national air quality management framework and information management system, and air quality management plans by District Assemblies.

Disease Burden Attributable to Ozone

The GBD study estimates the disease burden of ground-level ozone primarily based on its contributions to COPD, a debilitating lung disease seen mostly in older adults. In 2023, 470,000 deaths (95% UI: 108,000-801,000) from COPD were attributed to long-term exposures to ozone, accounting for nearly 14% (95% UI: 3–23) of all COPD deaths globally. This premature loss of life equates to 8.5 million (95% UI: 1.9–14.6) healthy years of life lost from COPD attributable to ambient ozone pollution across the world. Of the total deaths, ~430,000 deaths (91%) were in low- and middle-income countries, as defined by the World Bank. In the last two decades, the disease burden of ozone has increased by more than 50%, from 261,000 deaths in 2000 to 470,000 deaths in 2023.

As with $PM_{2.5}$, the burden of disease associated with ozone varies from place to place, given regional differences in ozone exposures, as well as underlying health and population characteristics. Countries in South Asia — particularly India (234,000 deaths [95% UI: 57,000–407,000]), Bangladesh (28,000 deaths [95% UI: 5,000–52,000]), and Pakistan (18,000 deaths [95% UI: 4,000–35,000]) — along with China (95,000 deaths [95% UI: 22,000–181,000], and the United States (13,000 deaths [95% UI: 3,000–23,000] experience the highest numbers of deaths due to exposure to ozone (**Figure 20**).

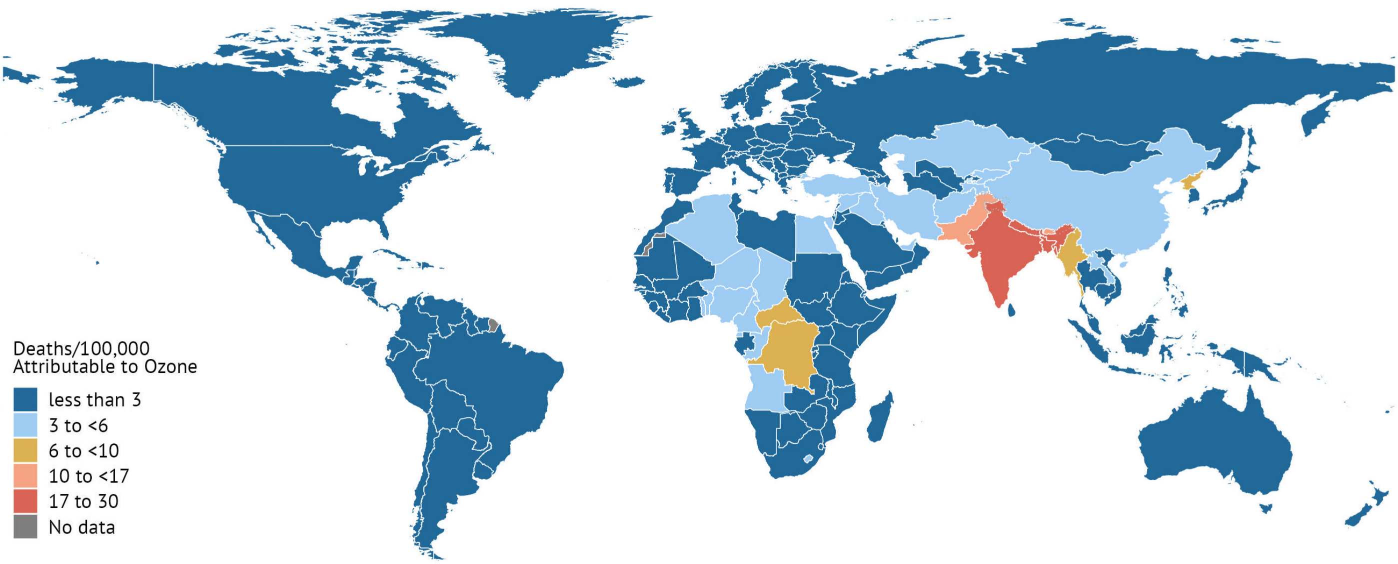


FIGURE 20: Global map of age-standardized rates of death attributable to ozone in 2020. Note: GBD only estimates the ozone disease burden linked to COPD.

Disease Burden Attributable to NO_2

The GBD study estimates the disease burden of NO_2 primarily based on its contributions to asthma, a disease that can emerge in early childhood or later in life. Studies show that being exposed to NO_2 can increase a child's chance of developing asthma, and there is strong evidence that breathing polluted air can worsen asthma symptoms and trigger acute episodes known as asthma attacks (HEI 2022). The impacts of asthma on quality of life, healthcare costs, loss of school days, and frequent hospital visits impose substantial social and economic burdens on children, their families, and health systems.

NO_2 exposures are estimated to have resulted in about 138,600 healthy years of life lost (95% UI: 8,000–571,000) due to asthma among children aged 5–14 years in 2023. Overall, estimates show the highest disease burden in high-income countries (**Figure 21**). However, the burden in much of the world is likely to be underestimated because asthma often goes undiagnosed and untreated in low-income countries, and there is insufficient data to gauge the true prevalence of asthma in about half of the countries studied. Since 2000, asthma's air pollution-linked burden in terms of years living with disability has declined in high-income countries and in Latin America and the Caribbean while rising in South Asia and East, West, Central, and Southern Africa.

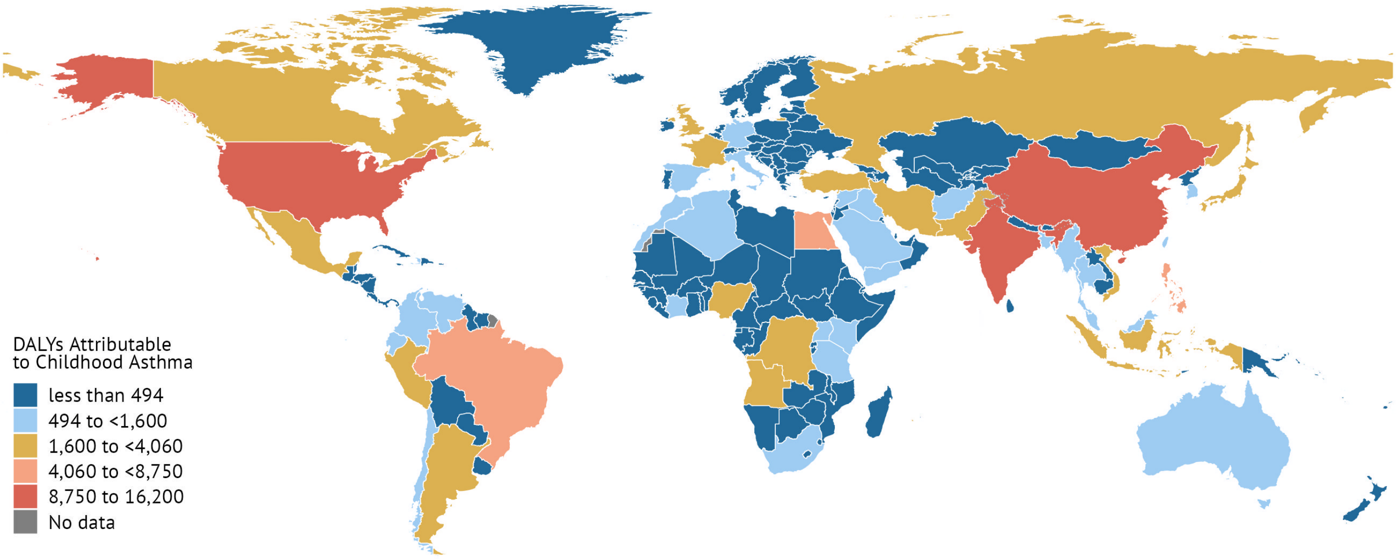


FIGURE 21: Global map of DALYs caused by childhood asthma among children ages 5–14 years attributable to NO_2 in 2023.

Conclusions

Air pollution threatens human life and economic productivity, with low- and middle-income countries seeing the worst impacts.

Air pollution continues to have devastating health impacts worldwide, with the largest health burdens experienced in low- and middle-income countries. Contributing to millions of premature deaths each year, as well as many years living with disability, exposure to air pollution directly harms health and indirectly harms economies and societies.

Air pollution is a major –but tractable– contributor to the world's leading causes of death. The burden of noncommunicable diseases is large and growing, in part due to aging populations, leading to increasing calls for strategies to mitigate these long-lasting and debilitating conditions. Strong evidence that air pollution is an important driver of noncommunicable diseases underscores the integral role of air quality interventions in developing strategies that can be effective in reducing their toll at the population level. Action taken to improve air quality — especially targeted toward key sectors, including energy, transport, and residential fuel use — can deliver health benefits (e.g., fewer strokes and asthma hospitalizations, improved birth outcomes, fewer heart attacks, and a reduced number of cancer and dementia cases) while producing healthcare savings.

Current trends suggest more changes lie ahead. Several trends are underway that may presage shifts in air pollution and its health impacts in the coming years. One factor is climate change, which is increasing the frequency and scale of wildfires, heat waves, and other extreme weather events. Wildfires can lead to temporary spikes in pollution exposures. Heat waves can also negatively impact air quality by increasing ozone formation, which can severely impact respiratory health. There is a need to better understand the health impacts of both wildfires and heat-related air quality impacts on both people living with NCDs and healthy people. For people with existing health conditions, wildfires can exacerbate health problems and increase the risk of premature death. At the same time, the global population is aging, and healthcare systems are coming under increasing strain. These trends can further undermine public health and preparedness and increase vulnerability to air pollution's health impacts.

On the other hand, there are also signs of progress around the world, with countries showing renewed commitments to curtailing air pollution and some seeing improvements because of their actions. A new WHO ***roadmap*** released in 2025 offers a clear goal and timeline for addressing air pollution, articulating a voluntary target to halve the health

Cloudy blue skies over Kampala, Uganda

The new WHO Roadmap includes a voluntary target of 50% reduction in the number of deaths due to human-made air pollution by 2040, compared to the 2015 baseline.

impacts of air pollution by 2040 through improved surveillance, knowledge synthesis, institutional capacity building, and global leadership. Upcoming regional and UN activities (e.g., COP30, upcoming high-level meetings, UN Environment Assembly) offer additional opportunities for bold commitments to curb air pollution.

Data and policies will be vital to continued progress. Robust, reliable data on air pollution and health can offer persuasive evidence to demonstrate the direct connections between reduced pollution, improved air quality, better quality of life, and economic opportunity for countries around the world. While the GBD study's estimates represent one of the most comprehensive sources of information available, there are inherent data limitations in any analysis of this size and scope. When interpreting the data and trends in this report, it is important to recognize that estimates of pollutant concentrations are drawn from multiple sources that may not always be directly comparable, health outcomes are not assessed in the same way everywhere, and understanding of the health effects of pollution is likely to evolve as additional studies are conducted. These limitations underscore the importance of continued air quality monitoring and disease surveillance to get the most accurate picture and inform effective air quality interventions. The need to further bolster data on air pollution levels and improve access to accurate health data is especially crucial for low- and middle-income countries, where data can be sparse but burdens can be high. With reliable information, broad awareness, and a shared commitment to a better future, it is never too late to take action to create cleaner air for future generations.

How Can We Make Progress?

The estimates of air pollution's disease burden presented in this report are intended to motivate action. Given the sizable contribution of air pollution to the NCD burden, both globally and in countries, air pollution should be integrated into policies and programs for NCD prevention and control. By leveraging evidence-based actions that are tailored to the local context, it is possible to create cleaner air for the world's growing populations.

Collect and utilize data on air pollution and NCDs. Given this large and increasing burden, action on air pollution is likely to be a key contributor toward reaching SDG target 3.4 (reduce premature NCD mortality by one-third by 2030). Accurate data on diseases and baseline health metrics is vital for health systems planning, estimating disease burden, and assessing the effectiveness of air quality interventions, both in terms of public health benefits and economic impacts. The health sector can also play a larger role through engagement in policymaking and identifying better ways for communicating risk. Meaningful collaborations between health and other sectors can also advance clean air action.

Use available evidence to inform decisions.

Organizations such as the Climate and Clean Air Coalition and the World Health Organization have produced a variety of resources that can be used to inform decision-making.

***Guidance for Action on Air Pollution*:** Guidance for action on air pollution: The Air Quality Management Exchange Platform (*AQMx.org*) was recently launched as a "one-stop shop" for technical tools and models, data, and knowledge to strengthen capacity among air quality managers worldwide. The platform was developed by the Climate and Clean Air Coalition and its partners in response to UN Environmental Assembly resolution 6/10 on promoting regional cooperation to improve air quality globally.

AQMx is designed to serve as a trusted source of information and resources to support governments, implementers, and stakeholders on the path to meeting interim targets identified in the WHO Air Quality Guidelines. It includes curated guidance for eight areas of air quality management — spanning from pollution monitoring and health impact assessment to public engagement and policy — with an initial focus on guidance for countries and cities with limited capacity or previous engagement in air quality management. It also includes a library of over 900 trusted resources and knowledge products, which will be regularly updated as new resources become available.

***Science Policy Summaries*:** The WHO Air Quality, Energy and Health Science and Policy Summaries *(SPS)* provide a concise overview of current knowledge and evidence on topics related to air quality, energy access, climate change, and health. These summaries are intended to support decision-makers by presenting key insights from scientific research. The summaries were developed through a global, multistakeholder consultation process including researchers and practitioners.

***WHO Air Quality Guidelines (AQGs)*:** The guidelines offer evidence-based public health recommendations and guidance on air quality and are based on evidence from studies on air pollution and health around the world. These guidelines were last updated in 2021.

Key Resources

Our monthly livestream, Science on the 7th, is an interactive livestream series where we hear from experts around the world on topics related to air pollution and health. Join us on the 7th of every month: *https://www.youtube.com/@HEISoGA/streams*

Global Burden Of Disease 2023 Methods

These references provide background details on the latest GBD methods used to estimate $PM_{2.5}$, NO_2 ozone, and household air pollution exposures and to estimate the premature deaths and DALYs reported in the State of Global Air this year.

Burden of Proof Visualization

Explore and download additional information and data on mortality and disease burden for air pollution, as well as other risk factors, at the IHME ***GBD Compare***.

Health Effects Of Air Pollution

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*The exposure estimates included in the Global Burden of Disease and State of Global Air incorporate city-level measurement data reported by countries to the World Health Organization and Open AQ, among many other sources. Explore, visualize, and download city-level data from the WHO Ambient Air Quality database and **OpenAQ**.*

Sources of Air Pollution

McDuffie E, Martin R, Yin H, Brauer M. 2021. Global Burden of Disease from Major Air Pollution Sources (GBD MAPS): A Global Approach. Research Report 210. Boston, MA: Health Effects Institute.

Mitigation of Air Pollution

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World Health Organization (WHO). 2021. WHO Global Air Quality Guidelines: Particulate Matter ($PM_{2.5}$ and PM_{10}), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide. Geneva: WHO. License CC BY-NC-SA 3.0 IGO.

*Explore information on the monitoring and management of air pollution on the **AQMx**.*

Videos

State of Global Air Initiative. 2024. Cleaner Air, Healthier Children. Boston, MA: Health Effects Institute. Available: ***https://www.stateofglobalair.org/resources/video/cleaner-air-healthier-children***.

State of Global Air Initiative. 2020. A Fragile Stage: Air Pollution's Impact on Newborns. Boston, MA: Health Effects Institute. Available: ***https://www.stateofglobalair.org/resources/video/fragile-stage-air-pollutions-impact-newborns***.

State of Global Air Initiative. 2020. Air Pollution and Climate Change. Boston, MA: Health Effects Institute. Available: ***https://www.stateofglobalair.org/resources/video/air-pollution-and-climate-change***.

UNICEF. 2024. What Does Air Pollution $PM_{2.5}$ Do Inside Children's Body and Brain? Available: ***https://www.youtube.com/watch?v=G1mUopisDX4***.

Key Definitions

Age-Standardized Rates

The total number of deaths or DALYs per 100,000 people, calculated based on a standard population distribution across age categories. Age-standardized rates allow direct comparison of the disease burden among countries with different population sizes and age distributions (e.g., older or younger). Higher air-pollution attributable, age-standardized disease rates reflect a combination of higher air pollution levels and populations that are more susceptible to the health impacts of pollution.

Burden of Disease

The GBD project measures the burden of disease for all risk factors, including air pollution, in terms of (1) deaths in a given year and (2) years of healthy life lost from death or disability, represented by disability-adjusted life years, or DALYs.

These measures of disease burden are estimated for each country using four components:

- Mathematical functions, derived from epidemiological studies, that relate different levels of exposure to the increased risk of death or disability from each cause by age and sex, where applicable;
- Estimates of population exposure to $PM_{2.5}$, household air pollution (HAP), NO_2, and ozone;
- Country-specific data on underlying rates of disease and death for each pollution-linked disease; and
- Population size and demographic data (age and sex) for each country.

Concentration

The amount of pollutant present in a unit volume of ambient air (Sexton 1988). Pollutant concentrations can be measured using ground-level monitors directly or estimated using air quality models or satellite data; for example, concentrations are closer proxies for air pollutant levels in our environment than emissions. Therefore, air quality standards are set using air pollutant concentrations. Typical units for concentration are $\mu g/m^3$, parts per million (ppm), and parts per billion (ppb).

Exposure

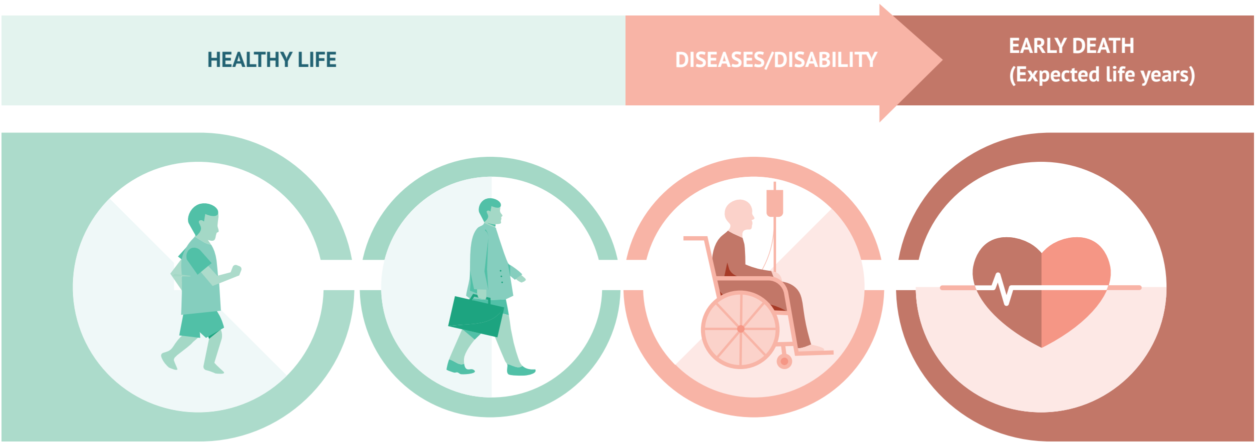
The pollutant concentration in the air at the point of contact between the external environment and human body (Sexton 1988) A person's exposure not only depends on air pollutant concentrations in the environment but also on their activities and behaviors that affect the magnitude, frequency, and duration of their contact with air pollutants. Therefore, individuals living in areas with the same air pollution concentrations do not necessarily have the same exposures.

Disability-Adjusted Life Years (DALYs)

DALYs represent both the years of life lost from premature deaths and years lived in poor health (e.g., years lived with paralysis from a stroke related to air pollution exposure). The level of poor health is weighted by the severity of the impact of each disease. One DALY equals one lost year of healthy life. DALYs are higher

DALY
Disability adjusted life year is a measure of overall disease burden, expressed as the cumulative number of years lost due to ill-health, disability or early death.

= years lived with disability + years of life lost



when younger people die compared with when older people die because young people still have many years ahead of them. Given the set of diseases currently attributed to air pollution in the GBD, most of the DALY burden stems from early deaths rather than years living with a disability; for this reason, the State of Global Air focuses largely on mortality.

Fine Particulate Matter, or $PM_{2.5}$

$PM_{2.5}$ refers to airborne particles measuring less than 2.5 micrometers in aerodynamic diameter (less than a 30th of the diameter of a human hair). Among the key air pollutants that are currently measured, long-term exposure to $PM_{2.5}$ is the most consistent predictor of poor health outcomes across populations. Long-term exposure to $PM_{2.5}$ is associated with illness and early death from diseases, including heart disease, lung cancer, chronic obstructive pulmonary disease (COPD), stroke, type 2 diabetes, lower respiratory infections (such as pneumonia), and adverse birth outcomes (such as preterm birth and low birth weight).

$PM_{2.5}$ concentrations are measured in micrograms of particulate matter per cubic meter of air, or $\mu g/m^3$. The GBD study estimates exposure to ambient $PM_{2.5}$ as the population-weighted annual average concentration, a measure that represents annual averages across an entire country or geographic region. Note that some people may be exposed to considerably higher concentrations than the exposure estimates presented here, especially if they live close to a pollution source or during short-term pollution spikes. For this analysis, annual average concentrations of $PM_{2.5}$, along with the 95% uncertainty interval (UI), were estimated across the entire globe, divided into blocks, or grid cells, each covering 0.1° × 0.1° of longitude and latitude (approximately 11 × 11 kilometers at the equator). To estimate the concentration to which someone living in a particular place is likely to be exposed, the concentrations in each block are linked with the number of people living within each block to produce a population-weighted annual average concentration.

Data from reference-grade monitoring stations and satellite observations are used in combination with global atmospheric models to produce the exposure estimates. Extensive comparisons of the estimates from satellite and modeling approaches with ground-level measurements demonstrate that estimates perform as reasonably accurate indicators of $PM_{2.5}$ in places where ground monitors do not exist or data are not publicly available.

Household Air Pollution (HAP)

HAP exposure results from burning solid fuels — such as wood, coal, charcoal, dung, and agricultural residues — for cooking using open fires or cookstoves. Solid fuels produce an array of harmful pollutants when burned; this report uses one of these pollutants, $PM_{2.5}$, as a representative proxy to estimate HAP health impacts.

Exposure to $PM_{2.5}$ related to HAP is estimated using a multistep process, beginning with estimating the proportion of populations that burn solid fuels for cooking. Data from international and national surveys, databases, and individual studies are used together with demographic data on household composition to estimate the percentage of men, women, and children of different ages who are potentially exposed to pollution as a result of cooking with solid fuels in each country. These percentages are then translated into $PM_{2.5}$ levels to which individuals are exposed based on data from the World Health Organization (WHO) Global Household Measurements Database and PURE-AIR using a mathematical model. These estimates likely understate the total exposure and disease burden of HAP in some regions (e.g., Eastern Europe and Central Asia) because they do not include exposures related to secondary cooking fuels, heating, or other residential activities.

Nitrogen Dioxide (NO_2)

NO_2 is a gaseous air pollutant that is mainly generated through the burning of fuel in vehicles, power plants, and industrial facilities. It belongs to a group of reactive gases known as nitrogen oxides (NO_x) and is often used as an indicator for this group and for the broader traffic-related air pollution mixture. NO_2 exposure has been associated with adverse health effects, including asthma and other respiratory diseases. In addition, NO_2 contributes to the formation of other pollutants, including ozone and secondary particulate matter.

For this report, exposure to NO_2 is defined as the population-weighted annual average concentration of NO_2 in parts per billion (ppb). The burden estimates for childhood asthma discussed in this report are expressed in years lived with disability (YLDs) for children and adolescents.

Noncommunicable Diseases (NCDs)

NCDs are long-lasting and not transmissible from one person to another. Examples include heart disease, diabetes, cancer, and COPD.

Number of Deaths

The number of deaths in a given year attributable to past exposure to air pollution.

Ozone

Ground-level, or tropospheric, ozone is a pollutant that harms human health, damages plants, and contributes to climate change. Unlike the primary pollutants, ozone is not released directly into the air but is formed through chemical interactions between NO_x and volatile organic compounds in the presence of sunlight. Ozone concentrations are measured in ppb. For this report, exposure to ozone is defined as the population-weighted daily maximum 8-hour average concentration in the warmest 6 months of the year. Note that this ground-level ozone is different from stratospheric ozone, which is protective against ultraviolet radiation. The 8-hour average ozone concentration is the same measure used in the WHO Air Quality Guidelines and as the exposure index in many epidemiological studies of ozone's health effects.

Premature Death

When an individual dies before reaching their potential maximum life expectancy for their age group.

Years Lived with Disability (YLDs)

One YLD represents the equivalent of one full year of healthy life lost due to poor health.

95% Uncertainty Intervals (UIs)

Estimates of uncertainty are provided for every value in the form of 95% UIs, representing the range between the 2.5th and 97.5th percentiles of the distribution of possible values.

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HEI is an independent air quality and health research institute. It is the primary developer of the State of Global Air reports and resources, the host and manager for the State of Global Air website, and the coordinator of input from all other members of the team. Key HEI contributors include Pallavi Pant, head of global initiatives; Hlina Kiros, research assistant; Abinaya Sekar, consulting research fellow; Victor Nthusi, consulting research fellow; Amy Andreini, science communications specialist; Kristin Eckles, senior editorial manager; Alexis Vaskas, digital communications manager; and Tom Champoux, director of science communications.

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The NCD Alliance (NCDA) is a registered nongovernmental organization based in Geneva, Switzerland, dedicated to supporting a world free from preventable suffering, disability, and death caused by noncommunicable diseases (NCDs). Founded in 2009, NCDA brings together a unique network of over 500 members in more than 100 countries into a respected, united, and credible global civil society movement. Key contributors from NCD Alliance are Liz Arnanz, Alison Cox, and Rachael Stanton.

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ZevRoss Spatial Analysis provided data visualization support and developed the interactive features on the State of Global Air website; ***Creative Science Writing*** provided writing support; Kristine Nemec provided editing support; ***Metropolis Creative*** designed the website; ***Charles River Web*** maintains the website; ***Studio Ping Pong*** provided design support; and ***David Wade*** provided composition support. Innodata, Inc., provided translations.

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