STATE OF GLOBAL AIR /2020

HOW DOES YOUR AIR MEASURE UP AGAINST THE WHO AIR QUALITY GUIDELINES?

A STATE OF GLOBAL AIR SPECIAL ANALYSIS

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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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WHAT IS THE STATE OF GLOBAL AIR?

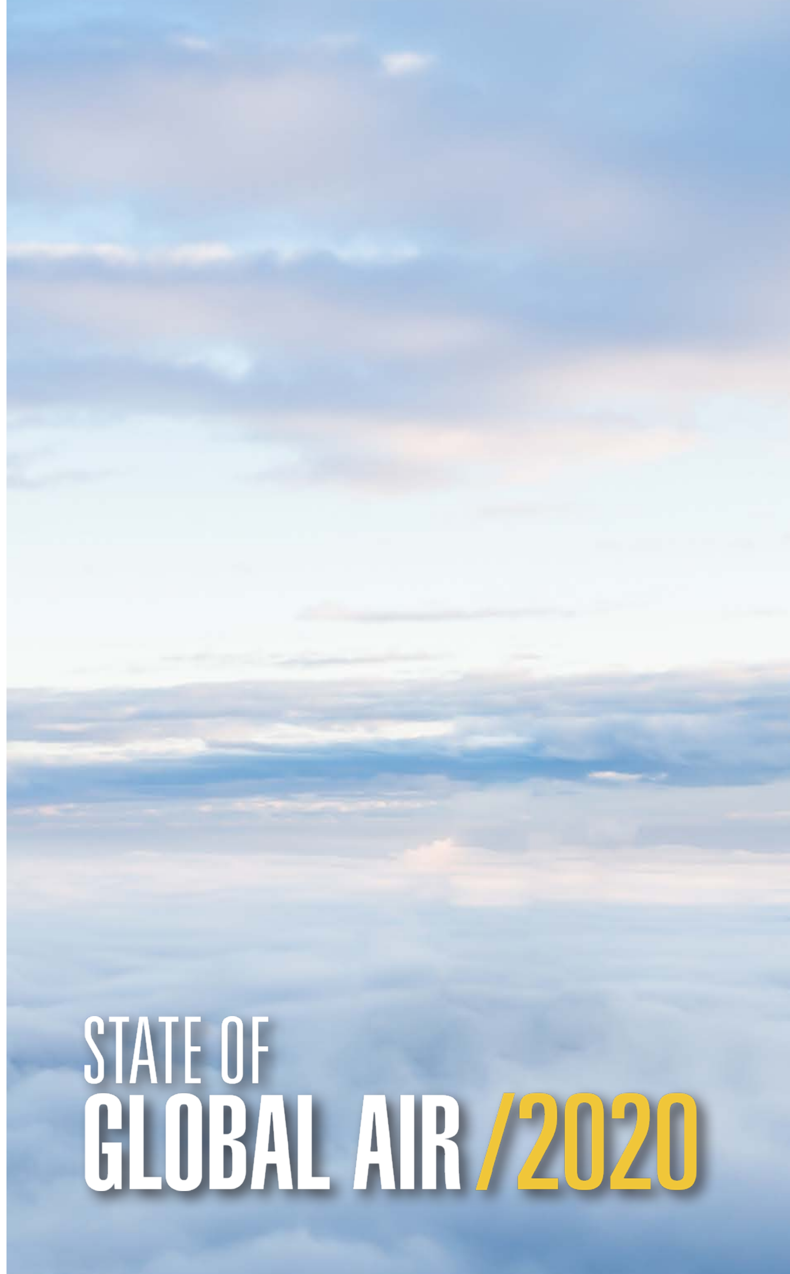
The *State of Global Air* report and interactive website offer a comprehensive analysis of the levels and trends in air quality and health for every country in the world. They are produced annually by the Health Effects Institute and the Institute for Health Metrics and Evaluation's (IHME's) Global Burden of Disease (GBD) project and are a source of objective, high-quality, and comparable air quality data and information.

WHO IS IT FOR?

The report and website are designed to give citizens, journalists, policymakers, and scientists access to reliable, meaningful information about air pollution exposure and its health effects. These resources are free and available to the public.

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 over 200 individual countries, territories, and regions, as well as track trends from 1990 to 2019. Find it at *www.stateofglobalair.org*.



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INTRODUCTION

Air pollution affects people of all ages and income levels in all areas of the globe.

Air pollution is a leading risk factor for deaths and disability around the world; in 2019 alone, exposure to air pollution was linked to 6.7 million deaths. Studies from across the world have documented the many ways in which air pollution can affect people's health, including making it difficult to breathe for those with asthma or other respiratory diseases; affecting the health of newborns and children; and sending older adults to the hospital due to heart and lung diseases. Through its impacts on mortality and morbidity, exposure to air pollution also shortens life expectancy. New studies continue to broaden our understanding of the wide range of effects that air pollution can have on human health. *To learn more about the health effects of air pollution, read our factsheet here*.

Measuring Up: How Clean is Our Air?

Despite all that is known about the effects of air pollution on health, little or no progress to improve air quality has been made in many parts of the world. 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) established by the World Health Organization (WHO) to help countries reduce air pollution. This State of Global Air Special Analysis compares how countries fare with respect to the updated AQGs and the associated interim targets released by the WHO in September 2021, using data for long-term average ambient fine particulate matter (i.e., $PM_{2.5}$) and ozone concentrations. Specifically, this report addresses the following questions:

- What percentage of the world's population is living in areas with $PM_{2.5}$ and ozone levels above the WHO AQG value and interim targets?
- What has been the degree of progress around the world in the last decade for meeting WHO AQGs and interim targets?

The data reported here offer both an account of global exposures to air pollution and a foundation for informing decisions and action toward cleaner air for all. We use data on levels and trends of ambient (outdoor) $PM_{2.5}$ and ozone from the Global Burden of Disease (GBD) 2019 study as reported in the State of Global Air 2020 report. *Learn more here*.

A much larger trove of data — with detailed statistics for over 200 countries in the world, tools for generating custom data tables and graphs, and factsheets for selected countries — is available at *www.stateofglobalair.org*.

About the WHO Air Quality Guidelines

In response to a request by the member states at the 68th World Health Assembly on May 26, 2015, in Geneva, Switzerland, the WHO undertook a multiyear process to revise the AQGs. The updated guidelines released in September 2021 are based on current evidence of health effects from exposure to air pollution and offer evidence-based public health recommendations and guidance on air quality for countries around the world (Table 1). It is understood that meeting the AQG values can be challenging for countries with high air pollution levels. In addition to the AQG values, the WHO has also recommended interim targets to facilitate realistic plans that can lead to gradual and meaningful reduction in the disease burden linked to air pollution. Together, the AQG values and interim targets provide a strong incentive for countries to improve air quality and protect people's health. *Learn more about the WHO AQGs here*.

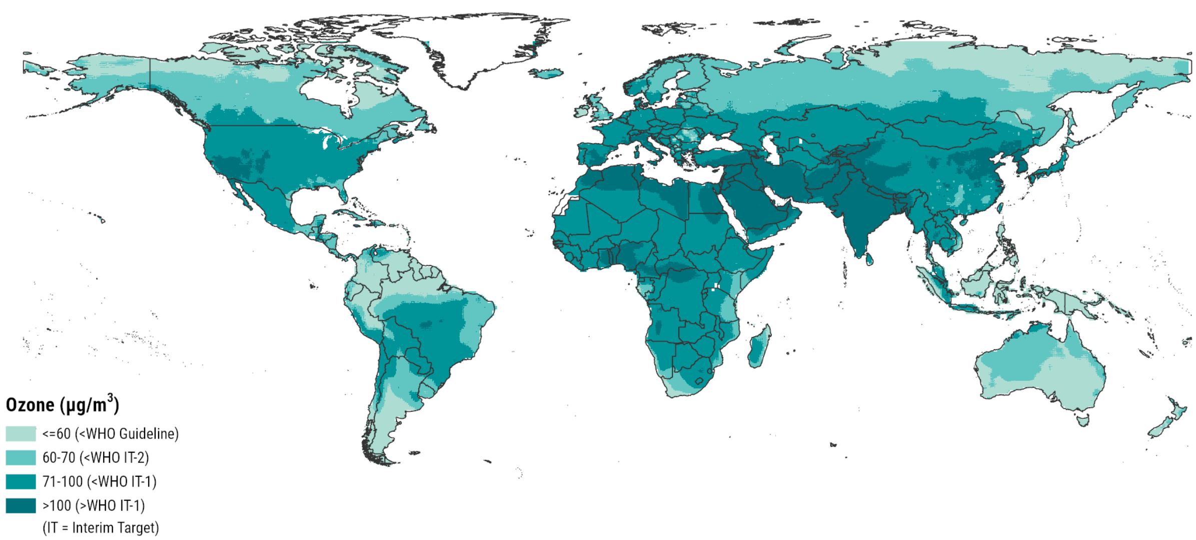
Air pollution accounts for more than 1 in 9 deaths globally.

TABLE I Updated WHO Air Quality Guideline levels and interim targets for major pollutants

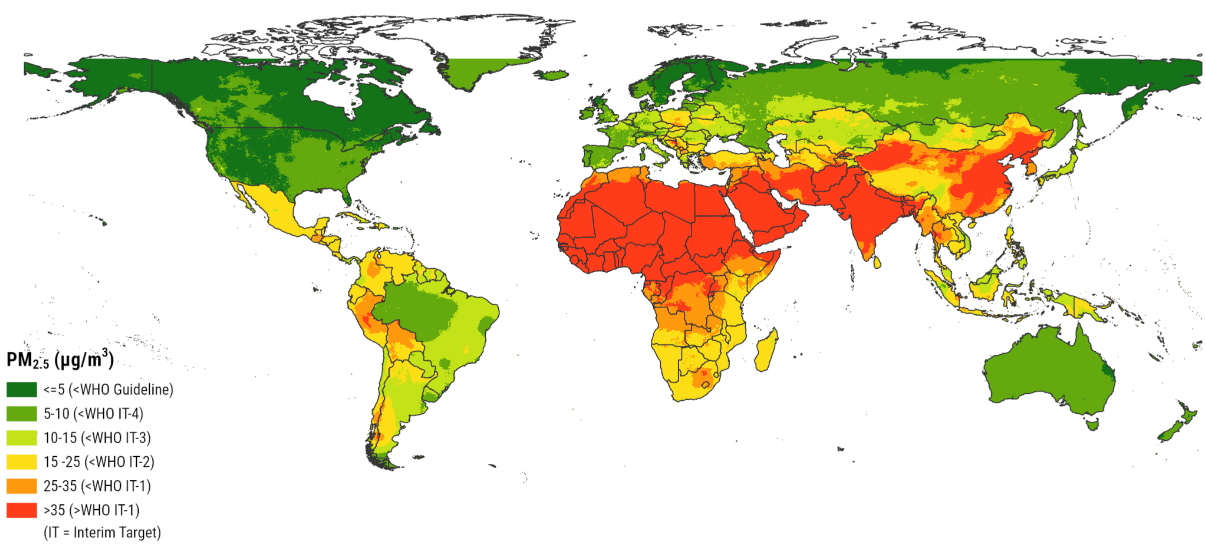
Pollutant	Averaging Time	AQG	IT-4	IT-3	IT-2	IT-1	Change Compared to 2005 AQG
$PM_{2.5}$ (μg/m³)	Annual	5	10	15	25	35	Tightened
	24-hour	15	25	37.5	50	75	Tightened
PM_{10} (μg/m³)	Annual	15	20	30	50	70	Tightened
	24-hour	45	50	75	100	150	Tightened
Ozone (μg/m³)	Peak season*	60	-	-	70	100	New
	8-hour	100	-	-	120	160	Unchanged
NO_2 (μg/m³)	Annual	10	-	20	30	40	Tightened
	24-hour	25	-	-	50	120	New
SO_2 (μg/m³)	24-hour	40	-	-	50	125	Loosened
CO (mg/m³)	24-hour	4	-	-		7	New

AQG = air quality guideline; IT 4–IT 1 = specific interim targets.

*Average of daily maximum 8-hour mean ozone concentration in 6 consecutive months with highest 6-month running average ozone concentration.



OZONE: Annual average ambient ozone concentrations in 2019 relative to the new WHO Air Quality Guideline



$PM_{2.5}$: Annual average ambient $PM_{2.5}$ concentrations in 2019 relative to the new WHO Air Quality Guideline

AMBIENT FINE PARTICLE AIR POLLUTION

Ambient fine particle air pollution refers to $PM_{2.5}$ (i.e., particles measuring less than 2.5 micrometers in aerodynamic diameter, and less than a 30th of the diameter of a human hair). These particles, as well as precursor chemicals that contribute to their secondary formation in the atmosphere, are emitted from vehicles, coal-burning power plants, industrial activities, waste burning, and many other human and natural sources. Ambient $PM_{2.5}$ concentrations are measured in micrograms of particulate matter per cubic meter of air, or $\mu g/m^3$.

In the updated AQGs released in September 2021, the annual guideline value was reduced from 10 $\mu g/m^3$ (recommended in the 2005 update) to 5 $\mu g/m^3$ based on recent evidence of the considerable adverse health effects of exposure to $PM_{2.5}$ at levels lower than 10 $\mu g/m^3$. Taken together, the guideline values and the interim targets enable countries to set realistic goals toward clean air and make steady progress in protecting their citizens' health against the effects of air pollution.

Around the world, ambient levels of $PM_{2.5}$ continue to exceed the updated AQG established by the WHO (Figure 1). Based on estimates for 2019, no country reported average national $PM_{2.5}$ levels below the WHO AQG of 5 $\mu g/m^3$, and only 25 out of 204 (12%) countries included in the analysis met the most-stringent IT-4 of 10 $\mu g/m^3$. Worryingly, almost a fourth of countries (49) assessed here did not meet even the least stringent WHO interim target of 35 $\mu g/m^3$ (IT-1). Among these countries, most were in Sub-Saharan Africa (25), North Africa and Middle East (17), and South Asia (7). This translates to more than half of the world's population living in areas where $PM_{2.5}$ levels exceed the WHO IT-1 in 2019. On the other hand, in high-income countries, less than 1% of the population is exposed to levels above this value.

In 2019, more than 50% of the world's population lived in areas that exceeded even the least stringent interim target (IT-1) set by WHO for $PM_{2.5}$ (35 $\mu g/m^3$).

Because these population-weighted $PM_{2.5}$ concentrations represent annual averages across entire countries, they include, but do not represent, the considerably higher concentrations that may be observed in some regions of the country, especially around cities or major pollution sources. Thus, it is likely that populations in certain regions within countries are exposed to even higher levels of ambient $PM_{2.5}$.

The updated WHO Air Quality Guideline for annual average $PM_{2.5}$ is set at 5 $\mu g/m^3$ based on evidence of health effects of 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 $\mu g/m^3$, 25 $\mu g/m^3$, 15 $\mu g/m^3$, and 10 $\mu g/m^3$.

Among the 20 most populous countries, half reported national $PM_{2.5}$ levels above the WHO IT-1; in 8 countries, more than 50% of the population lives in areas where $PM_{2.5}$ levels exceed the IT-1 (Figure 2). Of these 20 countries, 5 (Democratic Republic of the Congo, Egypt, Ethiopia, Nigeria, and Turkey) do not have national air quality standards for $PM_{2.5}$. In addition, several of these countries, including Democratic Republic of the Congo, Egypt, Ethiopia, Nigeria, Pakistan, the Philippines, and Vietnam, have a limited number of government-run, reference-grade monitoring stations (*more*).

Major disparities remain with respect to $PM_{2.5}$ levels globally, resulting in significant implications for public health worldwide. Progress in air quality remains very slow in countries where $PM_{2.5}$ levels are higher than the least stringent WHO target of 35 $\mu g/m^3$. For example, South Asian countries such as India and Nepal have reported very little improvement over the past decade, while $PM_{2.5}$ levels have continued to increase in countries in the Middle East and

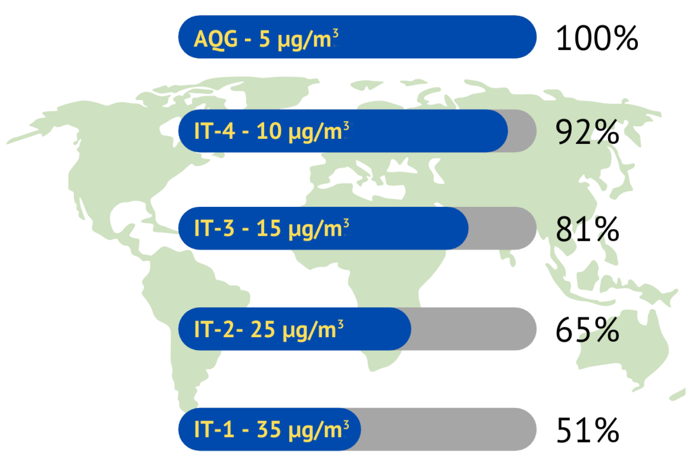


FIGURE 1 Percentage of the world's population living in areas where $PM_{2.5}$ levels exceed WHO recommendations.

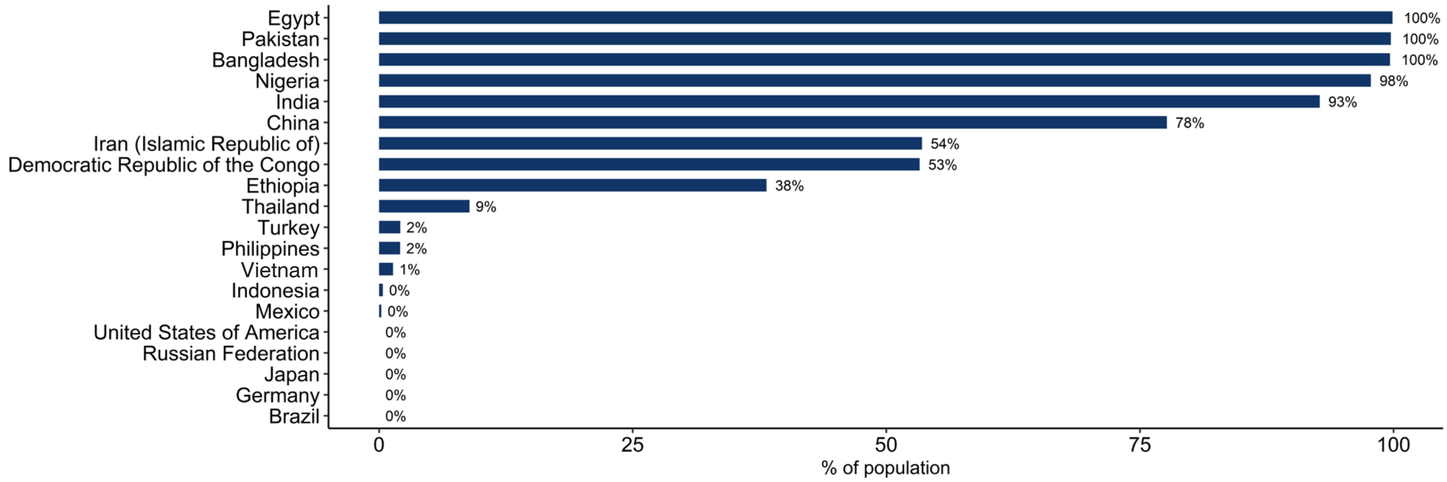
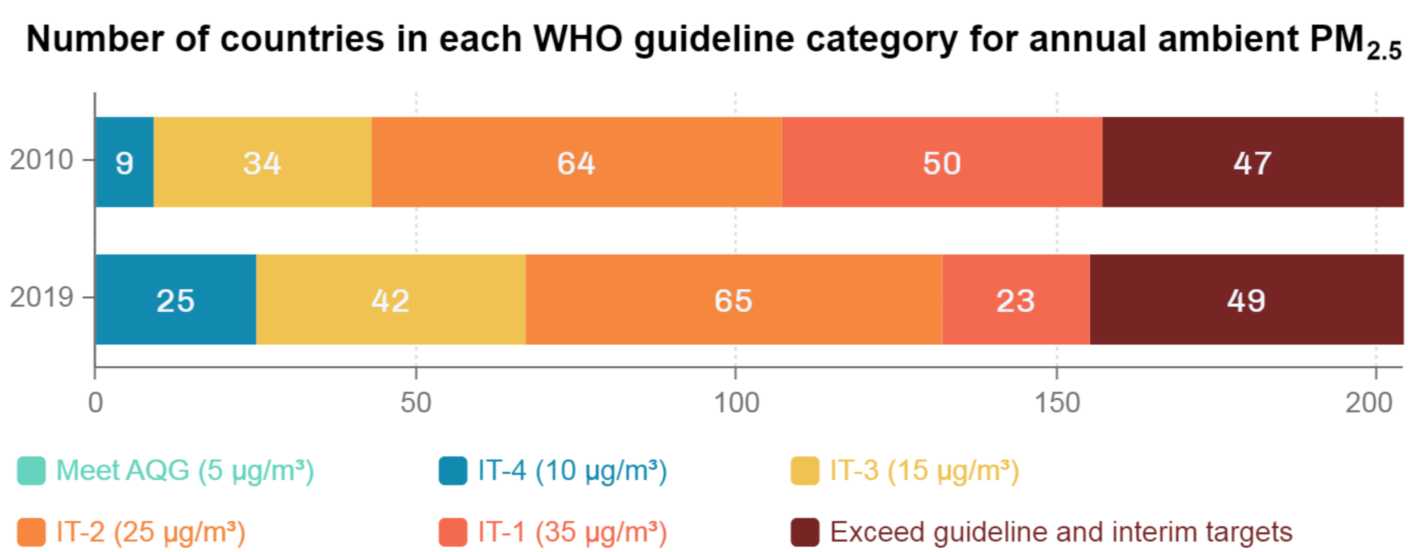


FIGURE 2 Percentage of population among the top 20 most populated countries living in areas where $PM_{2.5}$ levels exceeded the least stringent WHO target (35 µg/m³) in 2019.

Africa. However, compared to 2010, 14 more countries met the most stringent WHO IT-4 (10 µg/m³), and 8 more countries met IT-3 (15 µg/m³) in 2019.

Comparison of the current air quality levels and percentage of population living above the WHO AQG and interim targets can also underscore the potential for progress toward clean air. For example, 47% of the population of the Democratic Republic of the Congo lives in areas where $PM_{2.5}$ levels are below the IT-1, and 62% of the population in Ethiopia lived in areas below IT-4 in 2019. In China, $PM_{2.5}$ levels have dropped markedly in recent years, largely due to stringent air quality management efforts focused on key sources.

Many populous countries continue to experience extremely high levels of air pollution. In India, Pakistan, Bangladesh, Egypt, and Nigeria, more than 90% of the population in each country lives in areas where $PM_{2.5}$ levels exceed even the least stringent WHO IT-1.



AMBIENT OZONE POLLUTION

Ground-level, or tropospheric, ozone is a highly reactive pollutant that has adverse effects on human health as well as on food crops and other vegetation. It is not released directly into the air but is formed in a complex chemical interaction between nitrogen oxides (NO_x) and volatile organic compounds in the presence of sunlight. NO_x and volatile organic compounds are both produced by a variety of human activities. NO_x are emitted from the burning of fossil fuels (oil, gas, and coal) in motor vehicles, power plants, industrial boilers, and home heating systems. Volatile organic compounds are also emitted by motor vehicles, oil and gas extraction and processing, and other industrial activities.

Ozone pollution is accelerated by — and contributes to — climate change, and it is also a greenhouse gas contributing to global warming, which in turn creates increasingly optimal conditions for further ozone production. In urban areas, ozone levels can vary widely within and around cities depending on local and regional sources. In addition, ozone is an important regional pollutant, traveling long distances to suburban and rural areas and across national boundaries, leading to high ozone levels far from the emission sources that contribute to its formation. Ozone concentrations are measured in parts per billion (ppb) or µg/m^3.

The new WHO Air Quality Guideline for ozone is set at 60 µg/m^3 for 8-hour average 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/m^3 and 70 µg/m^3.

In the AQGs released in 2021, WHO established a new long-term peak-season average ozone AQG level. In the WHO guidelines, "the peak season is defined as the six consecutive months of the year with the highest six-month running-average ozone concentration."

On average, more than 40% of the world's population lives in areas where ozone levels exceeded the least stringent WHO interim target (100 µg/m^3) in 2019 (Figure 3). In South Asia, the entire population (100%) lives in areas where ozone levels exceed the WHO AQG, and in North Africa, the Middle East, Central Europe, Eastern Europe, and Central Asia, 95% of each population is exposed to levels above the guideline.

In 2019, 92% of the world's population lived in areas that exceeded the long-term ozone guideline of 60 µg/m^3.

Only 28 out of 204 countries meet the WHO AQG for ozone, and the majority are island states located in Southeast Asia, East Asia, Oceania, Latin America, and Caribbean regions. Three high-income countries also meet this guideline — Australia, Brunei Darussalam, and Ireland. However, almost one-fifth of countries (39 of 204) reported ozone levels above the least stringent WHO interim target of 100 µg/m^3 (IT-1). Among these countries, most are in North Africa and the Middle East (17), followed by high-income countries (6).

In contrast to $PM_{2.5}$, where low- and middle-income countries in Asia and Sub-Saharan Africa experience the highest exposures, ozone levels continue to be high among both high-income and low-and-middle income countries.

- In 17 out of the 20 most populous countries, 90% of the population lives in areas exceeding the WHO guideline for long-term ozone, including both high-income and low-and-middle income countries.
- Only 3% of the population in the Philippines lives in areas where the WHO guideline value for long-term ozone level is exceeded. On the other hand, countries including China, Germany, the United States, and India have more than 95% of their populations living in areas where the guideline value is not met (Figure 4).
- In three countries — India, Bangladesh, and Pakistan — more than 90% of the population lives in areas where ozone levels exceed even the least stringent WHO interim target (100 µg/m^3).

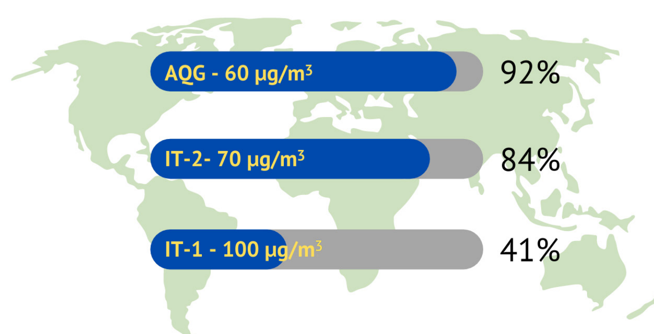


FIGURE 3 Percentage of the world's population living in areas where ozone levels exceed WHO recommendations.

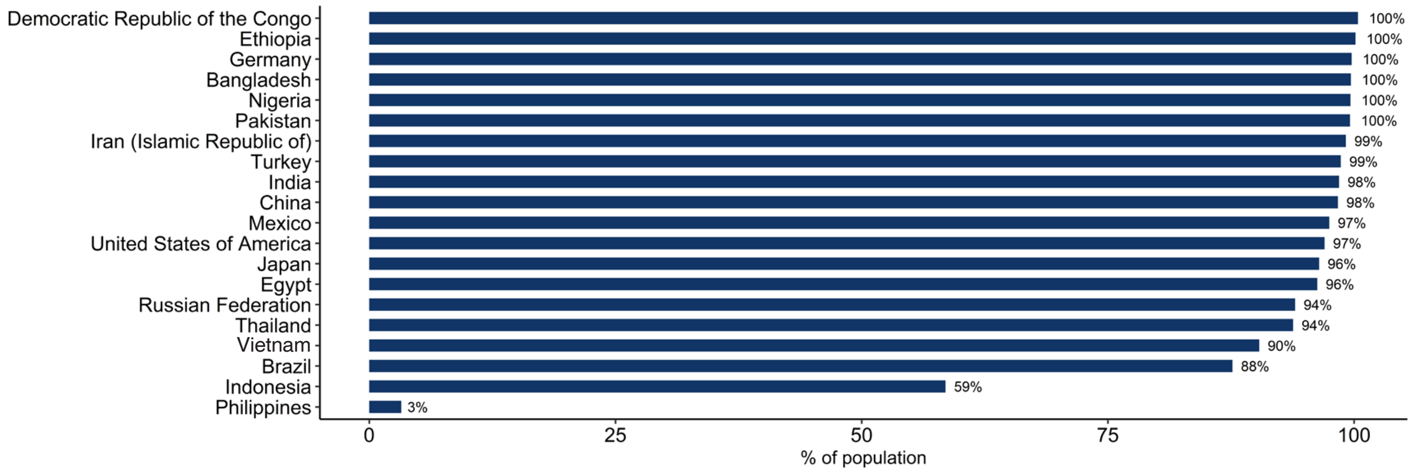
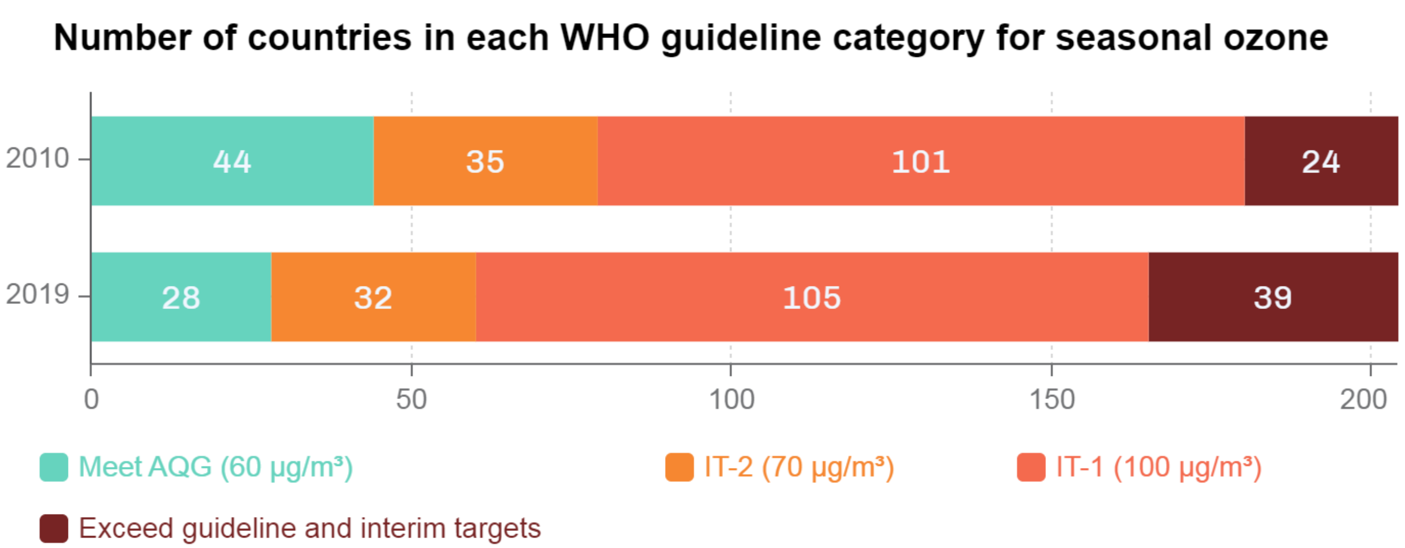


FIGURE 4 Percentage of population living in areas that exceeded WHO long-term ozone guideline of 60 μg/m³ in 2019.

- Of the 20 most populous countries, 9 do not have any standards for ozone (D: Democratic Republic of the Congo, Ethiopia, Indonesia, Japan, Nigeria, Pakistan, Russia, Turkey, and Vietnam.
- 90% of the population in 17 out of the 20 most populous countries lives in areas exceeding the WHO guideline for long-term ozone, including both high-income and low-and-middle income countries.

As reported in the State of Global Air 2020, ozone exposures have increased slowly but steadily over the past decade — a trajectory that is expected to continue because of warming temperatures and increased emissions of O_3 precursors. In fact, compared to 2010, 16 more countries failed to meet the new WHO guideline (60 μg/m³) for ozone in 2019, and more countries also exceeded the least stringent WHO interim target of 100 μg/m³.

Moving backward? Fewer countries met the WHO Air Quality Guideline for ozone in 2019 compared with those that did in 2010.



CONCLUSIONS

Air pollution remains an important risk factor for death and disability, and it affects human longevity worldwide with impacts comparable to those of other well-known risk factors including smoking, poor hygiene, and malaria. The updated WHO AQGs underscore the importance of improving air quality in countries around the world. Although they are not legally binding, they offer citizens and policymakers clear health-based benchmarks for progress. Furthermore, the guidelines are likely to influence global air quality standards both in the near- and long-term.

Progress in reducing the burden of disease attributable to air pollution will require continued tracking and analysis. Through the State of Global Air platform, we aim to continue providing data at global, national, and local scales to support action toward clean air.

The data presented here highlight the need for bold action, especially in countries where exposures continue to be very high. They also highlight the need for a long-term, multistep approach with progressively ambitious goals because many countries are unable to meet even the least stringent interim targets set by WHO in the near future. Although the AQGs themselves offer an ambitious target, in reality, the interim targets can serve as important milestones on the path toward clean air. However, actions need to be grounded in the understanding of the sources and drivers of air pollution and other risk factors at regional, national, and local levels.

How did we derive these results?

We compared estimates of population-weighted annual average $PM_{2.5}$ and average seasonal 8-hour maximum ozone levels for each country for 2019 as reported by the GBD study to the corresponding WHO AQG and interim values. To provide a consistent view of air pollution levels around the world, GBD scientists use sophisticated techniques to combine available ground measurements of air pollutants with observations from satellites and predictions from global chemical transport models. Instead of applying a mean concentration for a given country or area, a population-weighted concentration was used as it is a better estimate of population exposure by giving greater weight to the pollutant concentrations experienced where most people live. Learn more *here*.

In addition to national estimates, the GBD 2019 study also provided $PM_{2.5}$ and ozone measurements 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). Using this high-resolution data, combined with estimates on the number of people living in each grid, we calculated the percentage of people living in areas with air pollutant levels above WHO recommendations.

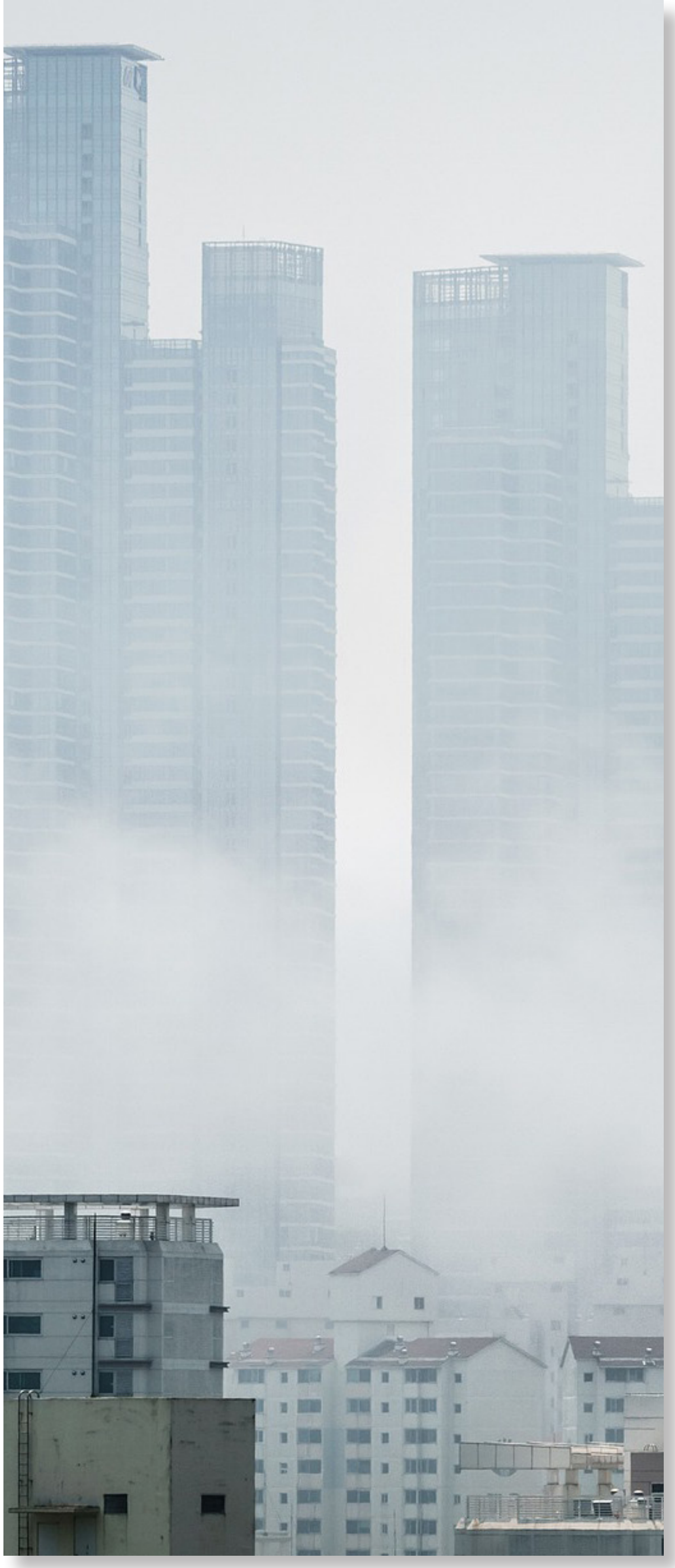
View interactive maps and other data at *www.stateofglobalair.org*. Gridded data are available upon request.

KEY RESOURCES

- Apte JS, Brauer M, Cohen AJ, Ezzati M, Pope CA. 2018. Ambient $PM_{2.5}$ reduces global and regional life expectancy. Environ Sci Technol Lett 5:546–551; *doi.org/10.1021/acs.estlett.8b00360*.
- Boogaard H, Walker K, Cohen A. 2019. Air pollution: The emergence of a major global health risk factor. Int Health 11:417–421; *doi.org/10.1093/inthealth/ihz078*.
- Hoffmann B, Boogaard H, se Nazelle A, Andersen ZJ, Abramson M, Brauer M, et al. 2021. WHO Air Quality Guidelines 2021–Aiming for Healthier Air for all: A Joint Statement by Medical, Public Health, Scientific Societies and Patient Representative Organisations. Int J Public Health 66:1604465; *doi.org/10.3389/ijph.2021.1604465*.
- World Health Organization. 2021. WHO Global Air Quality Guidelines: Particulate Matter ($PM_{2.5}$ and PM_{10}), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide. World Health Organization. Available: *https://apps.who.int/iris/handle/10665/345329*. License: CC BY-NC-SA 3.0 IGO.

STATE OF GLOBAL AIR REPORTS AND RESOURCES

- Health Effects Institute. 2020. State of Global Air 2019: A Special Report on Global Exposure to Air Pollution and Its Disease Burden. Boston, MA:Health Effects Institute.
- Health Effects Institute. 2020. State of Global Air 2020. Explore the Data: Download Maps and Data or Create Custom Plots. Available: *https://www.stateofglobalair.org/data/#/air/plot*.
- Health Effects Institute. 2020. State of Global Air 2020. Resources: Factsheets. Available: *https://www.stateofglobalair.org/resources?resource_category=factsheet#block-exposedformresources-all*.
- Health Effects Institute. 2022. How Does Air Pollution Affect Life Expectancy Around the World? A State of Global Air Special Report. Boston, MA:Health Effects Institute.



CONTRIBUTORS AND FUNDING

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HEI is an independent global health and air research institute. It is the primary developer of the State of Global Air report, the host and manager for this website, the coordinator of input from all other members of the team, and the facilitator of contact with media partners. Key HEI contributors include Pallavi Pant, senior scientist; Yi Lu, staff scientist; Joanna Keel, research assistant; Kristin Eckles, senior editorial manager; Sofia Chang-DePuy, digital communications manager; Tom Champoux, director of science communications; Aaron Cohen, consulting scientist at HEI and affiliate professor of Global Health at IHME; Robert O'Keefe, vice president; and Dan Greenbaum, president.

IHME

The Institute for Health Metrics and Evaluation

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Other Contributors

ZevRoss Spatial Analysis provided data visualization support and developed the interactive features of the website; Mary Brennan served as consulting editor; and David Wade composed the report.

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For any questions, please email us at *contactsoga@healtheffects.org*.
For the full dataset, please visit *www.stateofglobalair.org*.