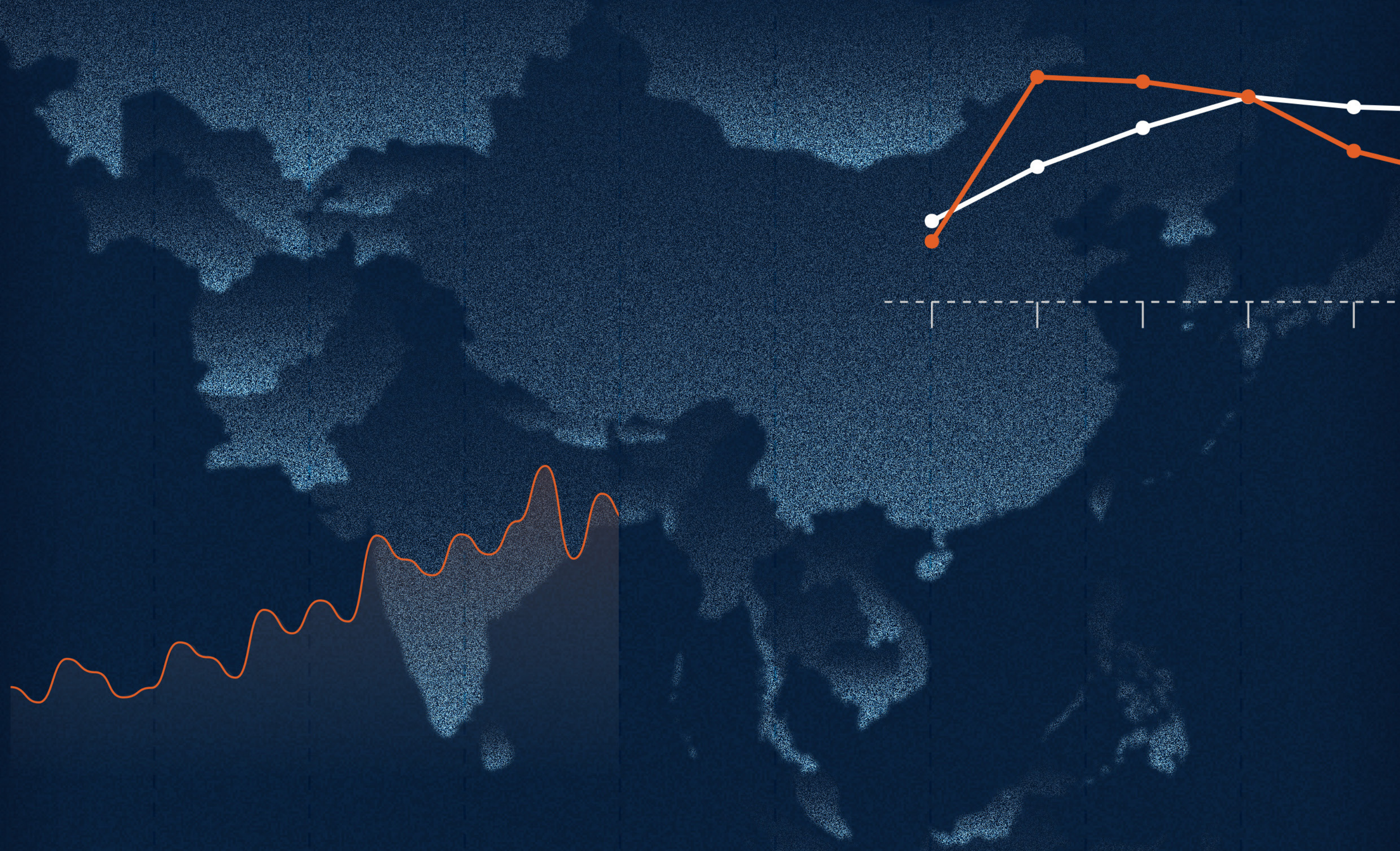
A STATE OF GLOBAL AIR REPORT

TRENDS IN AIR QUALITY AND HEALTH IMPACTS

INSIGHTS FROM CENTRAL, SOUTH, AND SOUTHEAST ASIA



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Health Effects Institute

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ABOUT STATE OF GLOBAL AIR

The State of Global Air (SoGA) is a research and outreach initiative to provide accurate, meaningful, and up-to-date information about air pollution and its health impacts 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, nongovernmental organizations (NGOs), and scientists access to high-quality, objective information about air pollution and its health impacts. All data, tools, and reports are free, open, and available to the public.

ABOUT THIS REPORT

This report presents information on exposures to and health impacts of fine particulate matter, ozone, and nitrogen dioxide from 1990 to 2021 for three Asian regions: South Asia, Central Asia, and Southeast Asia. The report draws upon the best available air quality data, estimates of health risks, and demographic data to produce globally comparable country-level data on air quality trends and the health impacts of air pollution.

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 at *https://www.stateofglobalair.org*.

Contents

Introduction

Air pollution is the leading environmental risk factor for poor health in Asia, affecting many millions of people across the continent.

Countries including India, Pakistan, Thailand, and Viet Nam experience some of the worst air quality episodes globally, putting a spotlight on local and regional air pollution. A clear case in point is the recurrence of air quality episodes in parts of Asia in October and November 2024. Cities including Lahore (Pakistan), Delhi (India) and Ust-Kamenogorsk (Kazakhstan) experienced poor air quality, resulting in shutdown of schools, and disruption to residents' daily activities.

Residents across Central, South, and Southeast Asia are routinely exposed to levels of air pollution above the health-based guidelines set by the World Health Organization (WHO) *(Figure 1)*, resulting not only in significant adverse health impacts but also a lower quality of life. In 2021, exposure to air pollution was among the leading risk factors for death and disability across these regions, contributing to more than 3.4 million deaths (HEI 2024). Exposure to air pollution has been found to result in increased illness and lower productivity, which in turn can result in missed workdays and diminished contributions to economic growth (Aguilar-Gomez et al. 2022; Neidell and Pestel 2023). Additionally, air pollution may impede cities' ability to attract skilled workers, further limiting economic competitiveness. According to the World Bank, between 4–11% of GDP equivalent was lost due to exposure to fine particulate matter, or $PM_{2.5}$, in 2019 in countries across Central, South, and Southeast Asia (World Bank 2021).

1 in 3

deaths in Central, South, and Southeast Asia are linked to air pollution.

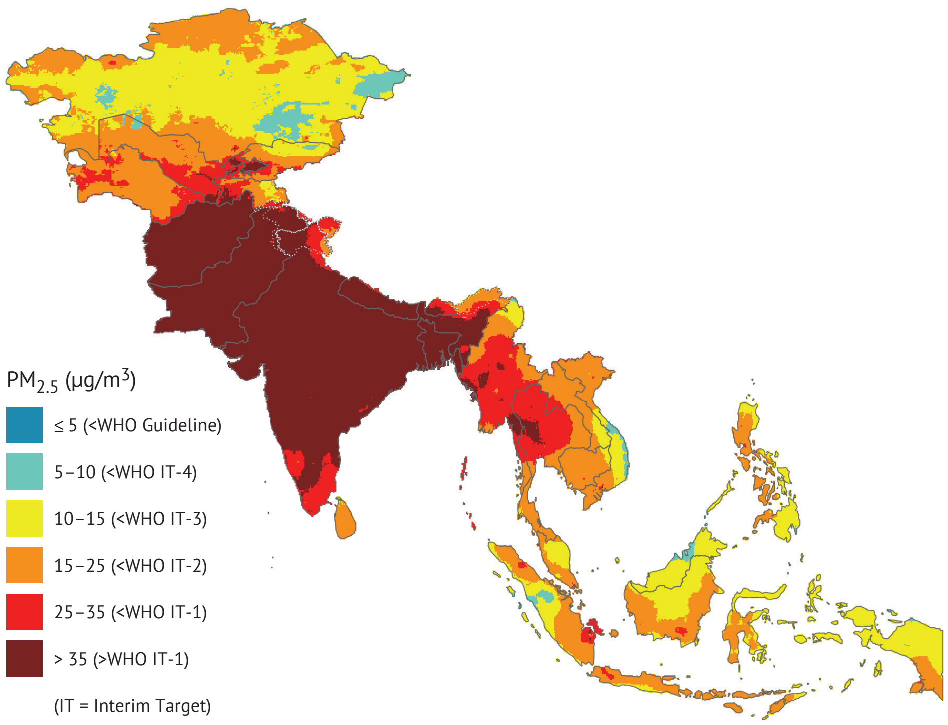


FIGURE 1. Comparison of annual average ambient $PM_{2.5}$ exposure in 2019 with *WHO Air Quality Guidelines*.

The level of population exposure is the main determinant of the burden of disease attributed to air pollution. Risk of a disease and death reduces gradually with the decreasing exposure, so each improvement in air quality is reflected in a better population health. Therefore, the World Health Organization has recommended Air Quality Guidelines (AQG) level and Interim Targets (ITs) as incremental steps in the progressive reduction of air pollution toward AQG levels in areas where air pollution is high. Together, the guideline value and interim targets provide a health-based framework for countries to improve air quality and protect people's health.

Across Asia, there is a growing public demand for action to improve air quality.

Indonesia

In 2019, in response to a citizen lawsuit in Jakarta, Indonesia, the court *ordered* the establishment of stricter national and regional air quality standards. They also mandated increased supervision of emissions and required the prevention and reduction of health impacts from air pollution, while also ensuring public participation and transparency in these efforts.

Thailand

In Chiang Mai, Thailand, a group of 10 legal experts, medical practitioners, and civil advocates took the $PM_{2.5}$ issue to court, which resulted in a court ruling that an action plan must be issued within 90 days.

India

In India, several policy interventions, including the phasing out of diesel vehicles in the Delhi National Capital Region, have resulted from court orders driven by citizen petitions.

Pakistan

Similarly, in Pakistan, interventions from the Lahore High Court and the Supreme Court of Pakistan resulted in the creation of the *Policy on Controlling Smog* in 2017 and the *Smog Commission*, which issued a public report in 2018.

Uzbekistan

In Tashkent, Uzbekistan, *public pressure* led the city to establish new rules and regulations on air pollution that address key sources of pollution, including coal-burning power plants and polluting fuels.

Yet there is limited funding for improving air quality across the region.

Overall, only 1% of the international development funding was allocated for outdoor air pollution. Despite significant health and economic impacts, development funding remains low for most countries in the region. Recent estimates from the Clean Air Fund have shown that between 2018 and 2022, around 70% of the total international development funding for outdoor air pollution was concentrated in three Asian countries: the Philippines (30%), Bangladesh (23%), and China (19%). In addition, philanthropic funding for air quality is notably low in parts of Asia, apart from China and India. Note that this does not represent the full scope of funding available for air quality management across the regions.

What this report covers

Systematic and consistent efforts to track progress toward reducing air pollution, as well as the impacts these reductions have on human health, remain essential. This report presents the latest comprehensive estimates of exposures to $PM_{2.5}$, nitrogen dioxide (NO_2), household air pollution (HAP), and ozone, and their impacts on human health across Central, South, and Southeast Asia at the national level. This report focuses on long-term exposures to each of these air pollutants and on associated health impacts. Long-term exposures are those that occur over multiple years and that studies have shown to result in the largest impact on chronic diseases, which are diseases that persist for a long time and can take several years to develop.

What countries does the report cover?

The report covers three regions in Asia:

Central Asia:
Kazakhstan, Kyrgyzstan, Turkmenistan, Tajikistan, and Uzbekistan

South Asia:
Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka

Southeast Asia:
Cambodia, Indonesia, Laos People's Democratic Republic (Lao PDR), Malaysia, Myanmar, the Philippines, Singapore, Thailand, Timor-Leste, and Viet Nam

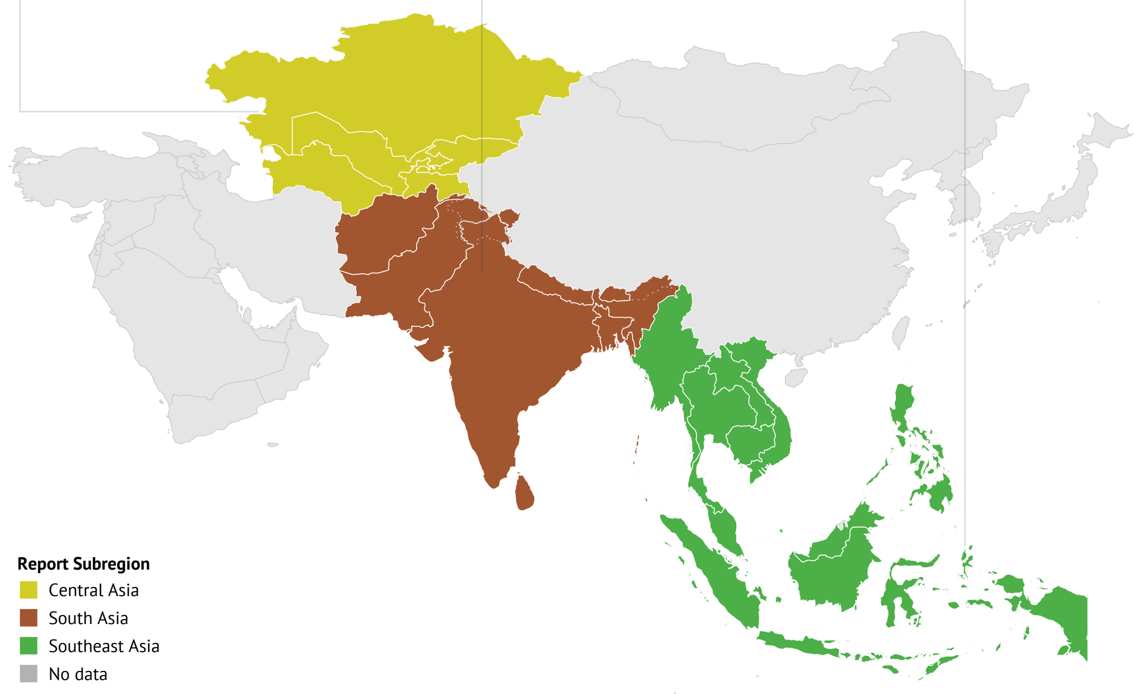


FIGURE i. Regions of Asia included in the State of Global Air Asia report

Of the countries included in this analysis, India, Indonesia, Pakistan, Bangladesh, the Philippines, Viet Nam, and Thailand rank among the 20 most populated countries worldwide.

Note that this report does not include countries in East and West Asia, most of which are middle- and high-income countries. Future editions of the State of Global Air report will cover the trends and patterns in these regions.

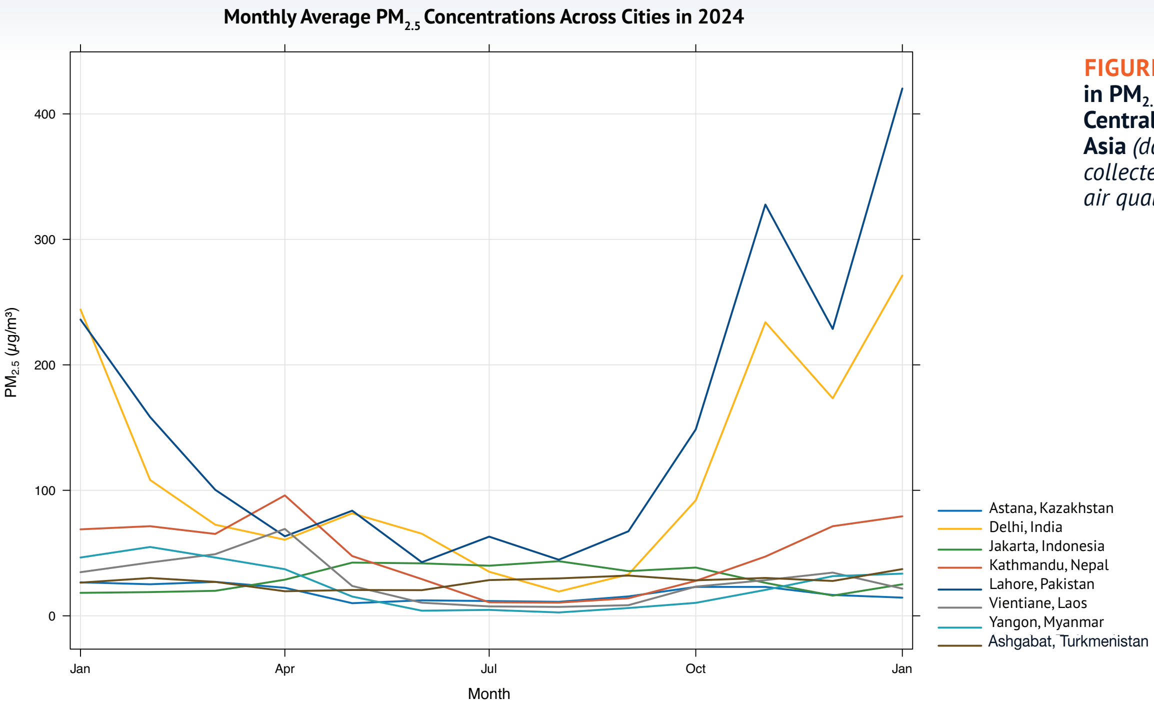


FIGURE ii: Monthly variability in $PM_{2.5}$ in select cities across Central, South, and Southeast Asia *(data source: AirNow, data collected using reference-grade air quality monitors)*

Cities across Central, South, and Southeast Asia are affected by air pollution due to rapid urbanization and industrialization. This assessment is based on population-weighted air pollutant concentrations. They represent annual averages across entire countries and include, but do not represent, the considerably higher concentrations that may be observed day to day or in certain seasons, especially around cities or major pollution sources (see page 22 for seasonal air pollution due to peatland fires in Southeast Asia). For city-level trends and health impacts, please refer to the State of Global Air cities *report* or the *data app* for cities.

What are the data sources for this report?

The main data source is the Global Burden of Diseases, Injuries, and Risk Factors Study (*GBD 2021*) of the Institute for Health Metrics and Evaluation. This collaboration of more than 10,000 researchers worldwide produces comparable global estimates of the impact of 88 environmental, behavioral, and dietary risk factors on health across 204 countries and territories from 1990 to 2021. The estimates draw on more than 190 studies examining the association between air pollution exposure and health outcomes worldwide, including 14 in the three regions covered in the report. In addition, we use data from peer-reviewed studies and reports that are cited within the text. Unless otherwise cited, all reported numbers on health impacts are from the GBD 2021.

Which health outcomes are considered in estimating the disease burden for air pollution?

For $PM_{2.5}$, the disease burden linked to ischemic heart disease, stroke, lung cancer, chronic obstructive pulmonary disease (COPD), type 2 diabetes, lower respiratory infections (LRIs) (such as pneumonia), and adverse birth outcomes (such as preterm birth and low birth weight) is estimated. Impacts of ambient $PM_{2.5}$ and $PM_{2.5}$ associated with household use of solid fuels for cooking (HAP) are included.

For ozone, the disease burden linked to COPD is estimated in adults over the age of 25.

For $PM_{2.5}$ and ozone, the disease burden is measured in this report by number of deaths attributed to the exposure.

For NO_2, the burden linked to pediatric (childhood) asthma is estimated in children and adolescents between the ages of 0 and 19 years. Health effects from NO_2 are measured in years lived with disability (YLDs) or disability adjusted life years (DALYs) for childhood asthma.

A larger trove of data — with detailed statistics for every country and more than 7,000 cities around the world, tools for generating custom data tables and graphs, and fact sheets for countries in the region — is available at *www.stateofglobalair.org*.

Key Definitions

Fine particulate matter, or $PM_{2.5}$: $PM_{2.5}$ refers to airborne particles measuring less than 2.5 micrometers in 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 and accurate 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, COPD, stroke, type 2 diabetes, LRIs (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 $\mu g/m^3$. For this report, exposure to ambient $PM_{2.5}$ is measured as the population-weighted annual average concentration, a measure that represents annual averages across an entire country or geographic region. 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 annual average $PM_{2.5}$ exposures, or concentrations that a population in a specific country is more likely to come into contact with, 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 these predictive methods (satellite and modeling approaches) with ground-level measurements demonstrate that they are reasonably accurate, and thus reasonable indicators of $PM_{2.5}$ where ground monitors do not exist or data are not made 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, and this report uses $PM_{2.5}$ to estimate their health impacts. The GBD estimates HAP only as the proportion of the population burning solid fuels for cooking. Exposure to $PM_{2.5}$ related to HAP is estimated using a multistep process, beginning with information on the proportion of populations that burn solid fuels for cooking. The proportion of households using solid fuels for cooking is estimated based on data from numerous international and national surveys, databases, and individual studies. This information is 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 WHO Global Household Measurements Database and PURE-AIR using a mathematical model. These estimates are likely to understate the total exposure and disease burden in regions like 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 linked to a variety of health effects, including asthma and other respiratory diseases. In addition, NO_x 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. Long-term exposure to NO_2 is estimated as annual average NO_2 concentration in parts per billion (ppb). The burden estimates for childhood asthma discussed in this report are expressed in YLDs for children and adolescents.

Ozone: Ground-level, or tropospheric, ozone is a pollutant that harms human health, damages plants, and contributes to climate change. Unlike other 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 average 8-hour daily maximum concentration in the warmest 6 months of the year. *Note that this ground-level ozone is different from stratospheric ozone, which is known to be protective against ultraviolet radiation.*

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) healthy years of life lost from death or disability, represented by disability-adjusted life years, or DALYs. It is estimated for each country using four components: (a) 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; (b) estimates of population exposure to $PM_{2.5}$, ozone, NO_2, and HAP; (c) country-specific data on underlying rates of disease and death for each pollution-linked disease; and (d) population size and demographic data (age and sex) for each country.

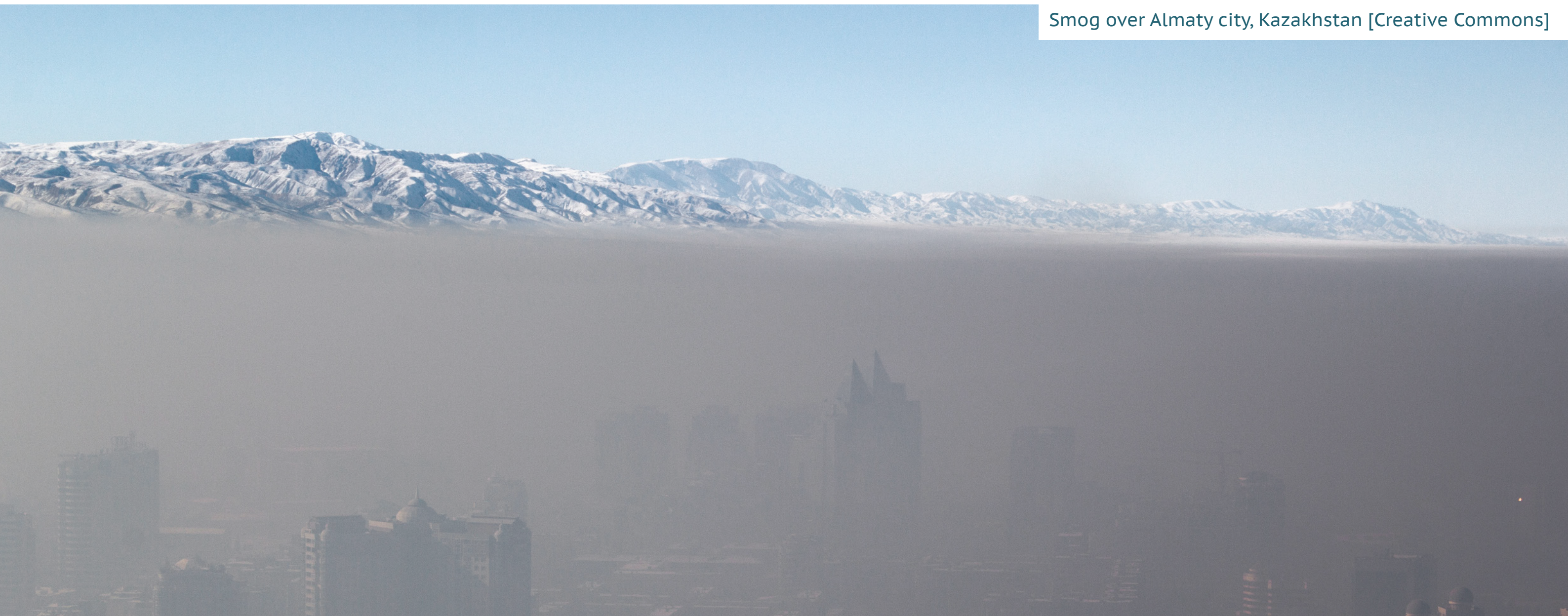
Number of deaths: The number of deaths in a given year attributable to past exposure to air pollution.

Age-standardized rates: The total number of deaths or DALYs (defined below) 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 distribution of ages in the population (e.g., older or younger). Higher air pollution–attributable, age-standardized rates of disease reflect a combination of higher air pollution levels and sicker populations.

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). One DALY equals one lost year of healthy life. DALYs are higher when young people die compared with when old people die because young people still had 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 of life with a disability; for this reason, the State of Global Air focuses largely on mortality.

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.



Smog over Almaty city, Kazakhstan [Creative Commons]

Nepal brick kiln [Source: Pixabay]

Air Pollution's Burden of Disease

Air pollution is a complex mixture including particles and various gases.

While hundreds of chemical compounds can be measured in the air, governments typically measure only a small subset as indicators of the different types of air pollution and major sources contributing to that pollution. These pollutants include $PM_{2.5}$, NO_2, sulfur dioxide (SO_2), ozone, and carbon monoxide, and are common in concentrations known to harm our health and ecosystems.

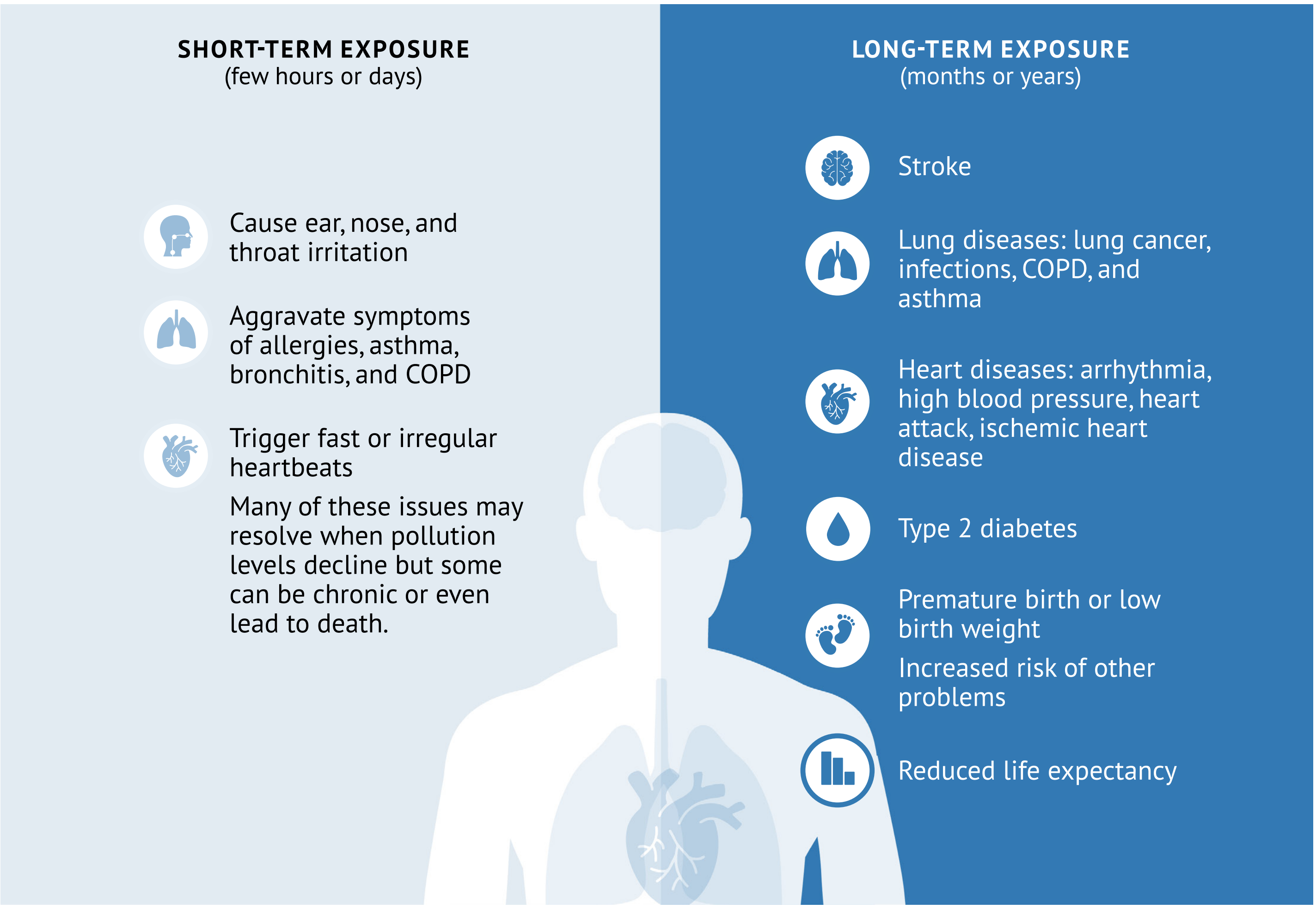
Air pollution exacts a devastating toll on health around the globe.

When someone breathes polluted air, the pollution passes through their lungs into the bloodstream. From there, it can reach their heart, brain, and other organs. Pollutants can even pass through the placenta to affect a developing fetus. Pollution causes inflammation in the lungs and other parts of the body, leading to health risks from major diseases. Exposure during pregnancy can also increase the likelihood of adverse birth outcomes, including preterm births, stillbirths, and miscarriage. Children face special risks from air pollution for two main reasons: first, they often inhale more polluted air in relation to body weight than adults, and second, the polluted air affects their health in different ways because their immune systems and lung, brains, and other organs are still developing (*learn more*). Over many decades, scientific studies have documented a wide range of health effects from short- and long-term exposures to air pollution. New studies continue to broaden our understanding of air pollution's effects throughout the lifespan.

1 in 8

global deaths in 2021 were linked to exposure to air pollution.

FIGURE x: Short- and long-term health effects of air pollution



Exposure to air pollution can cause a variety of health effects.

While high-pollution days can have short-term effects — like aggravating asthma symptoms — and lead to temporary spikes in hospitalizations for heart or lung diseases, the most severe impacts are caused by long-term exposures over many years. Understanding the risks of air pollution and the effects of different pollutants on the health of individuals can inform action and save lives (*learn more*).

Air pollution does not affect everyone equally.

People living in poorer regions suffer a higher burden, and most deaths occur in young children and older adults. Unequal disease burdens are caused not just by differences in exposures, but differences in social, economic, and demographic factors, which in turn affect a person's underlying health status, level of vulnerability, and access to medical care.

Various factors contribute to the total disease burden.

The disease burden of air pollution is influenced by pollutant exposure, demographic trends, and population health. As populations age, regions with a higher proportion of older individuals may experience more severe health impacts from air pollution. Reducing this burden is challenging, even if exposure levels stabilize or decrease. Growing populations, particularly those with more older adults, may see an increasing number of people affected by air pollution. This is because many chronic conditions associated with air pollution develop over years, leading to larger health impacts as populations continue to age.

Looking forward to 2050

While current trends indicate significant health impacts, what does the future hold?

According to analysis conducted as part of GBD 2021, it is expected that the YLDs, DALYs, and deaths will increase by 2050, largely because the proportion of older people is expected to increase in coming years. Effects are expected to be the most significant for Southeast Asia among the three regions.

In South Asia, with a safer environment it is estimated that DALYs will reduce by 21%. On the other hand, the effects will be small for Central Asia.

Woman in Karachi cooking food on open fire [Source: UNICEF]

Health Effects of Air Pollution

EVIDENCE FROM CENTRAL, SOUTH, AND SOUTHEAST ASIA

While the terms *health effects* and *health impacts* or *burden of disease* are sometimes used interchangeably, they measure different things. *Health effects* refers to the specific individual-level effects of air pollution (e.g., in relation to specific health outcomes), whereas *health impacts* or *burden of disease* measures the collective impact of air pollution on a population's health, often in terms of total number of deaths, years of life lost, and DALYs.

The data presented in this report offer insights into the disease burden linked to long-term exposures to air pollution over many years. Scientific studies conducted across Central, South, and Southeast Asia offer evidence of the health effects of air pollution based on local or national air quality and health datasets and contribute to the global evidence base. We highlight a few key findings below.

Short-term exposure to air pollution leads to increased hospitalizations for respiratory illnesses or cardiovascular diseases. Studies in India, Pakistan, Thailand, Sri Lanka, and Viet Nam have reported increases in hospitalizations for respiratory illnesses or cardiovascular diseases during periods of high exposures (Khwaja et al. 2012; Lin et al. 2024; Nhung et al. 2020; Phosri et al. 2019; Priyankara et al. 2021). Studies have also reported increased incidence of reduced lung function, LRIs, asthma, wheeze-related illness, and pneumonia in Bangladesh, Viet Nam, Thailand, and Singapore; in many studies, the effect is higher among children and older adults. In Singapore, short-term exposure to ambient $PM_{2.5}$ increased heart rate and diastolic blood pressure (Tan et al. 2020).

Exposure to $PM_{2.5}$ increases the risk of mortality (death). Studies conducted in India, Thailand, and Malaysia show increased risk for all-cause, respiratory, and cardiovascular mortality linked to exposure to ambient $PM_{2.5}$ (de Bont et al. 2024; Guo et al. 2014; Krishna et al. 2021; Mazeli et al. 2023).

The Indian Academy of Pediatrics released a consensus statement in 2021 highlighting the role of air pollution as an emerging contributor to respiratory allergies among children (Reddy et al. 2021).

Exposure to air pollution can influence the health of newborns and children under 5 years of age. Several studies across South Asia and Southeast Asia have reported that prenatal exposure to $PM_{2.5}$ leads to newborn children with lower birth weights and an increased likelihood of preterm birth. In Indonesia, exposure to $PM_{2.5}$ was linked to lower cognitive function among children (Jalaludin et al. 2022). In Indonesia, exposure to NO_2 increased the risk of acute respiratory infections among children aged 0–3 years (Suryadhi et al. 2020a). In Bengaluru (India), average temperature and NO_2 levels significantly influenced the number of childhood asthma hospital admissions (Kunikullaya et al. 2017). In Hanoi (Viet Nam), an increase in short-term exposure to NO_2 increased the number of LRI hospitalizations among children aged 0–7 years (Nhung et al. 2018). In Nepal, exposure to HAP was associated with reductions in child height-for-age and weight-for-age, as well as increased rates of stunted and underweight children (Lamichhane et al. 2020). Similarly, in India, exposure to $PM_{2.5}$ has been associated with a higher risk of stunting and lower weight-for-age (underweight) in children (Singh et al. 2019). A large review of studies conducted in Southeast Asia found that the relative risk of childhood asthma increases by 1.008 per 10 µg/m^3 rise in NO_2, indicating a higher likelihood of childhood asthma due to NO_2 (Luong et al. 2019). Other studies have associated exposure to NO_2 with higher risk of acute respiratory infections.

Exposure to air pollution is linked to a variety of noncommunicable diseases. Increased risk for a variety of noncommunicable diseases — including ischemic heart disease, stroke, lung cancer, COPD and type II diabetes — has been linked to exposure to air pollution (Schraufnagel et al. 2019; HEI 2024). In Chitwan, Nepal, exposure to biomass fuels was associated with an increased risk of lung cancer (Raspanti et al. 2016). In India and Indonesia, exposure to ambient $PM_{2.5}$ has been linked to increased risk for type 2 diabetes (Mandal et al. 2023; Suryadhi et al. 2020b). Exposure to ambient $PM_{2.5}$ has also been associated with specific cardiovascular health outcomes including increased blood pressure, incidence of hypertension, increased risk of cardiac arrest, increased carotid intima media thickness (a marker to assess the early stages of atherosclerosis) in India, Singapore, and Viet Nam.

Studies have also reported increased incidence of reduced lung function, LRIs, asthma, wheeze-related illness, and pneumonia in Bangladesh, Viet Nam, Thailand, and Singapore; in many studies, the effect is higher among children and older adults.

Exposure to ground-level ozone is linked with respiratory diseases. In Hanoi, Viet Nam, a higher risk of hospital admissions for respiratory disorders, particularly among children, was reported after exposure to ozone; the study found that each 10-µg/m^3 increase in ozone levels was associated with a 6.2% increase in hospital admissions for respiratory diseases among children in winter and a 1.2% increase in summer (Luong et al. 2018). In Chiang Mai, Thailand, exposure to ozone was associated with an increased risk of emergency visits for community-acquired pneumonia (Pothirat et al. 2019). A similar study in the same location showed association between exposure to ozone and prolonged hospitalizations among children aged 0–5 years due to LRI (Nhung et al. 2019).

Looking ahead: Overall, most epidemiological studies reporting health effects of $PM_{2.5}$ in these regions were conducted in the urban centers and many, if not all, are cross-sectional in nature or look at short-term exposures and their health effects. The results of these studies are consistent, in general, with global evidence (WHO 2021). However, given the differences in air pollution ranges, source mixtures, demographic characteristics, and underlying disease rates within the countries and across the entire region, a number of gaps remain in our knowledge of long-term exposure to air pollution and specific health effects, especially in Southeast and Central Asia. Limited data on health effects also creates larger uncertainty in disease burden estimates. Thus, closing the evidence gap can not only improve the burden of disease estimates, but also contribute to the global understanding on health effects of air pollution, especially at higher levels of exposure.

Curious about the evidence for the health effects of air pollution in South Asia? Check out the *DoSAAH interactive literature database* featuring 376 studies from across the region.

Air Pollution and Health in Central Asia

KAZAKHSTAN • KYRGYZSTAN • TURKMENISTAN • TAJIKISTAN • UZBEKISTAN

In Central Asia, levels of air pollution remain high, and air pollution continues to be one of the leading risk factors for poor health *(Figure 2)*. In 2021, there were over 63,000 deaths resulting from exposure from ambient $PM_{2.5}$ and HAP. Furthermore, 26% of the total noncommunicable disease deaths were attributed to exposure to air pollution in Central Asia. There are significant economic costs too. A UNICEF study in Bishkek estimated an annual welfare loss of 20 million USD or 1.6 billion KGS in 2021–2022 (UNICEF 2023).

1 in 4

LRI deaths in children under 5 years of age were attributed to air pollution in Central Asia in 2021.

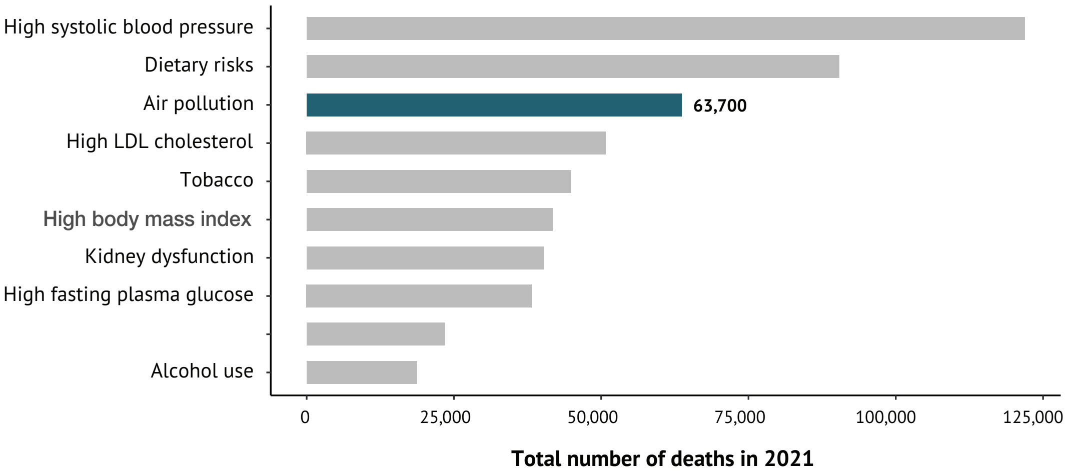


FIGURE 2. Ranking of risk factors by total number of deaths in 2021 in Central Asia. *Explore the rankings further via GBD Compare.*

Rates of noncommunicable diseases increase with age, many of which are also associated with air pollution. Older people experience the greatest loss of healthy life years due to noncommunicable diseases. There is a significant burden in older populations; 20% of the deaths in people over the age of 70 in Central Asia were attributed to air pollution in 2021. Furthermore, there were 4,700 deaths attributable to air pollution in children under 5 years of age, accounting for 25% of all deaths in children under 5 years of age *(Figure 3)*. In the region, the disease burden is largely driven by ambient $PM_{2.5}$ with small contributions from HAP and ozone.

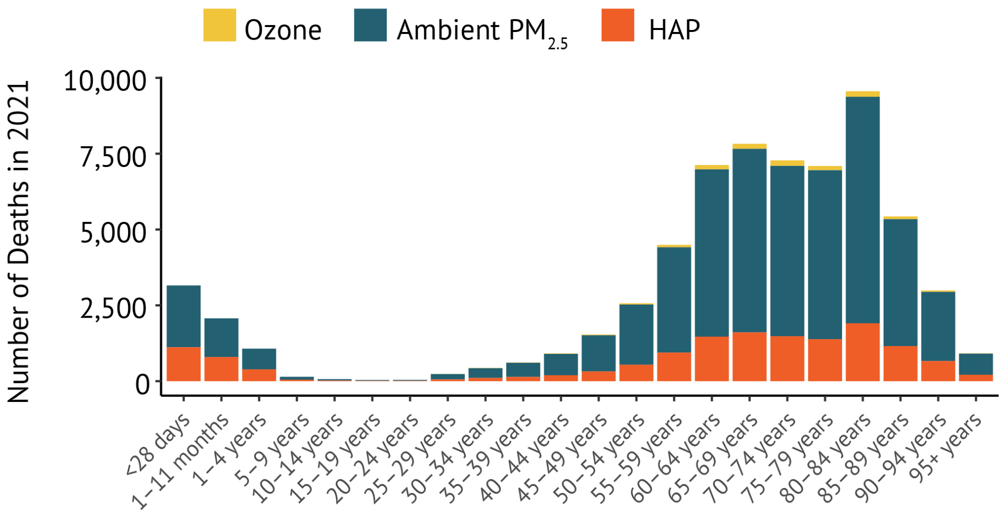


FIGURE 3. Distribution of deaths in 2021 attributable to ozone, ambient $PM_{2.5}$, and HAP by age in Central Asia.

Much of the disease burden of air pollution falls on older populations because aging is a risk factor for noncommunicable diseases.

Visit stateofglobalair.org to explore the data for your country or region.

Fine particulate matter

Exposure to $PM_{2.5}$ is a risk to health across Central Asia. In 2019, over 99% of the region's population experienced annual average $PM_{2.5}$ concentrations in ambient air that exceeded the WHO annual Air Quality Guideline of 5 μg/m³; and 27% of the population experienced exposures higher than 35 μg/m³, the least stringent interim target for $PM_{2.5}$. Tajikistan experienced the highest exposure to $PM_{2.5}$ with an annual average of 40.3 μg/m³ followed by Uzbekistan (34.1 μg/m³) in 2019. In good news, the levels of ambient $PM_{2.5}$, have stabilized and sloped downward after some increases in the early 2010s *(Figure 4)*. Reduction in $PM_{2.5}$ has also been reported by others (Kerimray et al. 2020). Cities in the region often experience even higher levels of ambient $PM_{2.5}$, especially in winter when there is a significant heating demand and thermal inversions are more frequent. In Bishkek, Kyrgyzstan, for instance, while annual mean $PM_{2.5}$ levels are 30 μg/m³, they can be as high as 80 μg/m³ during winter and in *Dushanbe*, Tajikistan, levels as high as 58 μg/m³ have been reported (Amiraev et al. 2023; World Bank, 2023). Several studies have reported high $PM_{2.5}$ levels and Tursumbayeva et al. (2023) provide a detailed summary of measured pollutant concentrations in the region to date.

Central Asian countries had some of the highest death rates across the three regions included in this report, with large between-country inequalities. There was a twofold difference in the age-standardized death rates attributed to exposure to ambient $PM_{2.5}$, with death rates in Uzbekistan (128 deaths/100,000 people) and Turkmenistan (104/100,000) being nearly 1.5–2 times higher than Tajikistan (67/100,000) or Kyrgyzstan (56/100,000).

1.5–2 times

Death rates attributed to air pollution in countries including Uzbekistan and Turkmenistan are nearly 1.5–2 times higher than the global average.

Sources of $PM_{2.5}$

While the major sources of $PM_{2.5}$ vary across countries and regions, significant worldwide contributors include residential fuel use, energy generation, industries, transportation, agriculture, windblown dust, and waste combustion. The situation is no different in Central Asia. Use of solid and fossil fuels (coal, oil and gas) contributes to 20–30% of the estimated ambient $PM_{2.5}$ levels in the region. In Tajikistan, nearly 40% of the total ambient $PM_{2.5}$

Children in Afghanistan

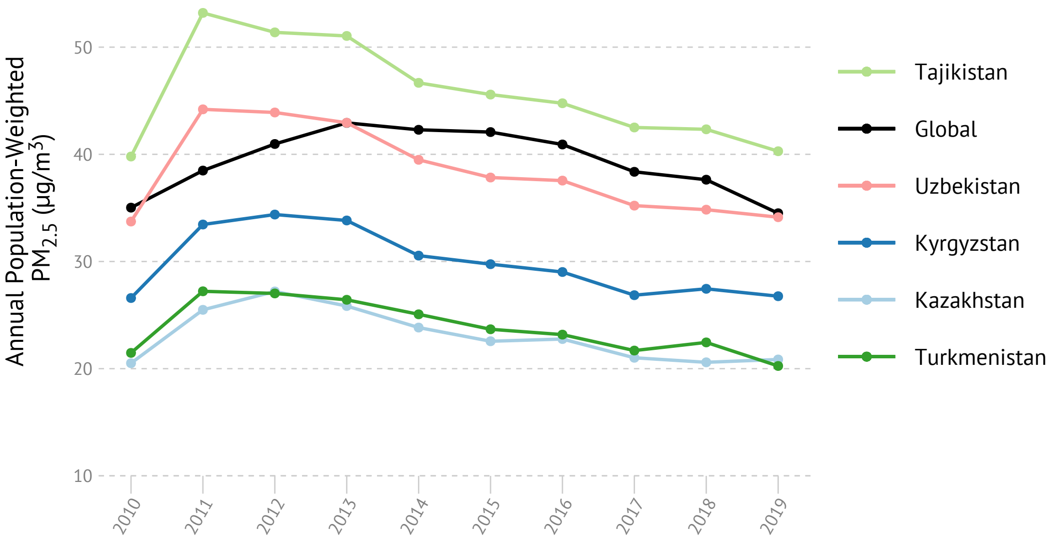
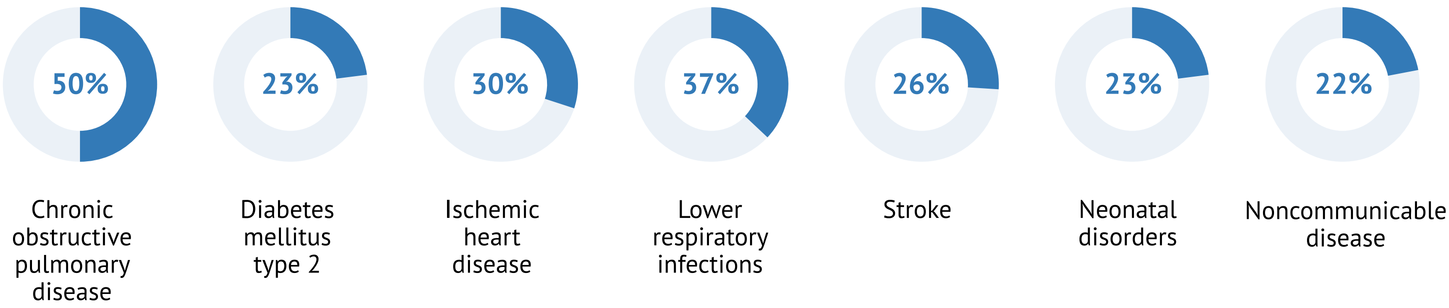


FIGURE 4. Trends in population-weighted annual average $PM_{2.5}$ concentrations in Central Asia, 2010–2019.

can be attributed to use of solid or fossil fuels (McDuffie et al. 2021). Many households in the region rely on small heating stoves and boilers and use coal or biomass as a fuel source; in Kazakhstan, more than 40% of households use coal for residential heating. Widespread use of coal heaters and older vehicles in several cities including Tashkent (Uzbekistan), Bishkek (Kyrgyzstan), and Dushanbe (Tajikistan) contributes to severe air quality episodes in winter (Amiraev et al. 2023). Coal combustion has been identified as an important contributor to city level ambient $PM_{2.5}$ in Central Asian cities (Mukhtarov et al. 2023; Tursumbayeva et al. 2023; UNEP and UNDP 2022).

The region is land locked with a combination of mountainous regions, deserts and steppe grasslands. Windblown dust is also an important contributor to $PM_{2.5}$. Dust storms in the Aral Sea Basin have been reported to contribute to high $PM_{2.5}$ levels in the region (Nobhakt et al. 2021). In recent years, there has been an increase in unseasonal dust storms due to changes in weather patterns (Xi et al. 2023). A study in Uzbekistan reported that during severe dust storms, instantaneous PM_{10} concentrations can reach up to 18,000 µg/m³, while $PM_{2.5}$ levels can remain above 300 µg/m³ for nearly 10 days (Nishonov et al. 2023).

Percentage of Deaths from Various Causes Attributed to Air Pollution in Central Asia in 2021



Ground-level ozone

Average exposure to ozone in Central Asian countries in 2019 (48 ppb, UI: 46-49) was comparable to the global average of 49.5 ppb (UI: 49.4-49.6) *(Figure 5)*. This is not surprising since seasonal population-weighted average ambient ozone concentrations generally vary less around the world compared with $PM_{2.5}$. On average, 99% of the population in Central Asian countries was exposed to levels above the peak season WHO guideline value of 60 μg/m³ (30.5 ppb), while 39% of the population experienced exposures higher than 100 μg/m³ (51 ppb), the least stringent interim target for ozone. In countries like Tajikistan, over 80% of the population lives in areas that exceed even the least stringent interim target.

In 2021, there were almost 4,000 deaths from COPD due to long-term exposure to ozone. COPD death rates linked to ozone exposure in Central Asian countries are lower than the global average (5.9 deaths/100,000 people). As a risk factor, exposure to ozone does not currently rank among the top 20 risk factors for poor health in any of the countries in the region.

80%

of the population of Tajikistan lives in areas that exceed even the least stringent interim target for ozone.

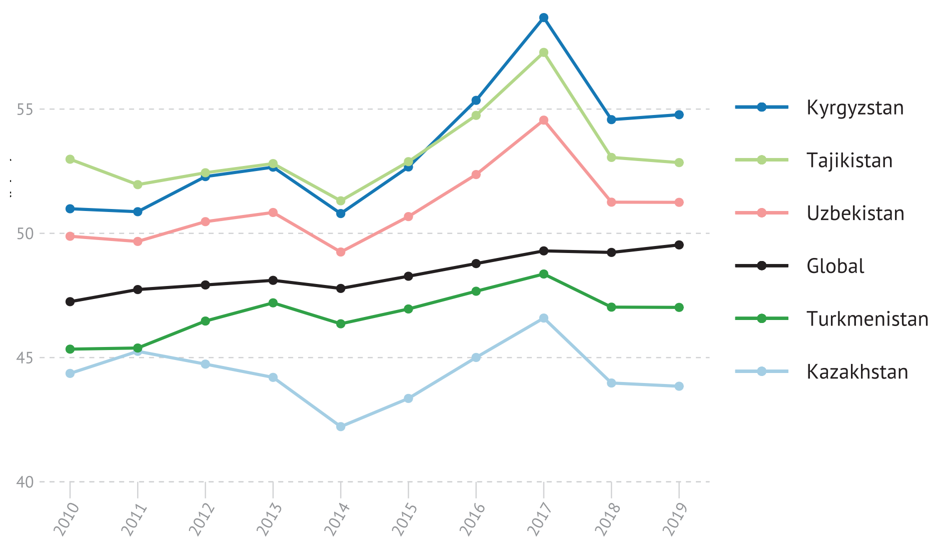


FIGURE 5. Trends in population-weighted average seasonal 8-hour maximum ozone concentration in Central Asia, 2010–2019.

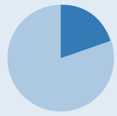
Nitrogen dioxide

Overall, among the three regions, countries in Central Asia experienced the highest average levels of NO_2 worldwide in 2019 with an average NO_2 exposure of 13.3 µg/m³ (UI: 0.76–13.3 µg/m³). Annual average exposures were highest in Tajikistan (14.4 µg/m³), Kyrgyzstan (15.1 µg/m³), and Uzbekistan (13.9 µg/m³); these values were all higher than the global average (12.4 µg/m³). While less than 1% of the population experienced exposures higher than 40 µg/m³, the least stringent interim target for NO_2, more than 30% of the region's population was exposed to levels above the WHO annual Air Quality Guideline of 10 µg/m³.

Furthermore, countries including Uzbekistan, Tajikistan, and Kazakhstan experienced increases of more than 30% in NO_2 exposures between 2010 and 2019 *(Figure 6)*. This is notably different from global trends, where levels of NO_2 have been largely declining.

High levels of NO_2 in Central Asian countries are linked, in part, to the old and polluting vehicle fleet and coal-fired power plants. Across most countries, the average vehicle age is well over 10 years, with some vehicles as old as 18–20 years. In fact, cities including Bishkek (Kyrgyzstan), Ashgabat (Turkmenistan), and Tashkent (Uzbekistan) rank among the cities with the highest annual average NO_2 exposures (*learn more*).Power plants and urban locations were also identified as NO_2 hotspots based on satellite data in Kazakhstan (Darynova et al. 2018).

In 2021, asthma linked to traffic-related air pollution exposure in Central Asia resulted in only a small burden: 480 YLDs in children under 5 years of age and 1,000 YLDs in children between 5–14 years of age. Overall, less than 1% of the asthma YLDs were attributed to exposure to NO_2 pollution in Central Asia.



35%

of the population in Central Asia experienced annual average NO_2 concentrations that exceeded the WHO annual Air Quality Guideline of 10 µg/m³ in 2019.

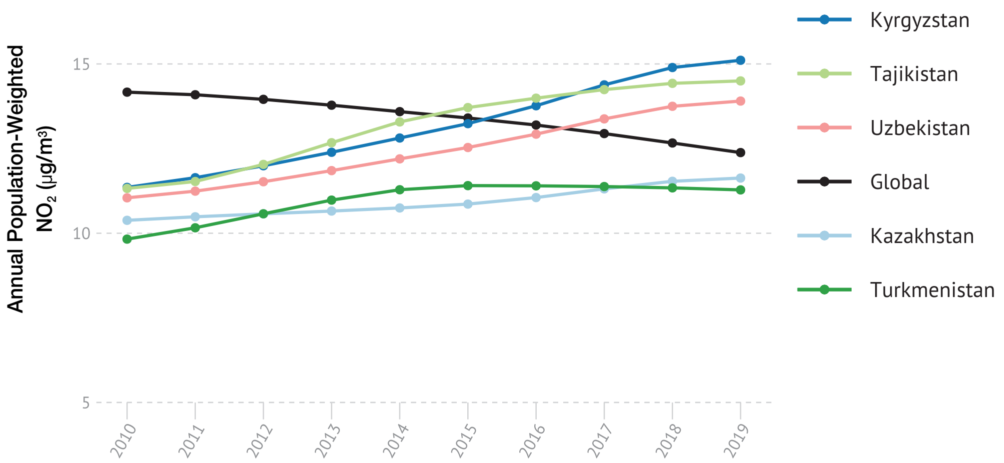


FIGURE 6. Trends in population-weighted annual average NO_2 concentrations in Central Asia, 2010–2019.

Note that there was a decline in NO_2 in 2020 due to COVID-related lockdowns and related restrictions on activities. This decline is not likely to indicate a long-term reduction and as such, data for 2020 have not been included in the figure.

Air Pollution and Health in Southeast Asia

CAMBODIA • INDONESIA • LAOS PEOPLE'S DEMOCRATIC REPUBLIC (LAO PDR) • MALAYSIA • MYANMAR • THE PHILIPPINES • SINGAPORE • THAILAND • TIMOR-LESTE • VIET NAM

Countries in Southeast Asia and their combined population of over 66 million people are exposed to varying amounts of ambient $PM_{2.5}$, NO_2, and ozone.

Air pollution ranks among the leading risk factors for deaths in the region, with 621,000 deaths linked to exposure to $PM_{2.5}$, 321,000 deaths for ambient $PM_{2.5}$, 300,000 deaths for HAP, and 13,000 deaths linked to exposure to ozone *(Figure 7)*.

Air pollution ranks among the leading risk factors for deaths in the Southeast Asia region.

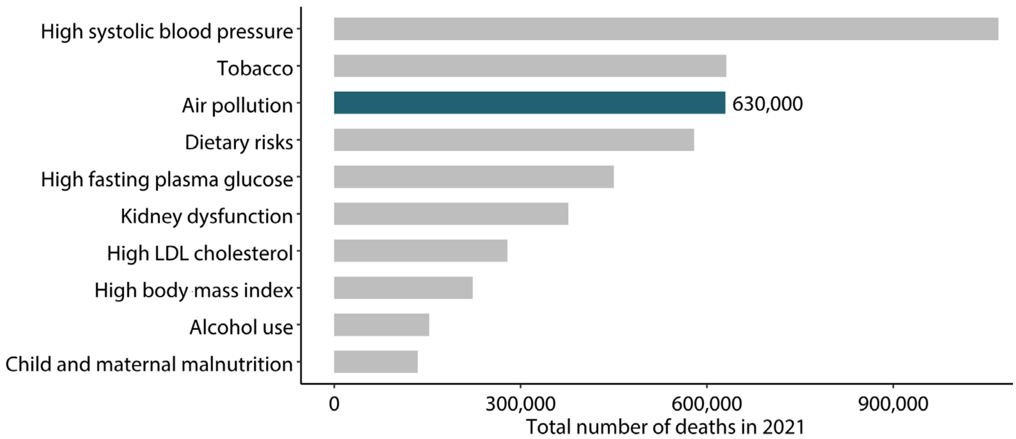


FIGURE 7. Ranking of risk factors by total number of deaths in 2021 in Southeast Asia.

Explore the rankings further via GBD Compare.

In countries including Cambodia, Lao PDR, and Myanmar, air pollution was the leading (#1) risk factor for deaths, resulting in 21,900, 9,200, and 101,600 deaths, respectively. In the Philippines, air pollution was the second leading risk factor for deaths in 2021, behind high blood pressure, resulting in 98,000 deaths. However, in Malaysia, air pollution was the seventh leading risk factor for deaths in 2021, behind high blood pressure, tobacco, dietary risk, and other risk factors; this is an improvement since 2000, when air pollution ranked as the fourth leading risk factor for deaths. Similarly, in Singapore, air pollution ranks as the sixth largest risk factor, resulting in nearly 1,600 deaths.

In the region, the air pollution–related disease burden is largely driven by particulate matter (both ambient $PM_{2.5}$ and HAP) with small contributions from ozone *(Figure 8)*. The burden is the largest among the youngest and the oldest — 24% of all deaths in children under 5 years of age and 20% of deaths in people over the age of 70 in Southeast Asia were attributed to air pollution in 2021. Across the region, 24% of the deaths due to noncommunicable diseases are linked to exposure to air pollution. Exposure to ambient $PM_{2.5}$ has been slightly declining each year since 2010, with little change in NO_2 and ozone exposure.

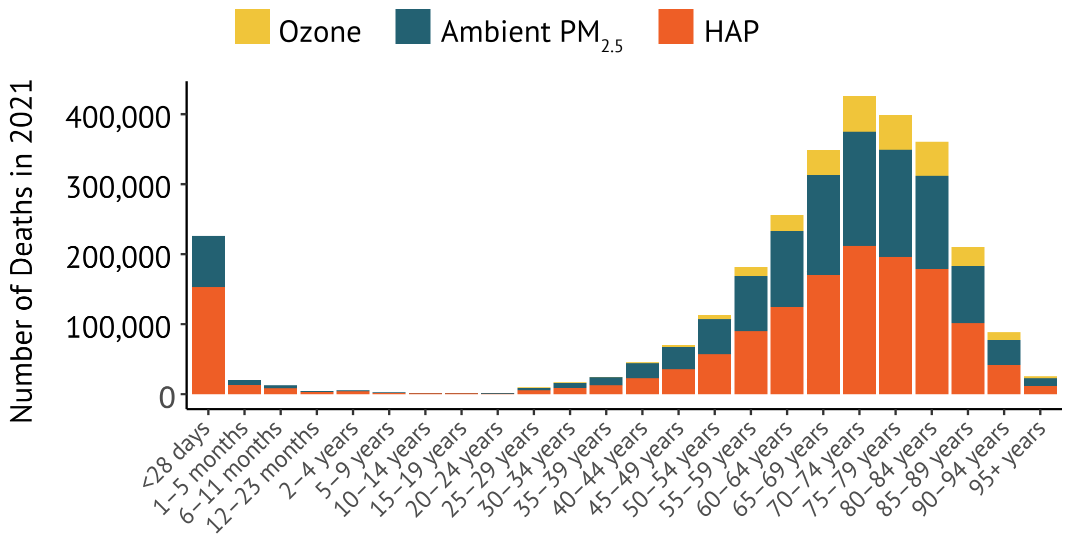
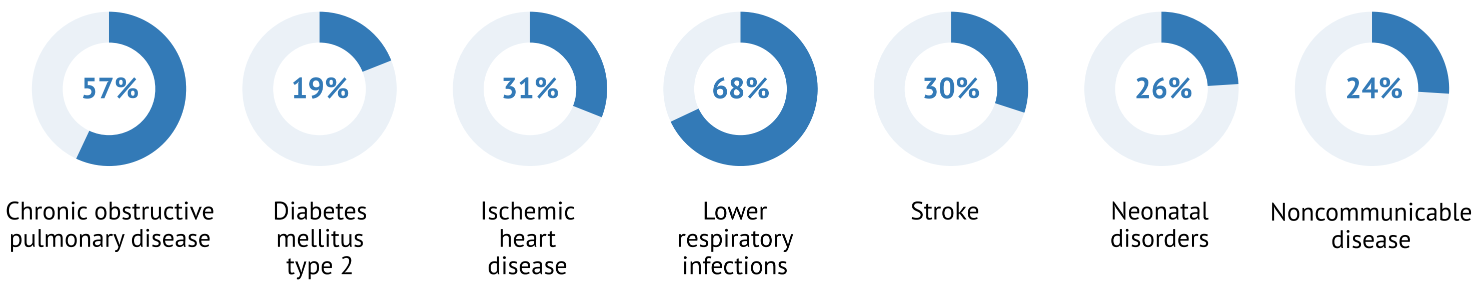


FIGURE 8. Distribution of deaths in 2021 attributable to ozone, ambient $PM_{2.5}$, and HAP by age in Southeast Asia.

Percentage of Deaths from Various Causes Attributed to Air Pollution in Southeast Asia in 2021



Fine particulate matter

Exposure to ambient $PM_{2.5}$ varies across Southeast Asia. In 2019, over 99% of the region's population experienced annual average $PM_{2.5}$ concentrations that exceeded the WHO annual Air Quality Guideline of 5 µg/m³; in good news, only 5% of the population experienced exposures higher than 35 µg/m³, the least stringent interim target for $PM_{2.5}$.

The average ambient $PM_{2.5}$ exposure in Southeast Asia was 22.2 µg/m³, below the global average (31.4 µg/m³) and within the WHO interim target 2 of 25 µg/m³. Overall, ambient $PM_{2.5}$ exposure across Southeast Asia slightly declined between 2010 and 2019, with a 4% reduction in ambient $PM_{2.5}$ exposure *(Figure 9)*. At the country level, between 2010 and 2019, progress has been slow in

many Asian countries; however, there have been notable reductions in three countries: Indonesia, Malaysia, and Singapore. Exposure to ambient $PM_{2.5}$ varies across Southeast Asia. In 2019, over 99% of the region's population experienced annual average $PM_{2.5}$ concentrations that exceeded the WHO annual Air Quality Guideline of 5 µg/m³;
in good news, only 5% of the population experienced exposures higher than 35 µg/m³, the least stringent interim target for ambient $PM_{2.5}$.

The average ambient $PM_{2.5}$ exposure in Southeast Asia was 22.2 µg/m³, below the global average (31.4 µg/m³) and within the WHO interim target 2 of 25 µg/m³. Overall, $PM_{2.5}$ exposure across Southeast Asia slightly declined between 2010 and 2019, with a 4% reduction in $PM_{2.5}$ exposure *(Figure 9)*.

The total number of deaths are highest among the largest, most populous countries, including Indonesia (129,300 deaths), Thailand (53,400 deaths), and the Philippines (43,200 deaths); each of these countries also rank among the 30 most populous countries in the world. In Southeast Asia, the highest age-standardized death rates for ambient $PM_{2.5}$ were observed in Myanmar (75 deaths/100,000 people), followed by Indonesia (68/100,000). The rates were the lowest in Singapore (19 deaths/100,000). Countries like Viet Nam, Myanmar, and Lao PDR have experienced increases of more than 70% in the number of deaths linked to exposure to ambient $PM_{2.5}$ since 2010.

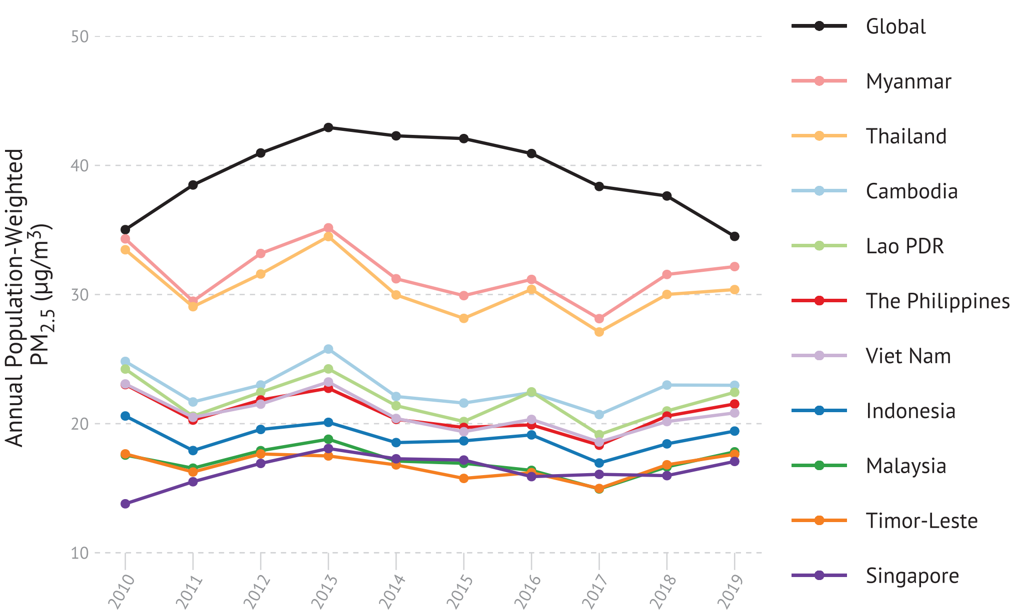


FIGURE 9. Trends in population-weighted annual average ambient $PM_{2.5}$ concentrations in Southeast Asia, 2010–2019.

94%

of households in Lao PDR use solid fuels for cooking, exposing almost 7 million people to high levels of HAP each year.

HAP is the second leading risk factor for deaths in the country, accounting for 13% of all deaths in Lao PDR. To face the challenge of pollution across the country, Lao PDR has created a *National Green Growth Strategy*. This strategy recognizes the health risks associated with exposure to air pollution and encourages a transition at the national scale to clean energy for cooking through measures to expand access to clean energy solutions as well as awareness campaigns to educate households about the benefits of clean energy.

Traffic in Bangkok

Sources of $PM_{2.5}$

In Southeast Asia, residential and industrial emissions are important local contributors to air pollution; biomass burning for land clearing is also a significant seasonal source of ambient $PM_{2.5}$. In addition, transboundary air pollution is a major contributor to air pollution in Southeast Asia. Across most countries, use of fossil fuels across various sectors (i.e., oil and gas and coal) is an important contributor to ambient $PM_{2.5}$. In Singapore, 47% of the estimated ambient $PM_{2.5}$ is linked to use of coal and liquid fuel and natural gas, while in Viet Nam, Malaysia and Indonesia, the contribution ranges between 26–34% (McDuffie et al. 2021). Other studies have also found energy, industry, and residential sectors to be key contributors to air pollution in the region (Gu et al. 2024).

One of the major seasonal contributors to air pollution in Southeast Asia is peatland fires. Southeast Asia is home to 56% of the world's peatlands, with 70% of these located in Indonesia and the remainder in other Southeast Asian countries. Peatlands are wetlands where organic matter, mainly decaying plants, accumulates in waterlogged conditions, forming carbon-rich peat. They are the largest natural terrestrial carbon store, holding more carbon than all other vegetation types combined. However, peatlands are rapidly degrading worldwide due to activities like clearing, deforestation, slash-and-burn agriculture, and drainage. The traditional slash-and-burn farming method, involving the burning of trees in farming fields, has led to higher emissions of particulate matter and other pollutants. This practice, combined with region-specific dry weather conditions, has further exacerbated the severity of haze. Epidemiological studies have shown that exposure to high pollution levels from agricultural and farming fires in this region leads to more mortality (deaths) and morbidity (illness) during the haze periods compared to nonhaze periods (Phung et al. 2022). The effect is higher among the poor, especially those in northern Lao PDR and Myanmar (Reddington et al. 2021).

Combustion of fossil fuels

for energy generation and use is a significant contributor to ambient $PM_{2.5}$ in Southeast Asia.

Ground-level ozone

Exposure to ozone in Southeast Asia varies, with large year-to-year variability throughout the last decade *(Figure 10)*. Across the region, 64% of the population lives above the WHO air quality guideline for ozone (60 µg/m³). Of note, in countries including Cambodia, Myanmar, and Lao PDR, almost 100% of the population is exposed to values above the WHO guideline. Some countries in the region experienced a decline in ozone exposure from 2010 to 2019, including the Philippines (19%) and Viet Nam (5%).

Across the region, 13,000 deaths were linked to exposure to ozone in 2021; this represents a nearly 65% increase in ozone-related deaths since 2010. Notably, in the Philippines and Singapore, the disease burden linked to exposure to ozone is relatively small (less than one death per 100,000 people).

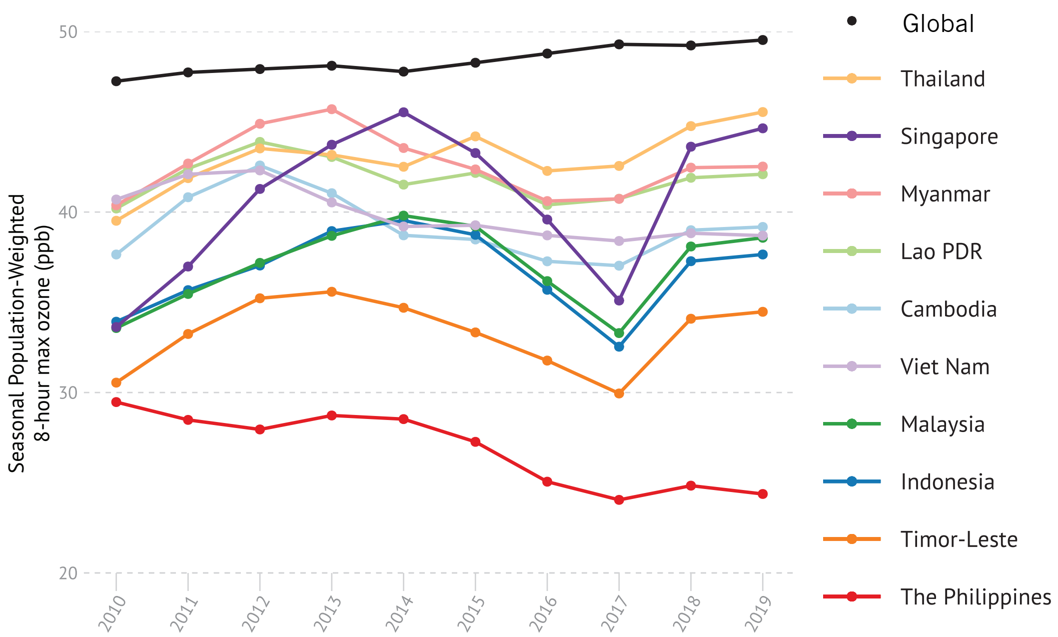


FIGURE 10. **Trends in population-weighted average seasonal 8-hour maximum ozone concentration in Southeast Asia, 2010–2019.**

Nitrogen dioxide

Overall, exposure to NO_2 in Southeast Asia is much lower compared to the other regions in this report, although there are exceptions. For instance, Singapore (28.6 µg/m³) experienced the highest NO_2 exposures in the region; levels in Singapore are, in fact, among the highest in the world. On the other hand, Timor-Leste (5.7 µg/m³) and Lao PDR (6.9 µg/m³) experienced relatively low NO_2 exposures in 2019 *(Figure 11)*. Some countries, for example, Viet Nam, have experienced an increase of more than 30% in NO_2 exposures between 2010 and 2019.

Singapore, however, has also experienced steep reduction in NO_2 exposures over time, with a 17% decline in NO_2 exposures between 2010 and 2019. The reduction reported here is consistent with other analyses. Since 2017 and 2018, all new petrol and diesel vehicles in the country are required to adopt Euro VI emission standards. In addition, the industrial emission standard for NO_2 was *tightened* from 700 mg/Nm³ to 400 mg/Nm³ in 2015 for new industrial plants, and by 2023 for existing industrial plants. Levels of NO_2 have also declined considerably

Singapore

has among the highest NO_2 exposures in the world.

Child in mask [Source: UNICEF]

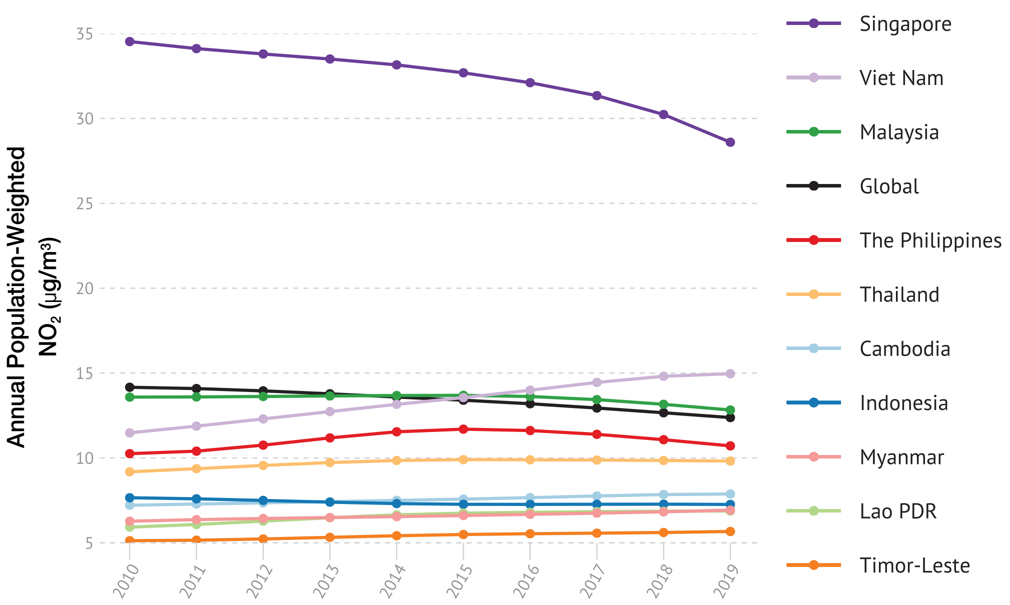


FIGURE 11. Trends in population-weighted annual average NO_2 concentrations in Southeast Asia, 2010–2019.

Note that the decline in NO_2 in 2020 was linked to COVID-related lockdowns and related restrictions on activities and is not likely to be indicative of long-term reduction.

in Indonesia in the last few years, and the national annual average (7.2 µg/m³) is well within the WHO guideline value of 10 µg/m³. Notably, Euro IV vehicle emission standards were implemented in the country in 2018.

In line with the exposure patterns, the impacts on childhood asthma were highest for Singapore, where 60% of all childhood asthma YLDs were linked to exposure to NO_2. The burden was also high in the Philippines (4,300 years of healthy life lost), Viet Nam (3,400 years of healthy life lost), and Indonesia (500 years of healthy life lost). For context, one YLD represents the equivalent of one full year of healthy life lost due to poor health.

Air Pollution and Health in South Asia

AFGHANISTAN • BANGLADESH • BHUTAN • INDIA • THE MALDIVES • NEPAL • PAKISTAN • SRI LANKA

Across South Asia, levels of air pollution remain high, with pollutants like $PM_{2.5}$, ozone, and NO_2 continuing to increase and cause a heavy burden on the health of millions. Just in 2021, India alone experienced 2.1 out of the estimated 2.6 million deaths from air pollution in South Asia. Of note, India is the most populous country in the world, with a population exceeding 1.4 billion.

41%

of all noncommunicable disease deaths in South Asia were linked to exposure to air pollution.

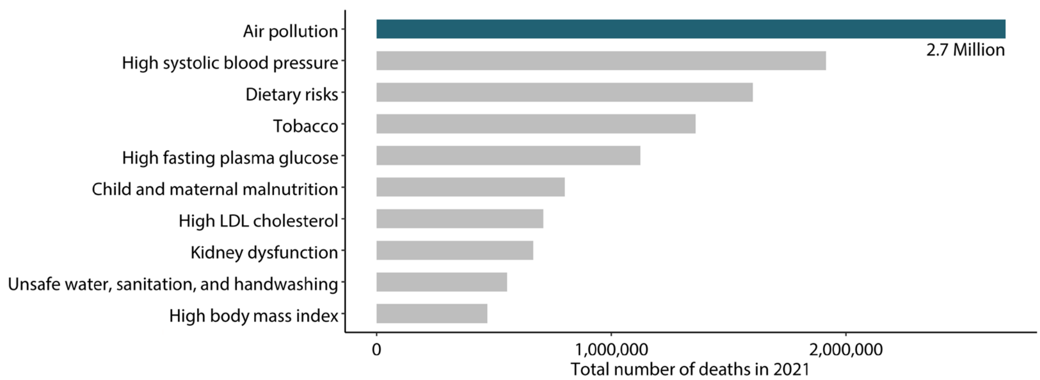


FIGURE 12. Ranking of risk factors by total number of deaths in 2021 in South Asia. *Explore the rankings further via GBD Compare.*

Exposure to $PM_{2.5}$ drives air pollution–related deaths, including 1.5 million attributable deaths from HAP and 1.2 million deaths from $PM_{2.5}$ *(Figure 13)*. An estimated 30% of all infant deaths in the first month of life (under 28 days of age) and 21% of deaths in older adults (age 70 years or older) in South Asia were attributed to air pollution in 2021. Of particular concern for older adults in South Asia is the impact of air pollution on noncommunicable diseases, such as heart disease, stroke, and cancer; 41% of all noncommunicable disease–related deaths in South Asia were linked to exposure to air pollution.

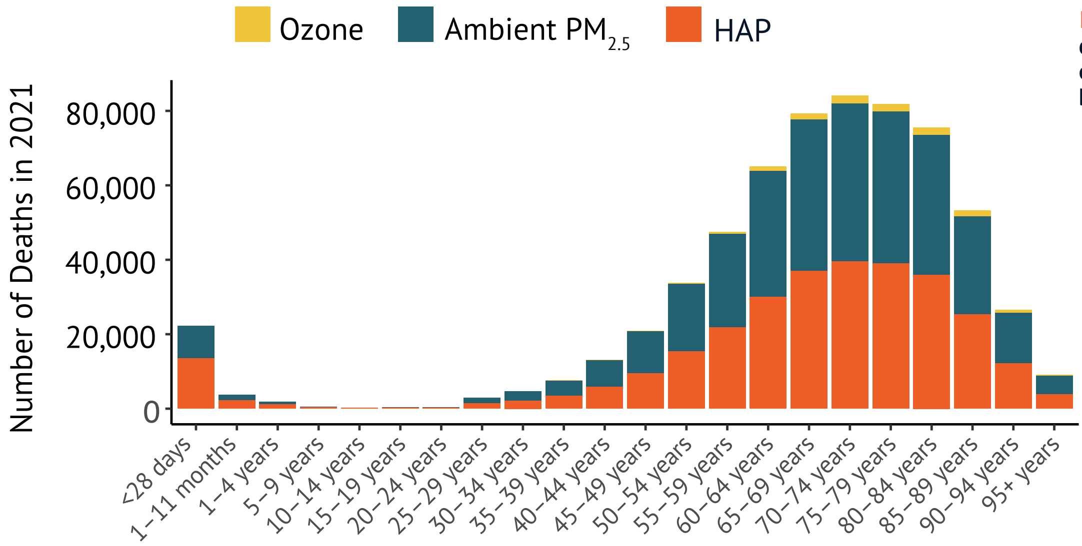


FIGURE 13. Distribution of deaths in 2021 attributable to ozone, ambient $PM_{2.5}$, and HAP by age in South Asia.

Fine particulate matter

South Asian countries continue to experience high ambient $PM_{2.5}$, pollution, with an annual average of 42.6 μg/m³ for the year 2019; this is higher than the global average (31.4 μg/m³) and 2.5 times higher than high-income countries. Countries including India (59.8 μg/m³), Afghanistan (58.3 μg/m³), Nepal (57.3 μg/m³), Pakistan (52.8 μg/m³), and Bangladesh (50.3 μg/m³) experience particularly high levels of ambient $PM_{2.5}$ *(Figure 14)*.

There were 1.2 million deaths in 2021 across South Asia because of exposure to ambient $PM_{2.5}$, The highest numbers of deaths were seen in India (947,600 deaths) and Pakistan (103,000 deaths); both countries rank among the 10 most populous countries in the world. Age-standardized death rates for ambient $PM_{2.5}$, were highest in India (91 deaths/100,000 people) and Pakistan (87 deaths/100,000 people), and lowest in Bangladesh (35 deaths/100,000) and the Maldives (25 deaths/100,000 people).

68%

of South Asia's population lives in regions where $PM_{2.5}$ levels surpass the least stringent WHO interim target of 35 μg/m³.

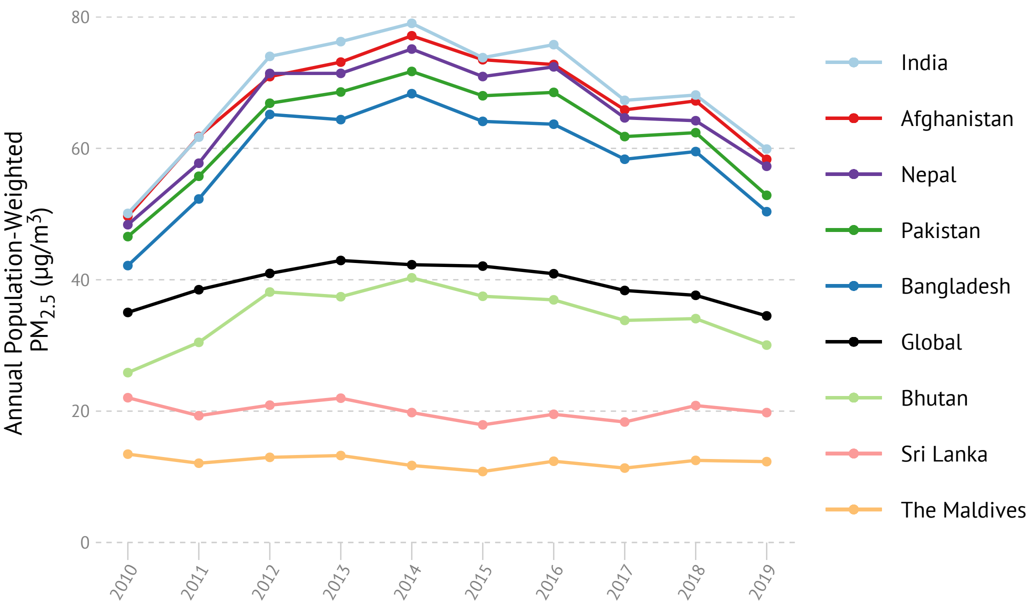
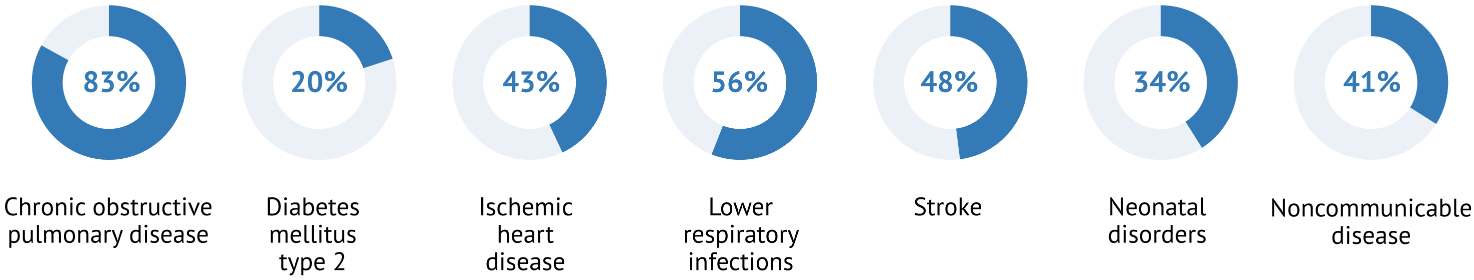


FIGURE 14. Trends in population-weighted annual average ambient $PM_{2.5}$ concentrations in South Asia, 2010–2019.

Percentage of Deaths from Various Causes Attributed to Air Pollution in South Asia in 2021



Sources of $PM_{2.5}$

In South Asia, residential fuel combustion is the primary contributor to ambient $PM_{2.5}$. In all South Asian countries except Afghanistan, residential sources account for more than 20% of ambient $PM_{2.5}$. Residential sources include combustion for cooking and heating; these sources are important to tackle as they contribute to both outdoor and HAP. Providing access to cleaner fuel and taking sustained efforts to provide clean fuel could significantly reduce pollution in this region. For more on the impact of HAP on health, see the textbox entitled *Toward Cleaner Air: The Challenge of HAP* on page 33.

Each winter, $PM_{2.5}$ levels in South Asian countries, particularly those in the Hindu Kush region, rise to dangerous levels. The combination of smoke and dust is trapped by the cold, dense air, forming thick layers of smog that persist over extended dry periods. During this time, there is extensive burning of agricultural stubble in the region. The region contributes substantially to regional and global food security by growing staple crops such as rice and wheat. Stubble burning not only affects air quality across the region but also severely affects the communities living near the agricultural fields.

In Afghanistan, approximately 50% of $PM_{2.5}$ pollution originates from windblown dust (McDuffie et al. 2021). This windblown dust also *affects the air quality in other countries in this region*. According to the Intergovernmental Panel on Climate Change, the severity and frequency of dust storms will increase due to rising global temperatures.

A study conducted in Northern India found that living in a district in the top quintile of fires per day was associated with a **threefold higher risk** of acute respiratory infections (Chakrabarti et al. 2019).

Ground-level ozone

In 2019, South Asia had the highest ozone concentrations (58 ppb, UI: 57–59) in the world. Additionally, 96% of the region's population was exposed to ozone levels above 100 μg/m³ (51 ppb), the least stringent interim target for ozone recommended by WHO. This region also experienced the largest increase in ozone exposure (7.4 ppb) over the last decade (i.e., 2010–2019). The increase is likely due to higher emissions of ozone precursor chemicals coupled with warmer temperatures. At the country level, Nepal and India had the highest ozone exposures of 67 and 66 ppb, respectively, in 2019. High ozone levels were also seen in Bangladesh and Pakistan, with exposures of 65 ppb and 63 ppb, respectively *(Figure 15)*.

3x–5x

Death rates linked to ozone exposure are 3–5 times higher in South Asian countries compared to the global average.

South Asian countries have some of the highest age-standardized death rates from ozone, including Nepal (32.2 deaths/100,000 people), India (24.1 deaths/100,000 people), and Bhutan (14.3 deaths/100,000 people), which significantly exceeds the global death rate from ozone exposure (5.9 deaths/100,000 people). Notably, around 50% of the global disease burden from exposure to ozone is from India.

While the number of deaths attributable to ozone is smaller than that for $PM_{2.5}$, ozone-attributable mortality has increased proportionally over the last decade: between 2010 and 2021, there was an 88% increase in ozone-related deaths in South Asia. These increases are driven collectively by the increase in levels of ozone, aging of the population, and a higher death rate from COPD. Furthermore, the disease burden due to ozone exposure is likely to increase in India between now and 2050 under the business-as-usual scenario, resulting in health impacts comparable to that of $PM_{2.5}$ (Conibear et al. 2018).

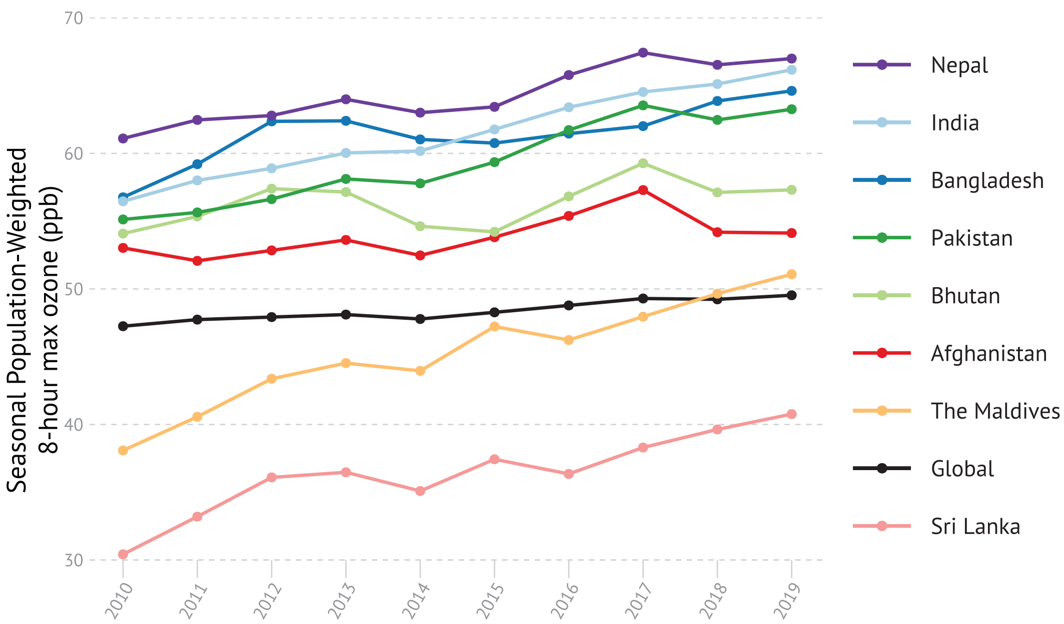


FIGURE 15. Trends in population-weighted average seasonal 8-hour maximum ozone concentration in South Asia, 2010–2019.

Nitrogen dioxide

Since 2010, NO_2 trends have largely remained constant across South Asia, with little change in overall exposure, except for a notable increase in Nepal *(Figure 16)*. Some countries in South Asia have much more stringent NO_2 air quality standards compared with other countries with long-established standards, including the United States, and are in line with interim targets recommended by WHO. In 2019, over 38% of the region's population experienced annual average NO_2 concentrations that exceeded the WHO annual Air Quality Guideline of 10 μg/m³; however, less than 1% of the population experienced exposures higher than 40 μg/m³, the least stringent interim target for NO_2.

Notably, Nepal has seen the largest increase in country-level NO_2 exposure (6.7 in 2010 to 11.3 μg/m³) in 2019. On the other hand, the Maldives (<1 μg/m³) and Bhutan (4 μg/m³) experienced relatively low NO_2 exposures. Across several countries in the region, there has been a significant increase in vehicle ownership and coal-burning for energy production and industrial use, both large contributors to NO_2 emissions. For example, the motorization index has grown 25 times since the 1990s in Nepal — the fastest growth in South Asia (Asian Transport Outlook, 2022).

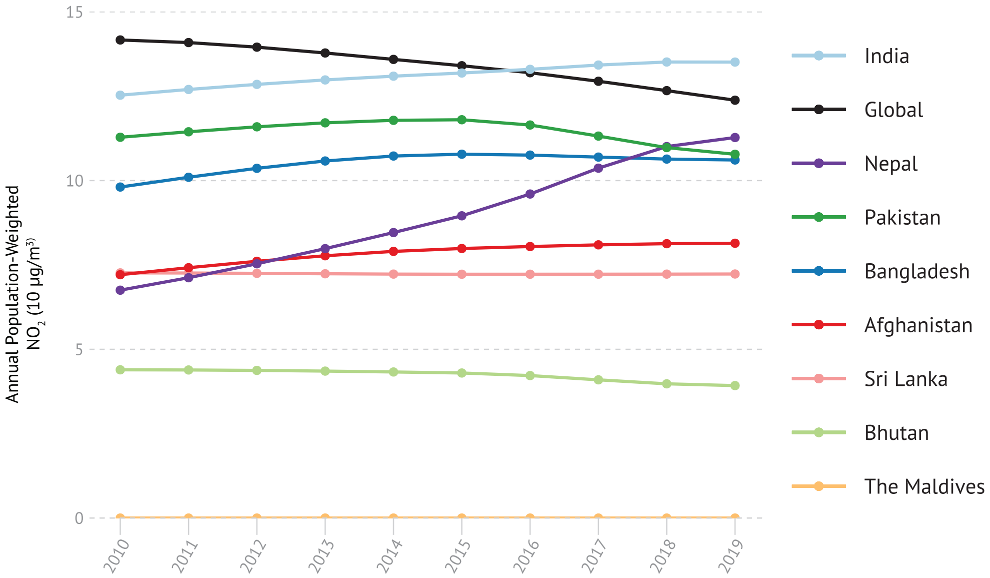


FIGURE 16. Trends in population-weighted annual average NO_2 concentrations in South Asia, 2010–2019.

Note that while data are also available for 2020, long-term trends were assessed for 2010 to 2019 due to a decline in NO_2 levels caused by COVID-19-related lockdowns and other restrictions in 2020.

The increase in NO_2 exposures in South Asia is partly linked to increased road traffic *(Figure 17)*. Specifically, increases in road traffic have led to greater fossil fuel combustion and a continued reliance on inefficient engines for transportation in highly populated cities.

Among South Asian countries, the highest disease burden for asthma among children and adolescents was observed in India (20,900 years of healthy life lost) and Pakistan (3,100 years of healthy life lost) in 2021.

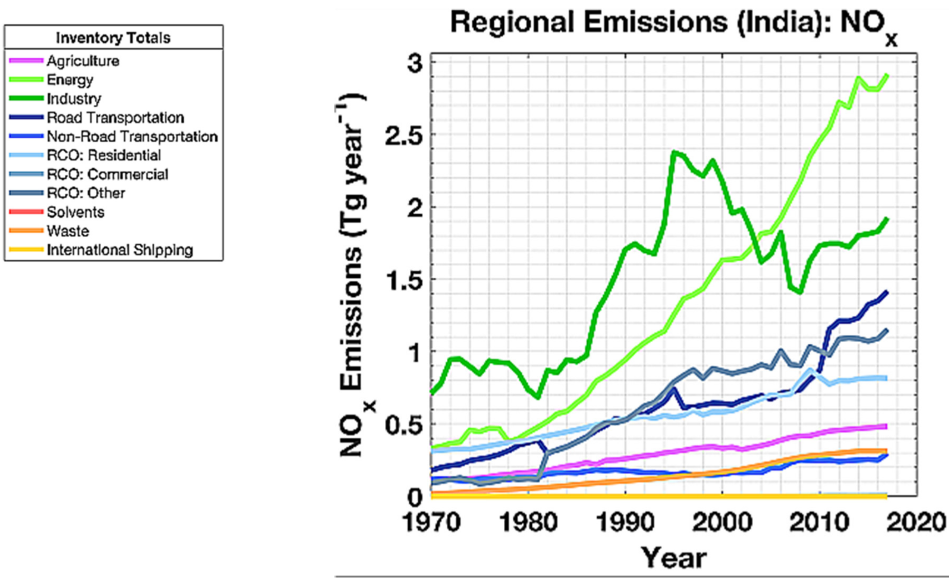


FIGURE 17. Trends in emissions of NO_x in India (McDuffie et al. 2021).

The State of Global Air *Explore the Data* allows for detailed comparisons of air pollution-attributable deaths and DALYs (both in absolute numbers and in age-standardized rates) between countries and among various regional groupings between 1990 and 2021.

Streets of Mumbai

Progress in reducing emissions from the transportation sector

Traffic-related air pollution (TRAP) continues to be an important risk factor for poor health across the globe. While high-income countries have made progress in reducing TRAP, in part due to air quality regulations and improvements in fuels and vehicular emission-control technologies, progress is lagging in countries in Central, South, and Southeast Asia. Exposure to NO_2, a marker for TRAP, is high in parts of Asia *(Figure iii)*. Reducing transportation emissions remains an important air quality and public health priority.

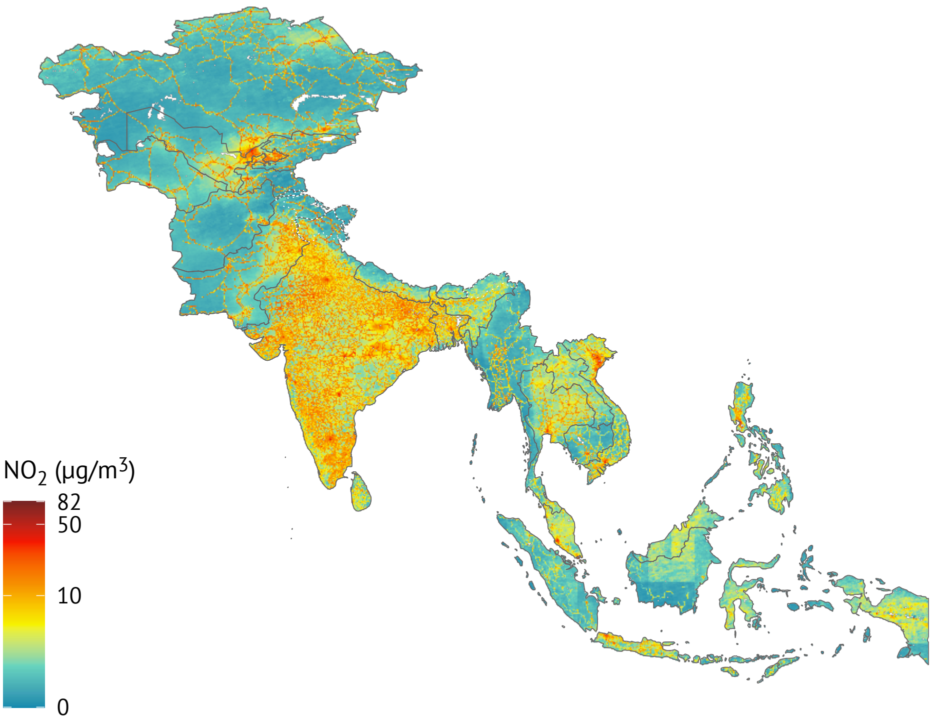


FIGURE iii. Gridded population-weighted annual average NO_2 concentrations in 2019 in Central, Southeast, and South Asia.

Tightening vehicle emission standards. Extensive empirical evidence and policy accountability studies have demonstrated that stricter vehicle emission standards can effectively reduce pollutants like NO_2 and $PM_{2.5}$. The following table illustrates the timelines for countries across the three regions and their respective vehicular emission standards for light-duty vehicles.

TABLE 1. Timelines of vehicular emission standards for light-duty vehicles across the region (Clean Air Asia 2024)

	YEAR																																		
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
European Union	Euro 2					Euro 3				Euro 4				Euro 5					Euro 6											Euro 7					
Bangladesh (metros)[a]	Euro 2																		Euro 3					Euro 4											
Bangladesh (gasoline)	Euro 2																						Euro 3		Euro 4										
Bangladesh (diesel)	Euro 1																						Euro 2		Euro 3										
Bhutan						Euro 1				Euro 2																	Euro 6								
Cambodia						Euro 1																			Euro 3		Euro 4					Euro 5			
India (metros)					Bharat 1	Bharat 2				Bharat 3					Bharat 4										Bharat 6										
India (nationwide)					Bharat 1					Bharat 2					Bharat 3							Bharat 4			Bharat 6										
Indonesia (gasoline)										Euro 2													Euro 4												
Indonesia (diesel)										Euro 2																	Euro 4								
Kazakhstan	Euro 2															Euro 3					Euro 4 and 5									Euro 6					
Kyrgyzstan													Euro 3								Euro 4	Euro 5													
Laos (gasoline)													Euro 2								Euro 6														
Laos (diesel)																					Euro 4														

Continued on next page

TABLE 1. *(Continued)*

	YEAR																																		
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Malaysia (gasoline)	Euro 2																								Euro 4					Euro 5					
Malaysia (diesel)	Euro 1				Euro 2																		Euro 4							Euro 5					
Myanmar (diesel)																												Euro 4							
Myanmar (gasoline)																										Euro 4									
Nepal					Euro 1												Euro 3																		
Pakistan (gasoline)																	Euro 2									Euro 5									
Pakistan (diesel)																						Euro 2				Euro 5									
Philippines								Euro 1				Euro 2									Euro 4														
Singapore (gasoline)	Euro 1					Euro 2													Euro 4			Euro 6													
Singapore (diesel)			Euro 1			Euro 2					Euro IV (HDVs) and Euro 2 (LDVs)								Euro V (HDVs) and Euro 4 (LDVs)				Euro 6												
Sri Lanka								Euro 1					Euro 2										Euro 4												
Tajikistan																											Euro 4								
Turkmenistan																																			
Thailand (gasoline)														Euro 3			Euro 4												Euro 5	Euro 6					
Thailand (diesel)														Euro 3			Euro 4												Euro 5		Euro 6				
Uzbekistan																							Euro 3	Euro 4					Euro 5						
Viet Nam												Euro 2										Euro 4					Euro 5								

[a] *Dhaka and Chittagong only*

Bold policy targets for electric vehicle adoption. Several countries in these regions have also set targets to encourage the adoption of electric vehicles, including buses, cars, and two-wheelers. For example, Indonesia plans to introduce 2 million electric vehicles and 13 million electric motorcycles by 2030, Cambodia has set a target for 40% of the cars and buses to be electric by 2050, and Sri Lanka aims to convert all state-owned vehicles to electric vehicles by 2050. In Kyrgyzstan, electric vehicles are exempt from import duties and registration tax, and in Pakistan, tax incentives have been introduced to promote local manufacturing of electric vehicles. *Explore policies and measures related to electric vehicles in Asia*.

Restrictions on import of old cars. Older vehicles continue to be an important source of air pollution, especially in Central Asia. Starting in January 2024, Tajikistan *banned the import of vehicles older than 2013 into the country*, including specialized vehicles and vehicles for transporting passengers and goods.

Toward Cleaner Air

THE CHALLENGE OF HOUSEHOLD AIR POLLUTION

Exposure to HAP is linked to a variety of health effects across age groups.

Exposure to HAP has been linked to pneumonia in children and lung cancer, stroke, COPD, cataracts, and cardiovascular disease in adults. Emerging evidence indicates that exposure to HAP may additionally be associated with a higher risk for ear infections, upper respiratory infections, and tuberculosis.

When pregnant women are exposed to HAP, the newborns are at a higher risk of being born early (premature birth) or too small for their age (low birth weight). The International Agency for Research on Cancer (IARC) has *classified* indoor burning of coal as a known human carcinogen and indoor burning of biomass as a probable human carcinogen. On the other hand, evidence across countries has shown that access to clean cooking fuels can not only reduce exposure to harmful air pollution but also improve people's health and quality of life (*learn more*).

Across Central, South, and Southeast Asia, over 1 billion people use solid fuels for cooking, or around 40% of the region's total population. Although exposure to $PM_{2.5}$ from household use of solid fuels for cooking (HAP) varies widely across countries *(Figure 18)*, the cumulative effect is a substantial disease burden, resulting in millions of deaths each year. In 2021, exposure to HAP resulted in 1.8 million deaths across the three regions. HAP also contributes to ambient $PM_{2.5}$; in some countries, HAP can account for more than 20% of ambient $PM_{2.5}$ (Chowdhury et al. 2023). In India, one estimate indicates that eradicating air pollution due to the use of solid fuels for cooking could result in the country meeting the national ambient air quality standard for $PM_{2.5}$; this would also reduce 13% of premature mortality across the country (Chowdhury et al. 2019).

Progress has been mixed. While countries including Indonesia and Viet Nam have seen significant reductions in solid fuel use for cooking, countries like Lao PDR and Timor-Leste have seen only slight reductions since 2010. In Indonesia, a *national program* designed to move households from kerosene cooking fuels to liquefied petroleum gas reached 50 million households by 2016. There is good news in South Asia as well - the percentage of the population relying on solid fuels for cooking is steadily decreasing across South Asia.

>70%

of the population is exposed to HAP in Myanmar, Bangladesh, Cambodia, Timor-Leste, and Lao PDR.

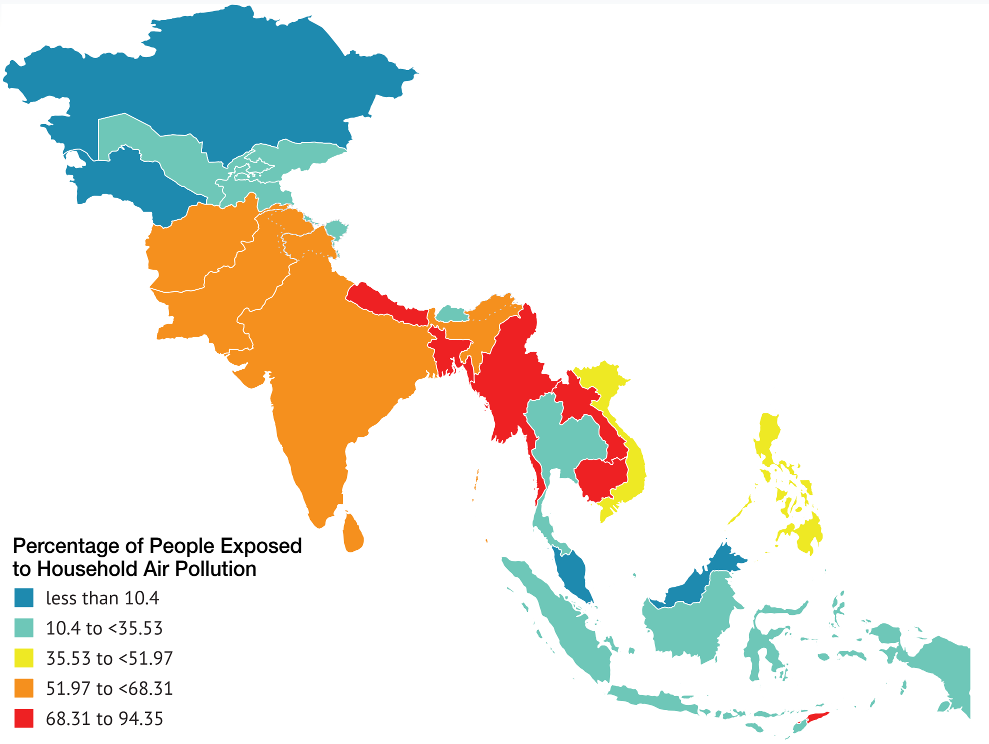


FIGURE 18. Percentage of population cooking with solid fuels in 2019 in Central, South, and Southeast Asia.

Newborns and children in Central, South, and Southeast Asia are heavily impacted by HAP. High levels of exposure during pregnancy can increase the risk of low birth weight and preterm birth (*learn more*). In 2021, 199,400 deaths (UI: 125,300–295,200) among children less than 5 years of age across Asia were linked to HAP exposure; 91% of these deaths were in South Asia.

The issue of HAP is closely linked to lack of access to clean energy. Reliance on fuelwood, which needs to be collected, also hinders educational and employment opportunities (especially for girls and women) and can contribute to deforestation. Access to affordable, reliable, sustainable, and modern energy for all are listed among the United Nations Sustainable Development Goals.

Nearly 1 in 2

years lived in disability due to cataracts is attributed to exposure to HAP in Nepal and Bangladesh.

The regional patterns of health impacts linked to HAP reflect both population sizes and the proportion of the population using solid fuels.

Central Asia	South Asia	Southeast Asia
13% of the region's households are exposed to HAP linked to use of solid fuels for cooking. In 2021, exposure to HAP led to 13,900 deaths in Central Asia. In some countries, HAP also substantially contributes to the health burden of cataracts. In Tajikistan and Kyrgyzstan, 28% and 26% of all YLD due to cataracts are attributable to exposure to HAP.	In 2021, almost 1.5 million deaths were attributed to HAP in children under 5 years of age, and 70% of deaths were linked to exposure to HAP. In Bangladesh and Nepal, exposure to HAP is responsible for 49% and 47% of all YLDs due to cataracts, respectively.	Nearly 46% of the population in Southeast Asia uses solid fuels for cooking, resulting in almost 300,000 deaths in 2021 alone.

Of note, the estimates presented here only account for cooking-related exposures and may undercount the health impacts since many households use solid fuels for heating.

Ongoing Efforts in Regional Cooperation on Air Pollution in Asia

Air pollution is a regional problem.

Air pollution knows no boundaries; pollutants emitted in one region can travel thousands of kilometers, affecting air quality in areas far from the emission source. Transboundary air pollution is a major concern across Central, South, and Southeast Asia due to climatology and geography; nevertheless, to date, the primary focus for air pollution continues to be local sources such as transportation, biomass burning, and dust. Recently, regional efforts to tackle air pollution have increased. One pollutant of interest is ozone. While 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. Populations across the three regions are exposed to high levels of ozone (*Figure 19*). Sand and dust storms are also a recognized transboundary problem in the region.

Several subregional agreements on air quality exist, but effective air pollution action will require **stronger regional coordination** as well as knowledge exchange.

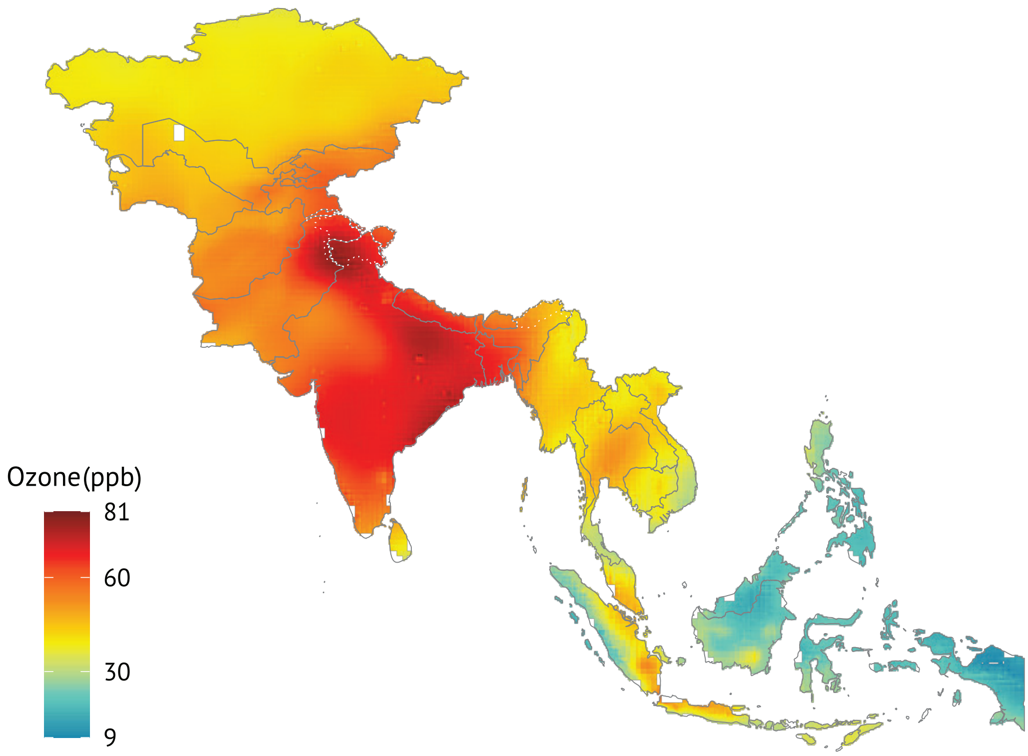


FIGURE 19. Map of national population-weighted average seasonal 8-hour daily maximum ozone concentrations in 2019 in Central, Southeast, and South Asia.

City smog

Below, we highlight a few recent regional programs addressing air pollution across Central, South, and Southeast Asia.

The Asia-Pacific Regional Action Programme on Air Pollution (*RAPAP*) is a region-wide action program aimed toward improving air quality through air quality management, facilitating air quality monitoring, sharing open data, exchanging best practices, supporting capacity building, and mobilizing multilateral cooperation.

Countries in Southeast Asia have long-standing regional agreements and initiatives for tackling transboundary haze pollution and acid deposition, including the *ASEAN Agreement on Transboundary Haze Pollution*. This agreement has led to the development of the ASEAN Specialised Meteorological Centre (ASMC) at the regional level to monitor and assess land and forest fires and the occurrence of transboundary smoke haze. Data collected between 2019 and 2023 show a reduction in the number of air pollution hotspots in the region.

There is also growing interest among countries in Central Asia in regional cooperation, especially regarding dust storms. In 2021, a comprehensive *Regional Strategy for Sand and Dust Storms (SDS) Management* in Central Asia was formulated, spanning the years 2021 to 2030. Its primary aim is to reduce the vulnerability of Central Asian nations and communities to the impacts of SDS by addressing active sources and strategizing proactive measures in destination regions. In 2022, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan adopted the *WHO Roadmap for Health and Well-being in Central Asia 2022–2025*, with air pollution as one of its action areas — marking the first road map of its kind in Central Asia.

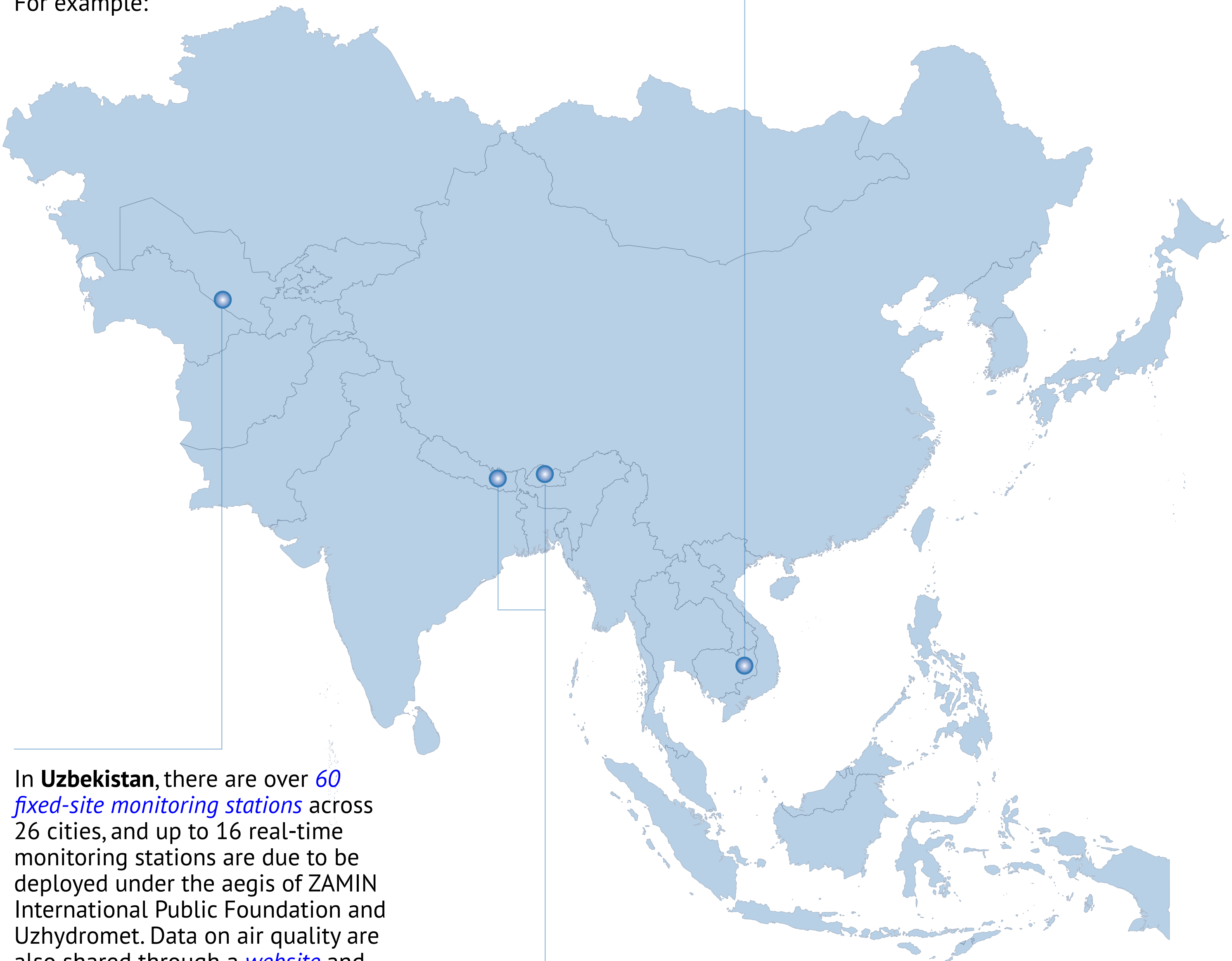
In South Asia, the *Malé Declaration* on Control and Prevention of Air Pollution and its Likely Transboundary Effects for South Asia was signed by countries in that region in 1998. This is the only existing intergovernmental framework in South Asia to address air pollution at the regional level. Although it made progress in its initial stages, a lack of funding and coordination resulted in a slowdown in activities. In recent years, there have been efforts to re-engage member states. The recent *Thimphu Outcome Towards Clean Air in Indo Gangetic Plains and Himalayan Foothills (June 2024)* also signals aspirational goals among South Asian countries for coordinated action toward clean air. Organizations including the World Bank have also made efforts to engage governments across South Asia to identify and implement *common solutions*.

Overall, it is clear that air pollution action will require better regional coordination as well as knowledge exchange. To that effect, the UNEA-6 *resolution* on regional cooperation further emphasizes the need for and importance of joint and cooperative action on air pollution. **There are also national-level approaches for air quality management planning that can be useful for countries across Asia.** The Philippines, for example, uses an airshed approach for air quality management with the understanding that air pollution control is more effective in areas with similar climate, meteorology, and topology. The entire country has been divided into 22 airsheds, starting with the Metro Manila airshed in 2001; the Metro Manila airshed has since been redesignated under the National Capital Region Airshed. Five airsheds have been designated as *geothermal* airsheds; each has a geothermal plant within the airshed. *Learn more*.

Recent progress on air quality monitoring across Asia

As of 2024, there has been rapid expansion of air quality monitoring capabilities across countries in Asia. In particular, this has been made possible by the availability of low-cost sensors, which have now been deployed in many cities across Central, South, and Southeast Asia. For example:

In **Cambodia**, the Department of Air Quality and Noise Management has installed 44 air sensors across its provinces. The data are shared daily through the Facebook page of the Ministry of Environment as well as outside the ministry building on a large screen.



In **Uzbekistan**, there are over *60 fixed-site monitoring stations* across 26 cities, and up to 16 real-time monitoring stations are due to be deployed under the aegis of ZAMIN International Public Foundation and Uzhydromet. Data on air quality are also shared through a *website* and the AirUz mobile app.

In **Nepal and Bhutan**, the International Centre for Integrated Mountain Development (ICIMOD) supports Nepal and Bhutan for maintaining their air quality monitoring stations to provide continuous and reliable data on air pollution.

At the same time, countries including Pakistan, Myanmar, and Afghanistan do not have any national air quality monitoring programs (*learn more*). In India, Indonesia, Thailand, Nepal, Viet Nam, and the Philippines, where real-time air quality data are collected regularly, *access to the data is limited*.

Child crossing polluted Buriganga River

Conclusions

Exposure to air pollution resulted in over 3 million deaths across Central, South, and Southeast Asia in 2021.

Collectively, exposure to fine particulate matter from ambient and household air pollution imposes a large burden on public health, contributing to a substantial number of early child and adult deaths and millions of years lived with chronic diseases and the associated disability. This also has broader societal and economic impacts. In recent years, ozone exposure and its health effects have also increased. Heightened public awareness of air quality and the burden of disease caused by air pollution is an essential step in reducing air pollution and improving people's health. Knowledge of long-term trends can help us understand patterns in the burden of disease experienced by populations across countries and help inform decision-makers about the most relevant actions for large-scale benefits.

While the health impacts of air pollution remain large, there are grounds for optimism: there is growing investment in monitoring air quality and the development of air quality management plans. A number of countries and cities in Central, South, and Southeast Asia have introduced legislation and policies to reduce air pollution; many also have air quality standards, largely in line with the interim targets set by WHO. Targeted policies are being implemented across a variety of sectors, from expanding access to clean energy for cooking and heating, promoting electric mobility, modernizing brick kilns, and developing solutions to reduce burning of agricultural waste. The progress thus far shows that with sustained, evidence-based implementation programs, clean air can be achieved, promoting better health for all.

Key Resources

GLOBAL BURDEN OF DISEASE 2021 METHODS

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

GBD 2021 Diseases and Injuries Collaborators. 2024. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990–2021: A systematic analysis for the Global Burden of Disease Study 2021. Lancet 403:2133–2161; *https://doi.org/10.1016/s0140-6736(24)00757-8*.

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GBD 2021 Forecasting Collaborators. 2024. Burden of disease scenarios for 204 countries and territories, 2022–2050: A forecasting analysis for the Global Burden of Disease Study 2021. Lancet 403:2204–2256; *https://doi.org/10.1016/s0140-6736(24)00685-8*.

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

For scientific evidence and perspectives on the health effects associated with exposures to $PM_{2.5}$, ozone, and related air pollution, see the following publications:

Anenberg SC, Mohegh A, Goldberg DL, Kerr GH, Brauer M, Burkart K, et al. 2022. Long-term trends in urban NO_2 concentrations and associated paediatric asthma incidence: Estimates from global datasets. Lancet Planet Health 6:e49–e58; *https://doi.org/10.1016/s2542-5196(21)00255-2*.

Boogaard H, Walker K, Cohen A. 2019. Air pollution: The emergence of a major global health risk factor. Int Health 11:417–421; *https://doi.org/10.1093/inthealth/ihz078.*

Brauer M, Davaakhuu N, Escamilla Nuñez MC, Hadley M, Kass D, Miller M, et al. 2021. Clean air, smart cities, healthy hearts: Action on air pollution for cardiovascular health. Glob Heart 16:61; *https://globalheartjournal.com/articles/10.5334/gh.1073*.

Clean Cooking Alliance. 2021. Hearths and Health: Evidence of the Global Impact of Household Air Pollution on Health. Available: *https://storymaps.arcgis.com/stories/e455c0a25dcf4b92a859f 5d38a26ce27*.

HEI Household Air Pollution Working Group. 2018. Household Air Pollution and Noncommunicable Diseases. Communication 18. Boston, MA: Health Effects Institute.

International Agency for Research on Cancer (IARC). 2013. Air Pollution and Cancer. IARC Scientific Publication No. 161. Lyon, France: World Health Organization. Available: *https://www.iarc.who.int/wp-content/uploads/2018/07/AirPollutionandCancer161.pdf*.

Lai PS, Lam NL, Gallery B, Lee AG, Adair-Rohani H, Alexander D, et al. 2024. Household air pollution interventions to improve health in low- and middle-income countries: An official American Thoracic Society Research Statement. Am J Respir Crit Care Med 209:909–927; *https://doi.org/10.1164/rccm.202402-0398st.*

Rajagopalan S, Landrigan PJ. 2021. Pollution and the heart. N Engl J Med 385:1881–1892; *https://doi.org/10.1056/nejmra2030281*.

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.

AIR QUALITY DATA

WHO (World Health Organization) 2022. WHO Air Quality Database 2023. Available: *https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database* [accessed 1 Feb 2024].

World Health Organization (WHO). 2023. Overview of methods to assess population exposure to ambient air pollution. Geneva: WHO. License: CC BY-NC-SA 3.0 IGO.

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

UNEP (2019). Air Pollution in Asia and the Pacific: Science-based Solutions. Available: *https://www.ccacoalition.org/resources/air-pollution-asia-and-pacific-science-based-solutions-summary-full-report* [accessed 1 August 2024].

United States Agency for International Development (USAID). 2019. LMIC Urban Air Pollution Solutions. Available: *https://urban-links.org/tools-resources/low-and-middle-income-countries-urban-air-pollution-solutions/* [accessed 2 May 2024].

World Health Organization (WHO). 2020. Personal Interventions and Risk Communication on Air Pollution. Geneva: WHO. License: CC BY-NC-SA 3.0 IGO. Available: https://www.who.int/publications/i/item/9789240000278 [accessed 1 August 2024].

Explore information on monitoring and management of air pollution on the Air Quality Management Exchange Platform.

VIDEOS

Cleaner Air, Healthier Children: *https://www.stateofglobalair.org/resources/video/cleaner-air-healthier-children*.

A Fragile Stage: Air Pollution's Impact on Newborns: *https://www.stateofglobalair.org/resources/video/fragile-stage-air-pollutions-impact-newborns*.

Air Pollution and Climate Change: *https://www.stateofglobalair.org/resources/video/air-pollution-and-climate-change*.

Science on the 7th: 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*.

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