STATE OF GLOBAL AIR /2020

HOW DOES AIR POLLUTION AFFECT LIFE EXPECTANCY AROUND THE WORLD?

A STATE OF GLOBAL AIR SPECIAL REPORT

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?

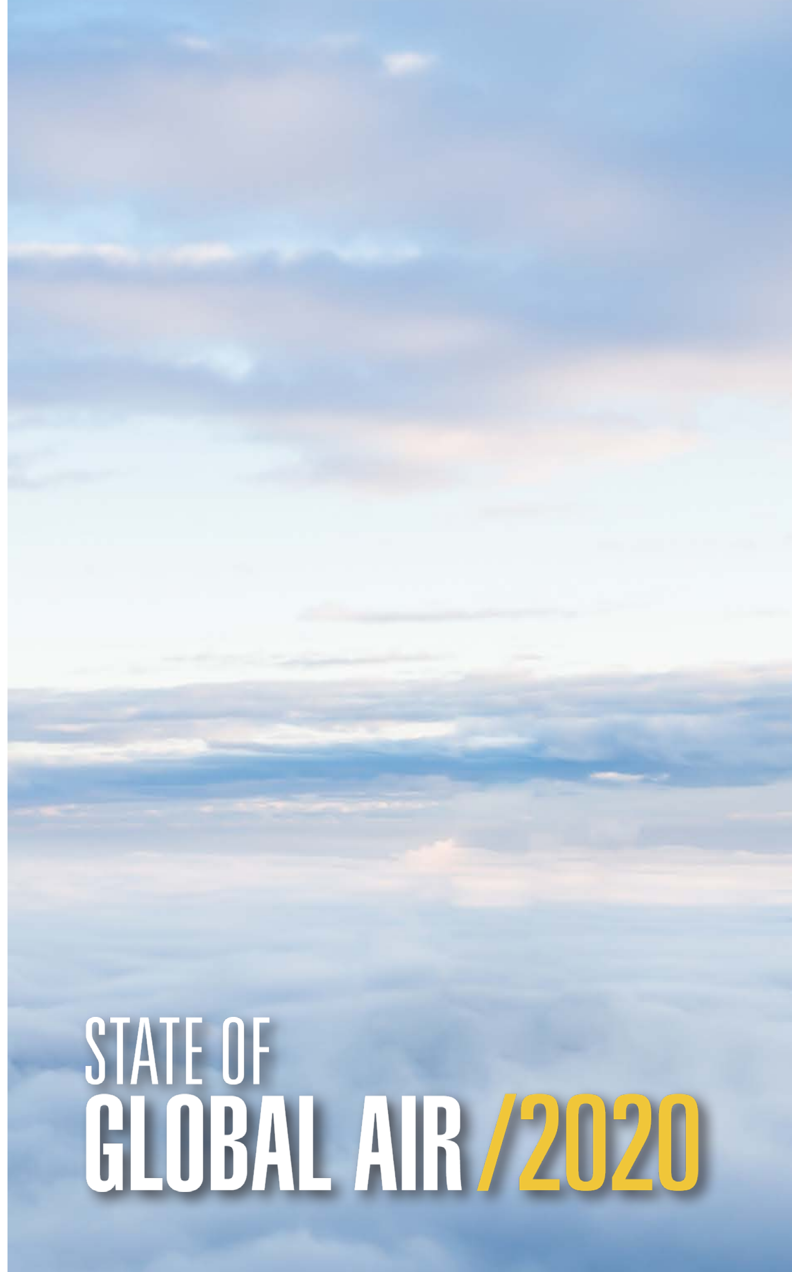
The *State of Global Air* report and interactive website offer a comprehensive analysis of the levels and trends in air quality and health for every country in the world. They are produced annually by the Health Effects Institute and the Institute for Health Metrics and Evaluation's (IHME's) Global Burden 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.

ABOUT THIS REPORT

Life expectancy is a summary measure of population health that provides a measure of how long an average individual in a population might be expected to survive. In this report, we address a simple question: How long can a newborn born in 2019 be expected to live, assuming that death rates are constant into the future?



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INTRODUCTION

AIR POLLUTION AND LIFE EXPECTANCY

The major global health effects of ambient and household air pollution are increasingly well understood. Millions of deaths are attributed each year to exposure to fine particulate matter ($PM_{2.5}$). Yet these seemingly large statistics are very difficult to put into scale and context. How does this vast burden of ill health and death shorten human life? Life expectancy is a summary measure of population health that provides a measure of how long an average individual in a population might be expected to survive. This report investigates the impact of air pollution on life expectancy around the world using data from the Global Burden of Disease Study (GBD) 2019.

How Much Does Air Pollution Reduce Life Expectancy?

Globally, the average human life is shortened by approximately 1.8 years by the combined impact of the three key air pollutants we considered here: ambient $PM_{2.5}$ (1.0 yr), household air pollution (0.7 yr), and ambient ozone (0.07 yr). Table 1 presents results for key regions and countries around the world. The combined impact of $PM_{2.5}$ in ambient air and from household use of solid fuels for cooking is greatest in countries with low- and low-middle sociodemographic index (SDI) values, where life expectancy is reduced by 2.7 years and 2.5 years, respectively. In the low-SDI countries, which are principally in sub-Saharan Africa (e.g., Ethiopia and Senegal), household air pollution's effect on life expectancy (1.9 yr) substantially exceeds that of ambient $PM_{2.5}$ (0.7 yr). In low-middle SDI countries (e.g., Nigeria, Kenya, and Myanmar), the average impact of ambient $PM_{2.5}$ and household air pollution is of a large and similar magnitude (average: 1.2 yr vs. 1.1 yr). In contrast, for middle- and high-SDI countries, ambient $PM_{2.5}$ is the main risk factor for reduced life expectancy from air pollution. These trends play out regionally as well. In sub-Saharan Africa (total ΔLE = 2.2 yr), the reduction in life expectancy from household air pollution (1.6 yr) is substantially greater than that from ambient $PM_{2.5}$ (0.5 yr), whereas in South Asia (total ΔLE = 2.8 yr), the reductions in life expectancy from both ambient $PM_{2.5}$ (1.5 yr) and household air pollution (1.1. yr) are both very large.

A child born in 2019 would die 12 months sooner, on average, than would be expected in the absence of exposure to $PM_{2.5}$.

Even in higher-income world regions, the impact of air pollution on longevity is not small. Life expectancy decrements (i.e., ΔLE) from ambient $PM_{2.5}$ are ~0.2–0.3 yr in high-income North America and Western Europe and 0.5–0.9 yr in Latin America and Eastern Europe. In comparison to other major risk factors for human health, these decrements in life expectancy are large. Of note, a key reason that air pollution contributes to loss of life expectancy is because it contributes to the risk of some of the important diseases, including ischemic heart disease, stroke, and lung cancer.

Results in Context

To put our results in context, we estimated the reductions in global and regional life expectancy that occur from a variety of other major threats to human health (Table 1). Compared to the 1.77 years (round-

TABLE 1 Years of life expectancy loss (ΔLE) by region for air pollution and other risks

Region	LE at birth (e_0)	Total air pollution	Ambient $PM_{2.5}$	HAP	WaSH	Tobacco	IHD	Stroke	Malaria	Cancer
Global	73.5	1.8	1.0	0.7	0.6	2.1	2.1	1.5	0.3	2.5
High SDI	81.0	0.4	0.3	0.0	0.0	2.0	1.7	0.8	0.0	0.0
High-middle SDI	77.5	1.1	1.0	0.1	0.0	2.4	2.7	1.7	0.0	3.0
Middle SDI	74.6	1.7	1.3	0.3	0.2	2.2	2.2	1.7	0.1	2.3
Low-middle SDI	69.7	2.5	1.2	1.1	0.8	1.9	1.9	1.4	0.2	1.7
Low SDI	65.5	2.7	0.7	1.9	1.6	1.2	1.5	1.1	0.8	1.4

e_0 = life expectancy at birth; HAP = household air pollution; WaSH = inadequate water, sanitation, and hygiene; IHD = ischemic heart disease; SDI = sociodemographic index.

ed to 1.8 years in Table 1) ΔLE that are attributable to ambient and household air pollution combined, eliminating the following risk factors or causes of death would hypothetically lead to increases in human longevity from the present day global-average life expectancy of 73.5 years: cancer (2.5 yr), ischemic heart disease mortality (2.1 yr), diseases related to tobacco smoking (2.1 yr), strokes (1.5 yr), inadequate water/sanitation/hygiene (0.6 yr), and malaria (0.3 yr). Even the very largest causes of and risk factors for ill health and death are associated with decrements in life expectancy of only a few years on average. For example, ischemic heart disease, a major underlying contributor to heart attacks, is the single-largest individual cause of death globally, resulting in 16% of all-cause global mortality and shortening the average life expectancy by 2.1 years.

Similar comparisons within individual countries and regions provide a useful sense of scale (Figures 1 and 2). For example, in low and low-middle SDI countries, the impact on human longevity of all air pollution (2.5–2.7 yr) is substantially greater than that of all cancers (1.4–1.7 yr) and tobacco smoking (1.2–1.9 yr). In the United States, ambient $PM_{2.5}$ air pollution (ΔLE = 0.24 yr) has a comparable scale of impact on life expectancy to breast cancer (0.24 yr) and diabetes (0.31 yr). In China, eliminating household and outdoor air pollution as risk factors for mortality would have a similar benefit to life expectancy (1.85 yr) as averting all deaths from ischemic heart disease (1.89 yr). In India, the life expectancy reduction from exposure to ambient $PM_{2.5}$ (1.51 yr) is greater than ΔLE from all cancers (1.39 yr). In short, ambient and household $PM_{2.5}$ air pollution have a combined impact on life expectancy that is of a magnitude comparable to the very largest threats to human health and longevity.

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What is Life Expectancy?

Life expectancy is a summary measure of population health that provides an estimate of longevity, or how long an average individual in a population might be expected to survive. The most used version of life expectancy is life expectancy at birth (referred to by demographers as e_0) and reflects how long a baby born in a given year can expect to live, assuming that the death rates in that year do not change in the future. This metric simplifies the complex nature of survival from birth to death in a population into a single, intuitively understandable value. Furthermore, life expectancy refers specifically to what happens on average for a population, not for each individual. Thus, if the life expectancy of a country is shortened by a year because of exposure to ambient $PM_{2.5}$, it does not stand to reason that each individual in that country lives one year less long. However, as with many apparently simple metrics, life expectancy involves some assumptions that are helpful to understand.

Life expectancy at birth is a prediction of future events that is estimated from current data. The fundamental inputs to the life expectancy calculation are current age-specific mortality rates. Well-established demographic equations are used to convert the age-specific mortality rates into a standard life table, which predicts the probability of an individual surviving from one age to the next and is used to plot a survival curve, which shows the fraction of a cohort that survives from birth to a given age. Figure 3 shows examples of a life table for two countries, China and Nigeria, for a child born in 2019. The life expectancy at birth (e_0) — the age to which an average individual born into a cohort survives — can be thought of simply as the area under the life table curve. For example, in Figure 3, the life expectancy at birth in China (76.3 yr) is greater than that of Nigeria (65.0 yr). This difference arises in large part because of the considerably higher infant mortality rate in Nigeria (note the sharp drop in survival in the first years of the plot). There are also notable differences in survival, which is considerably greater in China, through late childhood toward the end of middle age. The rapid drop-off in survival above ages 60 to 70 is typical.

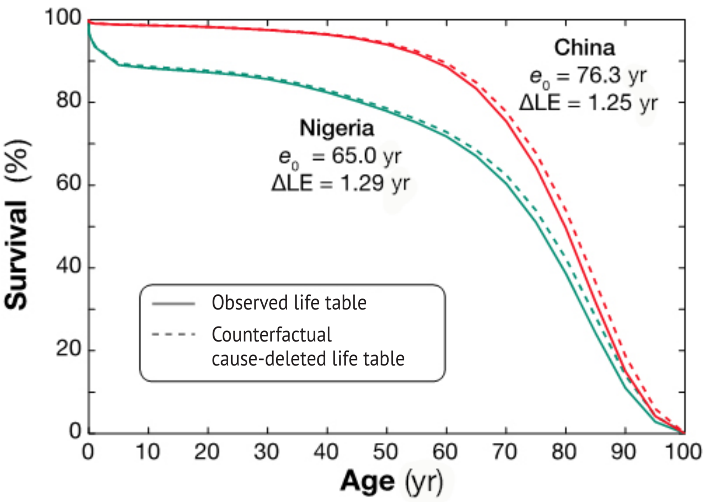


FIGURE 3 Survival curves and lost life expectancy for China and Nigeria. Baseline life expectancy at birth, e_0, is computed on the basis of observed mortality rates and can be thought of as the area under each of the solid lines. To estimate the impact of air pollution on life expectancy, a counterfactual survival curve where ambient $PM_{2.5}$ is removed as a risk factor for death is plotted as a dashed line. For each country, the area between the solid and dashed line can be thought of as proportional to the loss of life expectancy attributable to ambient $PM_{2.5}$ air pollution (ΔLE).

FIGURE 1 Estimated life expectancy loss by country for ambient $PM_{2.5}$ in 2019.

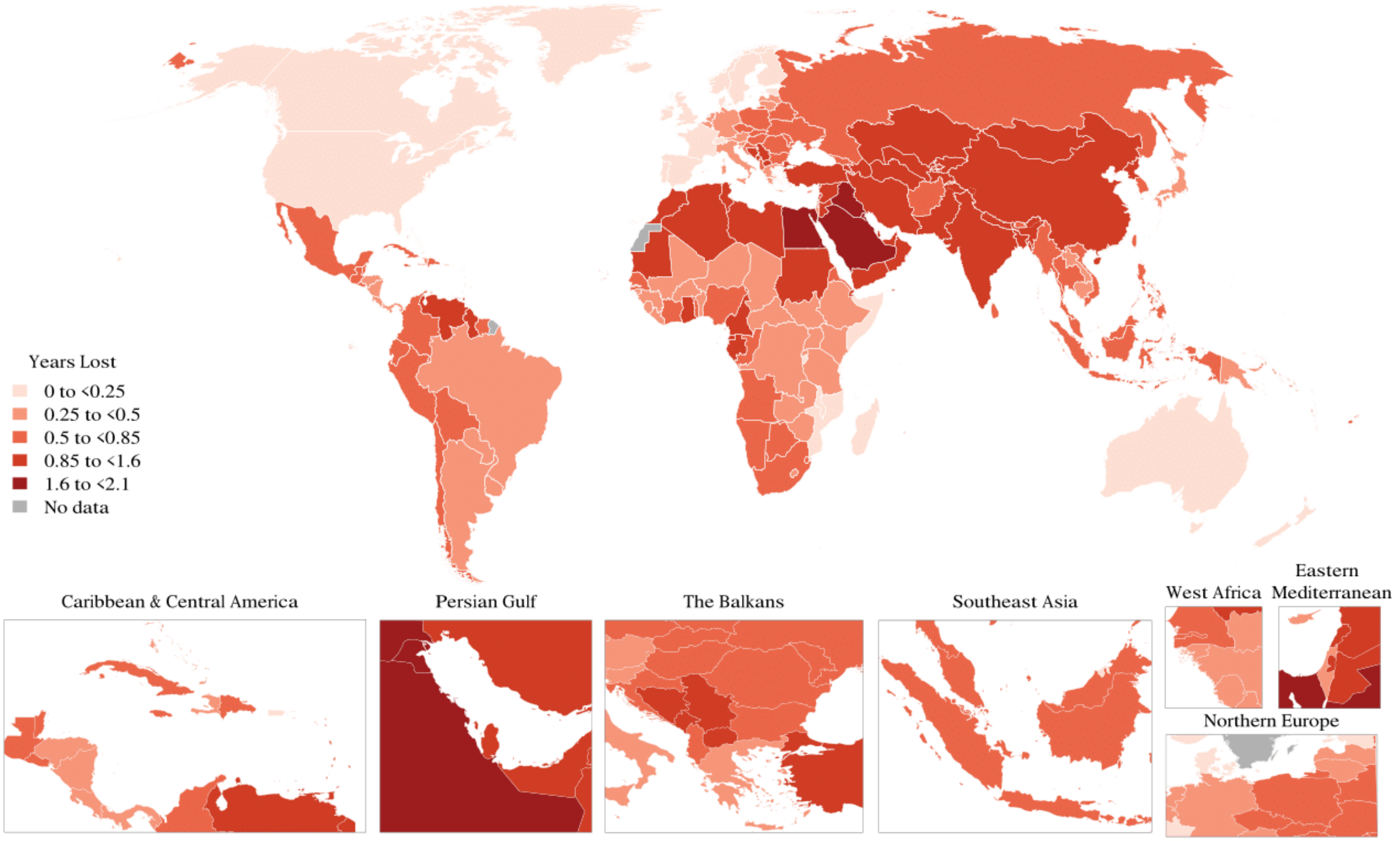


FIGURE 2 Estimated life expectancy loss by country for household air pollution in 2019.

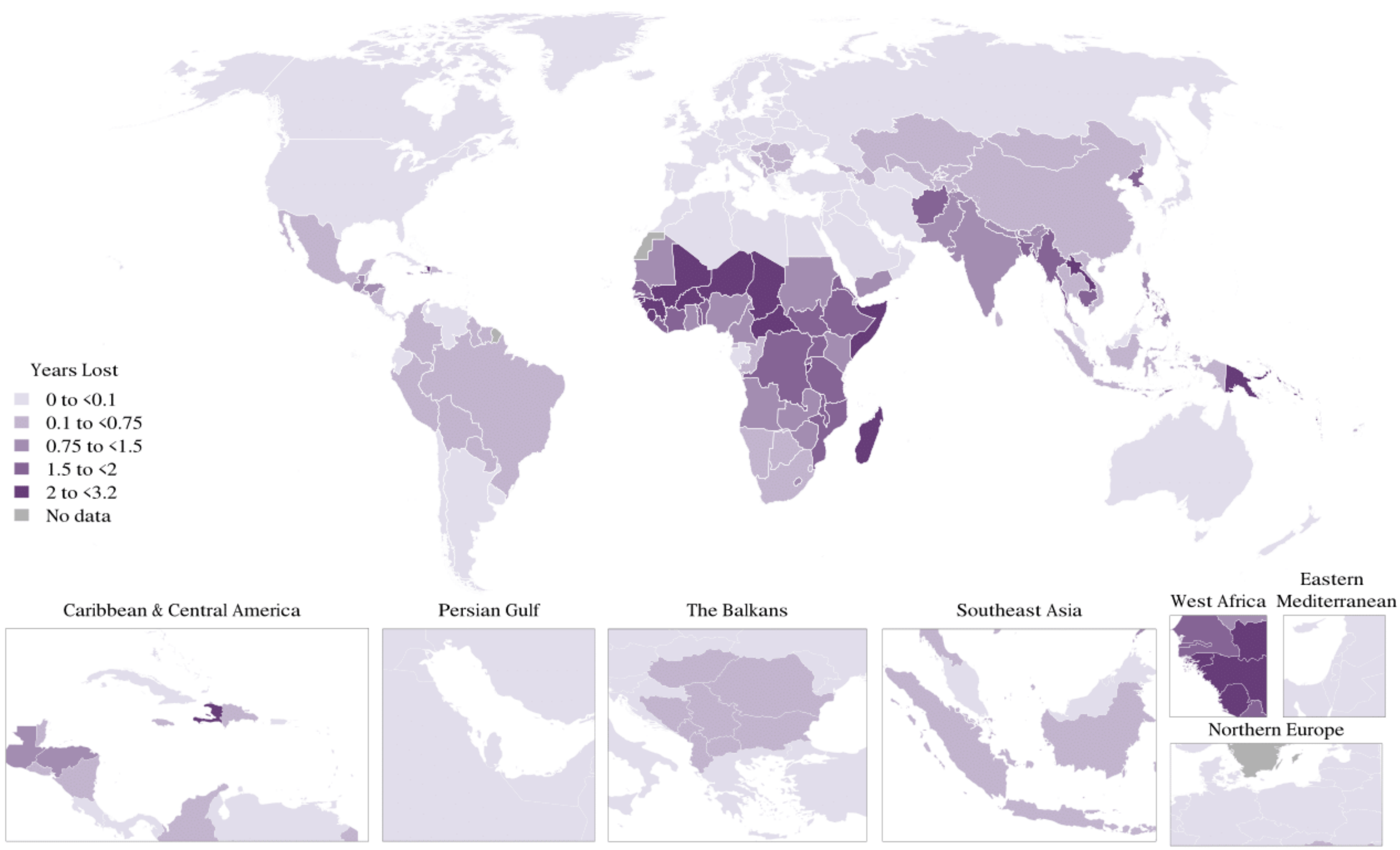
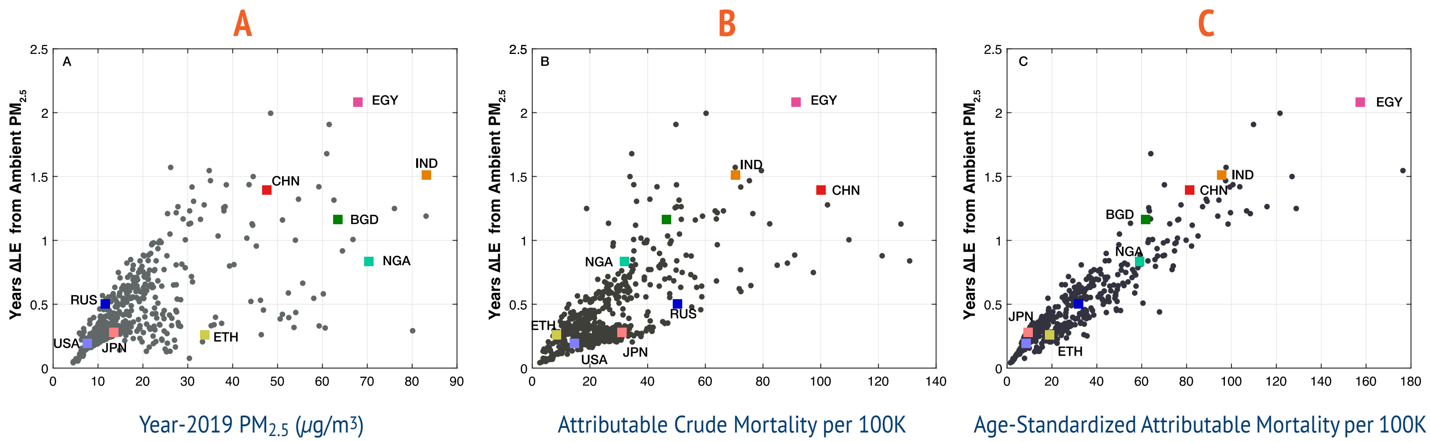


FIGURE 4 Examination of relationship of ambient $PM_{2.5}$ concentrations, attributable mortality statistics, and lost life expectancy from $PM_{2.5}$. Panel A illustrates the weak relationship between ambient $PM_{2.5}$ concentrations and attributable lost life expectancy (ΔLE). Panel B illustrates the relationship between observed (crude) mortality attributed to $PM_{2.5}$ and ΔLE. Panel C illustrates the relationship between age-standardized mortality attributed to $PM_{2.5}$ and ΔLE. *Explore the data on the State of Global Air Life Expectancy page*.



Exploring National Patterns in Life Expectancy Loss from Ambient $PM_{2.5}$

Figure 4 presents the country-by-country results for lost life expectancy attributable to ambient $PM_{2.5}$. Regions with especially large ΔLE from ambient $PM_{2.5}$ include the Middle East; North Africa; and South, Central, and East Asia. Results include 2.11 years of lost life expectancy in Egypt, 1.91 years in Saudi Arabia, 1.51 years in India, 1.32 years in China, and 1.31 years in Pakistan. The lowest impacts on longevity tend to be in regions with high baseline life expectancy and very low levels of ambient $PM_{2.5}$, including Norway, Sweden, Australia, and New Zealand (0.07–0.1 yr).

Overall, countries with higher levels of ambient $PM_{2.5}$ experience greater losses in life expectancy from ambient $PM_{2.5}$, but the relationship is far from linear (Figure 4A). Similarly, in countries with higher death rates from $PM_{2.5}$, the life expectancy loss attributable to $PM_{2.5}$ is generally higher, but not linearly so (Figure 4B). There are several reasons why this relationship is complex. First, the relationship between air pollution concentrations and premature mortality in each country depends on several complex factors: the rates of baseline disease, nonlinearities in the relationship between air pollution and relative risk, and the age distribution of the population. In particular, older populations tend to be more heavily impacted by air pollution, given that they have higher mortality rates, and diseases affected by air pollution mainly occur in older individuals. Second, the crude (actual) mortality rate attributed to air pollution is imperfectly correlated with lost life expectancy. All else being equal, a country with an elderly population will have higher levels of mortality from air pollution than a country with a younger or middle-aged population simply because the risk of dying of any cause is highest for the elderly. As an important consequence of this principle, for example, India experiences a 30% lower rate of crude mortality from ambient $PM_{2.5}$ than does China, despite $PM_{2.5}$ exposures in India being nearly the same as those in China. This result arises in large part because of the much younger population in India than in China (median age: 26 yr vs. 38 yr). Overall, however, deaths related to air pollution in the elderly segments of the population will lead to a lower loss of life expectancy than deaths that take place in middle-age or younger segments of the population. Thus, some countries with younger populations may have crude mortality rates attributable to air pollution that are suppressed by their younger population, but they still experience relatively high ΔLE from air pollution. To continue this example, the ΔLE attributed to $PM_{2.5}$ in India and China is of comparably large magnitude, at about 1.5 years of lost life expectancy.

One standard technique that epidemiologists use for clarifying this relationship is to compute a hypothetical age-standardized mortality rate attributable to air pollution, which holds constant for the country-to-country differences in the age distribution of the population. As shown in Figure 4C, the relationship between age-standardized mortality rates from $PM_{2.5}$ and its associated lost life expectancy is considerably stronger than the relationships in the other two panels of Figure 4.

Overall, a scientific advantage of measuring the health impact of air pollution in terms of its associated life expectancy loss is that this statistic is not strongly affected by the age distribution of the country, whereas the attributable mortality associated with air pollution depends strongly on the relative share of younger and older individuals in a population.

METHODS

How do we estimate the effect of air pollution on life expectancy?

To estimate the effect of air pollution on life expectancy for State of Global Air analyses, we use a cause-deleted life table. As the name implies, this is a life table computed on the basis of age-specific mortality rates where one or more causes of death (either diseases or risk factors) are artificially eliminated. By deleting specific causes of death, the probability of surviving from one age to the next slightly increases. For each air pollution-related risk factor in GBD 2019 (i.e., ambient $PM_{2.5}$, household air pollution, and ambient ozone pollution), we computed a hypothetical life table in which that particular factor was eliminated as a risk for premature death. Then, to put our air pollution results into context, we conducted a similar exercise for a wide range of other risk factors and causes of death. For the purposes of the analysis, age-specific attributable death rates as reported in GBD 2019 were used. The methods used here are described in detail by Apte and colleagues (2018). Of note, the results reported here are driven largely by estimates from $PM_{2.5}$ in ambient air and from household use of solid fuels for cooking (inclusion of ozone has a minimal impact on these results).

The State of Global Air 2020 Report describes in detail how the GBD project attributes mortality to air pollution. For details, please visit the State of Global Air website to learn about exposure and disease burden estimates. Of note, the country-to-country variation in mortality from air pollution is strongly affected not only by where the exposures to air pollution are highest, but also where the underlying susceptibility to air pollution is the highest, for example, in older populations or populations with higher baseline disease rates.

Figure 3 shows examples of these hypothetical cause-deleted survival curves (dashed lines) for mortality from ambient $PM_{2.5}$ in Nigeria and China. Note how in each case, the survival curve shifts slightly upward, indicative of the greater survival that would be expected in the absence of air pollution. Accordingly, in the absence of air pollution as a risk factor for death, we would expect life expectancy to increase. We use the term ΔLE to express the difference between the baseline life expectancy (e_0) and the cause-deleted counterfactual life expectancy (i.e., the life expectancy decrement caused by air pollution).

CONCLUSIONS & KEY RESOURCES

CONCLUSIONS

Air pollution is a major risk for ill health and death around the world. Because exposure to air pollution shortens life expectancy, reducing air pollution could help people live longer. In fact, the growing burden of disease from air pollution is among the major challenges facing national governments and public health officials, with far-reaching implications for national economies and human well-being. We estimate that the average human life is shortened by approximately 1.8 years due to the combined effect of ambient (outdoor) ozone pollution and fine particulate matter pollution ($PM_{2.5}$) in ambient air and in households from cooking with wood and other solid fuels. The combined impacts of these pollutant exposures are especially high in the world's lowest income countries (typically shortening a life by two to three years), while the impact on life expectancy of ambient $PM_{2.5}$ alone is highest in rapidly growing middle-income countries, such as India and China, where lifespans are shortened by ~1.5 years. These impacts on human life expectancy are quite large in comparison to other major diseases and threats to human health. The findings show that improvements in global air quality could lead to longer and healthier lives in many regions of the world.

KEY RESOURCES

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CONTRIBUTORS AND FUNDING

Health Effects Institute

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; Katherine Walker, principal scientist (*retired*); 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.

The Institute for Health Metrics and Evaluation

IHME is an independent population health research center at the University of Washington School of Medicine, Seattle. It provides the underlying air pollution and health data and other critical support for this project. Key IHME contributors include Michael Brauer, faculty; Katrin Burkart, faculty; Sarah Wozniak, post-bachelor fellow; Kate Causey, post-bachelor fellow; Charlie Ashbaugh, project officer; and Ashley Marks, research manager.

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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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