BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH, NEW DELHI

Original Application No. 249/2020

In the matter of:

Santosh Gupta… … … … … … … Applicant

Versus

Ministry of Environment, Forest and Climate Change & Others… … … … Respondent

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NDOH: 05.11.2020

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SHIBANI GHOSH, Advocate, *Amicus*

04.11.2020

New Delhi

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Written Submissions on behalf of the *Amicus Curiae*

It is most respectfully showeth:

1. That the latest research on exposure to air pollution and risk of death from COVID-19 infection suggests that 'air pollution is an important cofactor increasing the risk of mortality from COVID-19'. The study also states that this finding should provide 'extra motivation for combining ambitious policies to reduce air pollution with measures to control the transmission of COVID-19'. The study estimates that particulate air pollution contributed ~15% to COVID-19 mortality worldwide.

   Copy of study 'A. Pozzer *et al*, 'Regional and global contributions of air pollution to risk of death from COVID-19' *Cardiovascular Research*, doi:10.1093/cvr/cvaa288' is annexed herewith and marked as **Annexure A**.

   Two Indian media pieces on the study: i) Aparna Banerjea, 'After studies, it's clear that air pollution contributes to Covid mortality:

ICMR' *Mint*, 27 October 2020; and ii) Sandipan Talukdar, 'Air Pollution May Account for 15% of COVID-19 Deaths Worldwide, Says New Study', *NewsClick*, 28 October 2020 are also annexed as **Annexure B (colly)**.

2. That keeping in view the impact of firecrackers on COVID-19 patients as well as persons with respiratory illnesses, the Government of Rajasthan has banned the use of firecrackers from the date of the order till 31 December 2020.

Copy of order dated 2 November 2020 and related Gazette Notification dated 03 November 2020 is annexed herewith and marked as **Annexure C (colly)**.

3. That the Government of Odisha 'considering the potentially harmful consequence of burning of crackers amidst COVID-19 pandemic situation and approaching winter' has prohibited the sale and use of firecrackers from 10 to 30 November 2020.

Copy of order dated 3 November 2020 is annexed herewith and marked as **Annexure D (page ___ to ___)**.

4. That the Central Pollution Control Board in its report titled 'Report on Ambient Noise Levels & Ambient Air Quality during Deepawali Festival 2018 & 2019' has made the following pertinent conclusion:

> 'Barium exceeded AAQCVs (4.0 µg/m3) in Delhi, Kolkata, Agra, Bhopal and Lucknow. This year with the promotion of Green Cracker and new formulation crackers

increase in Barium concentration was not expected.' (emphasis added)
(AAQCVs - Ambient Air Quality Criteria Values)

Copy of CPCB's report is annexed herewith and marked as **Annexure E**.

5. That the 'State of Global Air 2020' report released by the Health Effects Institute and the Institute for Health Metrics and Evaluation's Global Burden of Disease Project estimates that India witnessed 980,000 deaths attributable to PM2.5. The report also states the following with regard to connections between air pollution and COVID-19:

- Long-term exposure to air pollution can cause many of the health conditions associated with increased vulnerability to COVID-19, such as diabetes, cardiovascular disease, and chronic obstructive lung disease.
- Exposure to air pollution has been shown to affect the body's immune defense, increasing susceptibility to respiratory and other infections.
- Studies of the SARS-CoV-1 outbreak in 2002–2004 reported an association between higher air pollution levels and higher than expected death rates for that disease.
- A few early studies of COVID-19 similarly appear to suggest that areas with higher air pollution levels experience higher rates of infection or of case fatalities.

Copy of the 'State of Global Air 2020' report and a related factsheet are annexed herewith and marked as **Annexure F (colly)**.

An article on the Report: 'India recorded highest infant deaths due to air pollution in 2019, shows study', *Scroll.in*, 21 October 2020 is annexed herewith and marked as **Annexure G**.

6. That various government officials and doctors have made statements which link air pollution to increase in risk of COVID-19 infection.

Some of the relevant media pieces referring to these statements have been annexed herewith and marked as **Annexure H (colly).**

7. That the Hon'ble Supreme Court in *Arjun Gopal and Others v Union of India and Others* (2019) 13 SCC 523 has observed that in environment law, precautionary principle is one of the well-recognized principles which is followed to save the environment. The Hon'ble Court further stated that very word 'precautionary' indicates that such measure is taken by way of precaution which can be resorted to even in the absence of definite studies. On the issue of conflict of fundamental rights, the Hon'ble Court has observed that Article 21 is given supremacy over the right to carry on business enshrined in Article 19(1)(g). Right to health is recognized as a facet of Article 21 of the Constitution, and therefore, as a fundamental right, assumes greater importance. The Hon'ble Court has further observed that Article 25 is subject to Article 21 and is a particular religious practice is threatening the health and lives of people, such practice is not entitled to protection under Article 25.

8. That it is submitted that the Hon'ble Court in the aforementioned judgment in Para 48.1 (page 555) directed that only crackers mentioned in Suggestions II and III would be permitted to be

manufactured and sold and that the production and manufacture of all other forms of crackers were banned. For sake of convenience, the suggestions are reproduced herein below:

> "II. Use of Reduced Emission firecrackers (Improved crackers) - (a) Avoidance of use of ash as desiccant or filler materials in crackers for reduction in particulate mater by 15-20%. These can be implemented subject to approval by PESO, and (b) usage of charcoal meeting specifications of explosives and pyrotechnics as prescribed by PESO.
>
> III. Use of Reduced Emission firecrackers (Green crackers: Safe water and air sprinklers (SWAS) – Low emission sound and light emitting functional crackers with PM reduction by 30-35% and significant reduction in NOx and SO2 due to in-situ water generation as dust suppressant and low cost due to usage of low cost oxidants. These can be implemented subject to approval by PESO."

9. That in the last hearing held in that matter on 3 March 2020, the Hon'ble Supreme Court while dealing with allegations of violation of its orders gave the following direction:

> "The Joint Director, Central Bureau of Investigation (CBI) at Chennai, is directed to make a detailed investigation regarding the alleged violation of this Court's earlier orders by the aforesaid respondents-manufacturers by using the ingredients which have been banned and by mislabeling their products contrary to the directions of this Court as stated in the instant application."

Copy of order dated 3 March 2020 of the Hon'ble Supreme Court in *Arjun Gopal v Union of India* is annexed herewith and marked as **Annexure I**.

10. That it is submitted that green crackers *per se* though generate less pollution nevertheless they are a major contributor towards pollution as reflected in the CPCB report referred to above. Consequently, the only alternative left under the circumstances is to take stern and surgical step to check the proliferation of all kinds of crackers in the interest of general public health and life particularly during this phase of severe COVID-19 pandemic.

11. That in view of the above, the Hon'ble Tribunal may consider issuing the following directions:

- Suspend all licenses issued by any authority for sale of all kinds of firecrackers
- Any person found selling any kind of firecrackers would impliedly be an abettor to environmental pollution and liable for environmental damage, and it is suggested that an amount of not less than Rupees one lakh may be imposed on such person as a fine (please refer to Section 15, Environment (Protection) Act 1986)
- In case of individuals found using or allowing the use of any kind of firecrackers, the Hon'ble Tribunal may consider imposing a fine of a sum not less than of Rupees ten thousand.

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04.11.2020
New Delhi

ANNEXURE A 10

ESC European Society of Cardiology

Cardiovascular Research
doi:10.1093/cvr/cvaa288

Regional and global contributions of air pollution to risk of death from COVID-19

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Time for primary review: 6 days

Aims The risk of mortality from the coronavirus disease that emerged in 2019 (COVID-19) is increased by comorbidity from cardiovascular and pulmonary diseases. Air pollution also causes excess mortality from these conditions. Analysis of the first severe acute respiratory syndrome coronavirus (SARS-CoV-1) outcomes in 2003, and preliminary investigations of those for SARS-CoV-2 since 2019, provide evidence that the incidence and severity are related to ambient air pollution. We estimated the fraction of COVID-19 mortality that is attributable to the long-term exposure to ambient fine particulate air pollution.

Methods and results We characterized global exposure to fine particulates based on satellite data, and calculated the anthropogenic fraction with an atmospheric chemistry model. The degree to which air pollution influences COVID-19 mortality was derived from epidemiological data in the USA and China. We estimate that particulate air pollution contributed ~15% (95% confidence interval 7–33%) to COVID-19 mortality worldwide, 27% (13 – 46%) in East Asia, 19% (8–41%) in Europe, and 17% (6–39%) in North America. Globally, ~50–60% of the attributable, anthropogenic fraction is related to fossil fuel use, up to 70–80% in Europe, West Asia, and North America.

Conclusion Our results suggest that air pollution is an important cofactor increasing the risk of mortality from COVID-19. This provides extra motivation for combining ambitious policies to reduce air pollution with measures to control the transmission of COVID-19.

Keywords COVID-19 • Air pollution • Fine particulate matter • comorbidity • mortality

1. Introduction

Poor air quality, especially from fine particulate matter with a diameter <2.5 μm ($PM_{2.5}$), is one of the leading risk factors, and responsible for many excess deaths.[1,2] The global loss of life expectancy from long-term exposure to ambient air pollution exceeds that of infectious diseases, and is comparable with that of tobacco smoking.[1–3] The mortality from COVID-19 depends on comorbidities, including conditions that increase cardiovascular risks such as arterial hypertension, diabetes mellitus, obesity, and established coronary artery disease, as well as respiratory conditions such as asthma and chronic obstructive pulmonary disease (COPD), being similar to those that are influenced by air pollution.[3–6] The risk of death is strongly related to age, being particularly high in those aged >70. It is also higher amongst males, economically disadvantaged populations, and in some ethnic groups. In assessing the relationships between exposures to risk factors and outcomes, potential confounders therefore need to be accounted for in the design of studies and in data analysis. These include the age distribution of the population, availability of hospital beds (and intensive care capacity), and the proportion of the population living in poverty.

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A recent study, using an ecological design, assessed how environmental influences modify the severity of COVID-19 outcomes in the USA.[7] Potential confounders were identified, and statistical models were used to relate long-term exposure to ambient $PM_{2.5}$ to COVID-19 deaths. The computed mortality rate ratios (MRRs) express the relative increase in COVID-19 deaths for each microgram per cubic meter increment of $PM_{2.5}$ in ambient air. The $PM_{2.5}$ data were derived from satellite and ground-based measurements combined with atmospheric modelling,[8] and the confounders were determined from county-level censuses, homeland infrastructure, and meteorological data. Here we test the assumption that the derived MRRs are representative for the populations of other countries (China) and consider the global impact. In the present study, we apply the MRRs to estimate the excess mortality, i.e. the fraction of COVID-19 deaths that could be avoided if the population were exposed to lower counterfactual air pollution levels without fossil fuel-related and other anthropogenic emissions. We emphasize that our results are provisional, based on epidemiological data collected up to the third week of June 2020, and a comprehensive evaluation will need to follow after the COVID-19 pandemic.

1.1 SARS and air pollution

In the early 2000s, the first severe acute respiratory syndrome coronavirus (SARS-CoV-1) appeared in China (Guangdong Province). The virus was zoonotic, as it originally developed in bats.[9] The World Health Organization (WHO) reported that it resulted in a SARS epidemic with >8000 cases in 26 countries, mostly in south-east Asia and in Canada.[8] The disease emerged in November 2002 and was contained in July 2003. SARS-CoV-1 and SARS-CoV-2 have many similarities, as their RNA genomes are closely related and the viruses enter the host cells by binding to the same entry receptor angiotensin-converting enzyme 2 (ACE2).[10–12] About 2–14 days after infection, the systemic symptoms of both diseases are alike, and a similar fraction of patients develops severe symptoms with a mortality rate that increases strongly with advanced age.[13–16] In China alone, >5000 cases of SARS-CoV-1 were reported, leading to nearly 350 fatalities. Since the exposure to ambient air pollution is associated with respiratory and cardiovascular diseases, it was hypothesized that health outcomes of SARS were aggravated by poor air quality. A study in 2003 corroborated that in parts of China with moderate levels of air pollution, the risk of dying from the disease was >80% higher compared with areas with relatively clean air, while in heavily polluted regions the risk was twice as high.[17]

1.2 COVID-19 and air pollution

In 2019, the related second virus strain appeared (SARS-CoV-2) in China (Hubei Province), which also developed in bats,[4] causing COVID-19, which grew from an epidemic into a pandemic in the early part of 2020. A Chinese analysis indicated that the risk of symptomatic infection typically increases by ~4% for each year of age between 30 and 60, and that the lethality is highest for individuals >60 years.[15] COVID-19 is associated with a combination of respiratory and cardiovascular complications, which may comprise myocardial infarction, heart failure, venous thrombo-embolisms, and increases in biomarkers,[18] which are also found in connection with high levels of air pollutants.[5] In a recent analysis of 5700 patients hospitalized with COVID-19 in the New York City area, the most common comorbidities were hypertension (57%), obesity (42%), and diabetes (34%),[19] representing cardiovascular risk factors that are also observed in relation to elevated $PM_{2.5}$ concentrations,[5,20] suggesting additive or synergistic effects on the cardiovascular system. In addition, advanced age is a strong risk factor for cardiovascular disease, and the effects on immune function may be equally important for COVID-19 susceptibility. The age dependency coincides with that of excess mortality from $PM_{2.5}$.[3,15] The COVID-19 mortality rate has been estimated to be ~4% in symptomatic cases, in part because pre-existing conditions such as cardiovascular and respiratory disorders increase the risk.[21]

Considering the cardiovascular and respiratory health impacts of air pollution, the relationship to COVID-19 mortality is not unexpected. Preliminary studies addressed the influence of air pollution on COVID-19 in different regions. In China, the incidence of COVID-19 was found to be significantly enhanced by $PM_{2.5}$,[22] while a correlation between ambient $PM_{2.5}$ and the mortality rate was also established.[23] In Italy, it was found that the high pollution concentrations that are typical for the Po valley, especially in the Lombardy region of which Milan is the capital, were associated with a high mortality rate.[24] As mentioned above, in the USA the severity of COVID-19 outcomes was linked to $PM_{2.5}$ exposure, making use of Medicare data for >60 million people and nationwide air quality measurements.[7] Data were collected for 98% of the population in 3087 of the total number of 3142 counties, of which ~42% had reported COVID-19 deaths up to the third week of April 2020. The death counts relied on data from the Coronavirus Resource Center of the Johns Hopkins University.[25] The study accounted for 20 potential confounding factors including population size, age distribution, population density, time period since the beginning of the outbreak, time elapsed since the home confinements, hospital beds, number of individuals tested, meteorological conditions, and socioeconomic and risk factors such as obesity and smoking.[7] The results showed significant overlap between the causes of death in COVID-19 patients and those that lead to mortality from $PM_{2.5}$. The MRR, i.e. the percentage increase of COVID-19 mortality risk per $\mu g/m^3$ increase of exposure to $PM_{2.5}$, was found to be 8%, with a 95% confidence interval of 2–15%.[7] The calculations are continually updated based on the most recent data (up to 18 June at the time of writing), showing no significant changes in the MRR in the preceding 4 months.

2. Methods

2.1 Global model and data

We applied a global atmospheric chemistry general circulation model (EMAC) which comprehensively simulates atmospheric chemical and meteorological processes and interactions with the oceans and the biosphere, in the same set-up as in recent studies on climate change, air pollution, and public health.[3,26] In addition to the standard simulation, we performed two sensitivity calculations: (i) with fossil fuel-related emissions removed and (ii) with all anthropogenic emissions removed. The model results were used to estimate the ratio of fine particulates in simulation (i) and (ii) and the standard simulation. The annual atmospheric near-surface $PM_{2.5}$ concentrations were taken from model-integrated satellite data, for the year 2019.[8,27] The horizontal resolution is 0.01 by 0.01 degrees, corresponding to a grid size of ~1 km × 1 km. The near-surface concentrations of $PM_{2.5}$ for fossil fuel-related and all anthropogenic emissions are estimated by scaling this data set to the ratios (i) and (ii) obtained with the EMAC model simulations.

2.2 Relative risk

To estimate the relative risk (RR or hazard ratio) of excess COVID-19 mortality from the long-term exposure to air pollution, we used the exposure–response function of the WHO,[28]

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$$RR = \left(\frac{X+1}{X_0+1}\right)^{\beta},$$

RR is a function of the concentration of air pollutants, which specifies annual average exposure dependent on location (grid cell) derived from the data mentioned above. X is the pollutant ($PM_{2.5}$) and X_0 is the pollutant threshold concentration below which exposure does not have implications for public health. Both β and X_0 are estimated by fitting to data from the literature with a least square method (*Figure 1*). We adopted the threshold $PM_{2.5}$ concentration (X_0) from Burnett *et al.*[2] (i.e. < 2.4 $\mu g/m^3$ $PM_{2.5}$), forcing the curve fitting into this range. We tested different exposure–response functions, e.g. of Burnett *et al.*,[2] and values for X_0, and find that the results are not sensitive to these assumptions.

Because the COVID-19 mortality rate ratio due to air pollution, based on data in the USA alone,[7] may not represent countries with very high fine particle concentrations (associated with a lack of observations in such regions), we investigated the effect of including data from the enhanced mortality rate derived for the Chinese SARS epidemic in 2003.[17] We make the assumption that SARS and COVID-19 mortality are similarly affected by long-term exposure to air pollution. Since the analysis for SARS was based on the Chinese Air Pollution Index (API), we converted the API to $PM_{2.5}$ concentrations following empirical relationships from the literature.[29,30] The large uncertainty range in the fitting function to a large degree derives from those in these relationships (black squares and ranges in *Figure 1*). In spite of uncertainties, the curves for the USA only and those that include the Chinese results are almost identical, providing confidence in the function derived for conditions in the USA only.

2.3 Attributable fraction

We calculated RR globally using $PM_{2.5}$ distributions calculated under the standard scenario. The attributable fraction (AF) of COVID-19 mortality to air pollution is calculated from the RR by AF = 1 – 1/RR. From the globally distributed, gridded AFs, we aggregated into regional and country-level AFs, weighted according to the population density, in order to account for the varying population distributions within regions and countries. The population data for the year 2020 were obtained from the NASA Socioeconomic Data and Applications Center (SEDAC), hosted by the Columbia University Center for International Earth Science Information Network (CIESIN).[31] Our definition of AF does not imply a direct cause–effect relationship between air pollution and COVID-19 mortality (although it is possible). Instead it refers to relationships between the two, direct and indirect, i.e. by aggravating comorbidities that could lead to fatal health outcomes of the virus infection.

3. Results

3.1 Attribution of COVID-19 mortality

To estimate the AF from exposure to ambient $PM_{2.5}$ to COVID-19 mortality, we used the epidemiological data from the USA (red curve in *Figure 1*). The chronic exposure to $PM_{2.5}$ in the years prior to the COVID-19 outbreak was estimated on the basis of satellite observations over the year 2019. The anthropogenic and fossil fuel-related fractions were calculated with the global EMAC model. Here we focus on anthropogenic and fossil fuel-related $PM_{2.5}$ to determine the impact of potentially avoidable air pollution on COVID-19 mortality. *Figure 2* and *Table 1* present the average fractions of COVID-19 mortality attributed to the exposure to $PM_{2.5}$ pollution, both globally and regionally. *Table S1* (available as Supplementary material online) lists the results for all countries. To account for the different population distributions within countries, e.g. between rural and urban areas, the averages have been weighted accordingly.

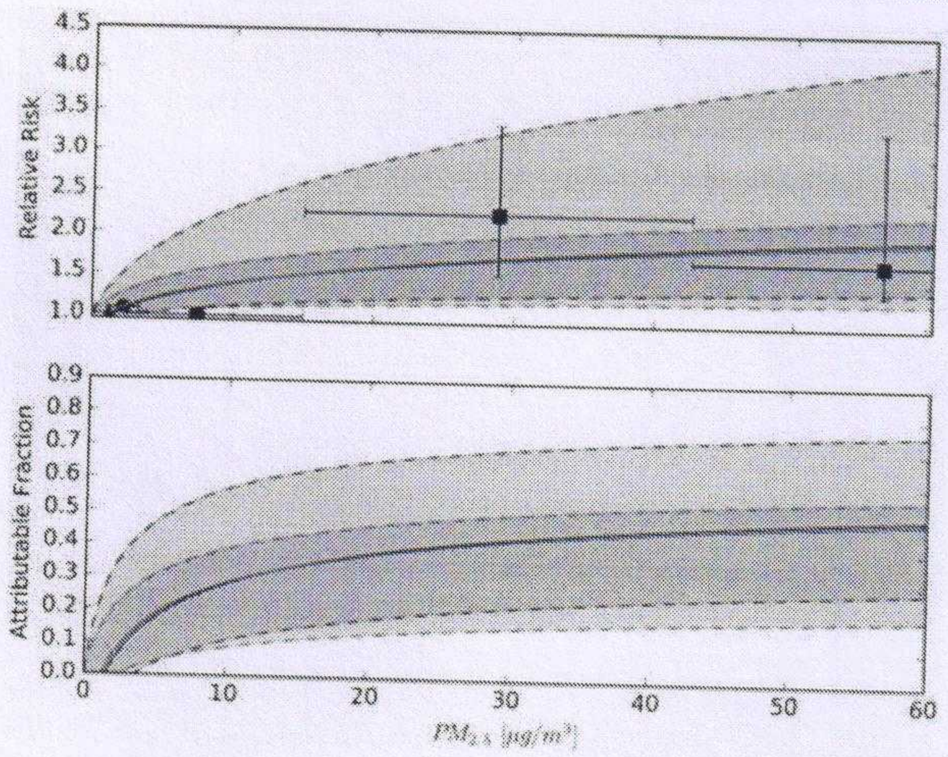


Figure 1 Exposure-response dependencies, based on a log-normal relationship[28]. The relative risk (or hazard ratio), from which the attributable fraction has been derived, is based on mortality rate ratios attributed to air pollution in the COVID-19 pandemic[7] and the SARS epidemic[17], indicated by the black bullet and squares, respectively. The triangle represents the threshold concentration below which $PM_{2.5}$does not have health implications[2]. The red curves depict the function fitted to the data from COVID-19 in the USA only[7], plus the threshold[2] (triangle and bullet). The blue curves depict the function fitted to all data[2,7,17]. The colored ranges show the 95% confidence intervals, which are wider after including the SARS-related results (blue), mostly due to uncertainty from converting Chinese API's into $PM_{2.5}$concentrations (black squares).

In regions with strict air quality standards and relatively low levels of air pollution, such as Australia, the attributable fraction by human-made air pollution to COVID-19 mortality is found to be a few percent only. Relatively high fractions occur in parts of east Asia (~35%), central Europe (~25%), and eastern USA (~25%). The country-level contribution to COVID-19 that we find for China, i.e. 27% (95% confidence interval 13 – 47%), agrees well with that found for the SARS epidemic in 2003.[17] The largest country-average fractions are found in the Czech Republic, Poland, China, North Korea, Slovakia, Austria, Belarus, and Germany, all above 25% (Supplementary material, *Table S1*). Globally, anthropogenic air pollution contributes ~15% (7 – 33%) to COVID-19 mortality, which could have been largely prevented, for example by adopting the air quality regulations applied in Australia (annual $PM_{2.5}$ limit of 8 $\mu g/m^3$). The global mean contribution of fossil fuel use to the anthropogenic fraction is ~56%, being highest in North America (83%), West Asia (75%), and Europe (68%) (*Table 1*).

4. Discussion

4.1 Pathophysiological aspects

Both the air pollutant $PM_{2.5}$ and the SARS-CoV-2 virus enter the lungs via the bronchial system (portal organ), with potential systemic health impacts through the blood circulation. Both $PM_{2.5}$ and SARS-CoV-2 cause vascular endothelial dysfunction, oxidative stress, inflammatory responses, thrombosis, and an increase in immune cells.[32–36] The SARS-CoV-2 infection facilitates the induction of endothelial inflammation in

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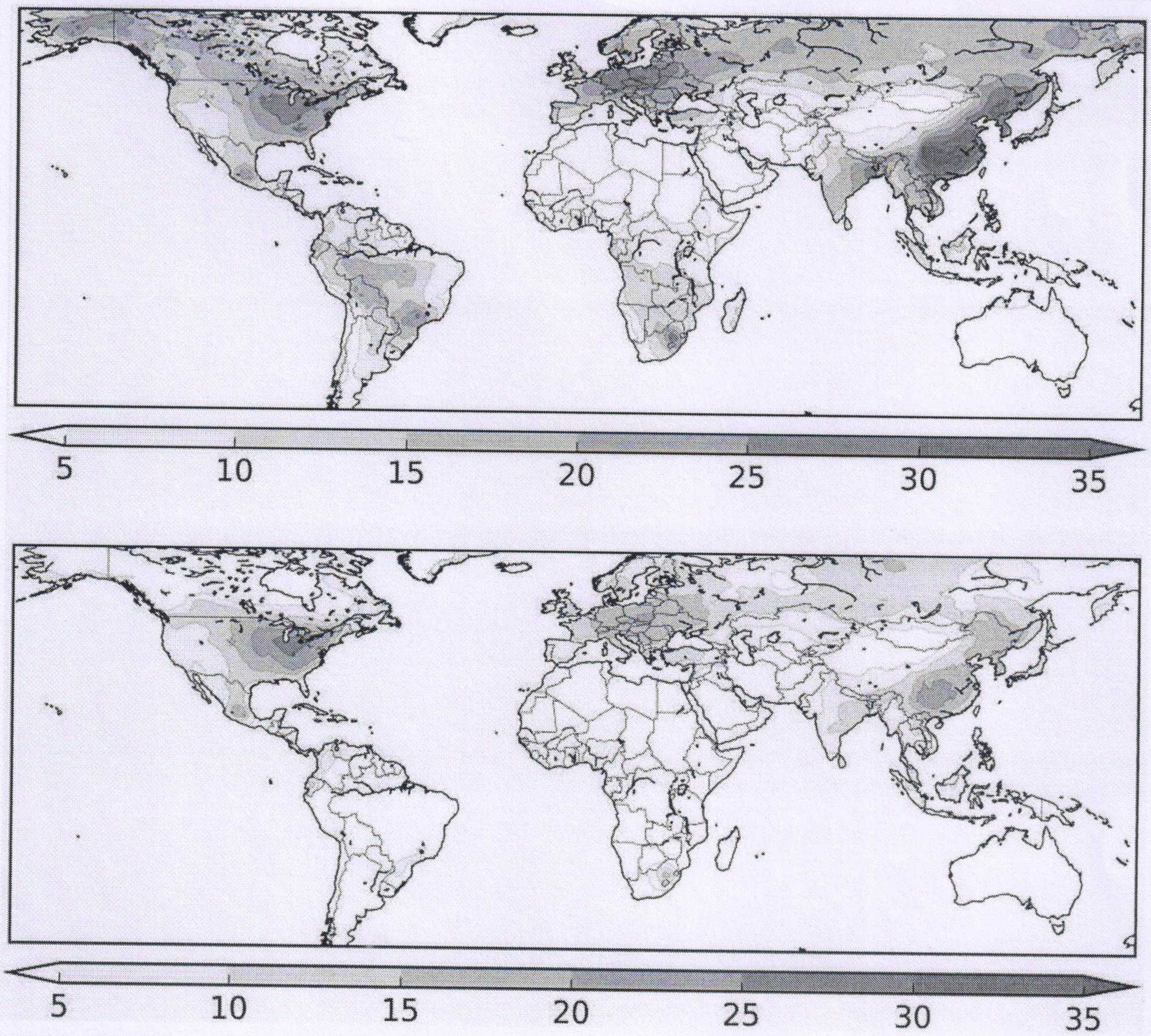


Figure 2 Estimated percentages of COVID-19 mortality attributed to air pollution from all anthropogenic sources (top), and from fossil fuel use only (bottom). The regions with high attributable fractions coincide with high levels of air pollution. The mapped results account for population density, thus reflecting population weighted exposure to $PM_{2.5}$.

several organs as a direct consequence of viral cytotoxic effects and the host inflammatory response, which can aggravate pre-existing chronic respiratory and vascular (coronary) dysfunction, and cause lung injury by alveolar damage, as well as stroke and myocardial infarction by inducing plaque rupture.[37] Potential common pathophysiological mechanisms of increased risk thus relate to endothelial injury[33,38] and pathways that regulate immune function.[39,40] Further, there are strong indications of increased susceptibility to viral infections from exposure to air pollution.[41–46]

Lung injuries, including the life-threatening acute respiratory distress syndrome and respiratory failure, as well as acute coronary syndrome, arrhythmia, myocarditis, and heart failure, were shown to be clinically dominant, leading to critical complications of COVID-19.[47,48] Recent studies in China, the USA, as well as Europe indicate that patients with cardiovascular risk factors or established cardiovascular disease and other comorbid conditions are predisposed to myocardial injury during the course of COVID-19.[19,46,49–52] From the available information, it thus follows that air pollution-induced inflammation leads to greater vulnerability and less resiliency, and the pre-conditions increase the host vulnerability. Air pollution causes adverse events through myocardial infarction and stroke, and it is an additional factor capable of increasing blood pressure, while there is emerging evidence for a link with type 2 diabetes and a possible contribution to obesity and enhanced insulin resistance.[36] Bronchopulmonary and cardiovascular pre-conditions, including hypertension, diabetes, coronary artery disease, cardiomyopathy, asthma, COPD, and acute lower respiratory illness, all negatively influenced by air pollution, lead to a substantially higher mortality risk in COVID-19. Furthermore, it seems likely that fine particulates prolong the atmospheric lifetime of infectious viruses, thus favouring transmission.[53] It is possible that future research will reveal additional pathways that mediate the relationship between air pollution and the risk of death from COVID-19.

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Table 1 Regional percentages of COVID-19 mortality attributed to fossil fuel-related and all anthropogenic sources of air pollution

Region	Population (million)	COVID-19 mortality fraction attributed to air pollution (%)	
		Fossil fuel-related emissions	All anthropogenic emissions
Europe	628	13 (6–33)	19 (8–41)
Africa	1345	2 (1–19)	7 (3–25)
West Asia	627	6 (3–25)	8 (4–27)
South Asia	2565	7 (3–22)	15 (8–31)
East Asia	1685	15 (8–32)	27 (13–46)
North America	525	14 (6–36)	17 (6–39)
South America	547	3 (1–23)	9 (4–30)
Oceania	28	1 (0–20)	3 (1–23)
World	7950	8 (4–25)	15 (7–33)

The 95% confidence levels are given in parentheses.

4.2 Limitations

Our results indicate that the long-term exposure to high levels of fine particulate matter is a significant cofactor that influences the severity of COVID-19 outcomes. Since $PM_{2.5}$ in China and the USA, from which epidemiological data have been used, is dominated by anthropogenic sources that are potentially preventable, we focus our analysis on this fraction of $PM_{2.5}$. The good agreement of our results for the USA and China is in line with recent studies, showing that the association between air pollution and excess mortality is valid for many different countries.[2,55] Nevertheless, the calculations of RRs (hazard ratios) and the AF to mortality rely on the use of data from an ecological study design that has limitations, even though 19 county-level variables and one state-level variable, some of which are more important than air pollution, were considered as potential confounders in the analysis—and the $PM_{2.5}$ exposure data have been extensively cross-validated.[7] However, we acknowledge that residual confounding cannot be excluded. While cross-sectional ecological studies do not allow conclusions about cause–effect relationships, the biological mechanisms of air pollution-related disorders, acting as comorbidities in COVID-19, are well documented.[56,57] Recent studies in England and The Netherlands corroborate the positive relationships between air pollution and the number of COVID-19 cases, hospital admissions, and mortality.[58–60] The reported MRRs for $PM_{2.5}$ range from 1–7% to 13–21% (we applied 2–15%), which confirms the significant role of air pollution but emphasizes the large uncertainty ranges. Furthermore, our approach is likely to realistically approximate the contribution of fossil fuels and other anthropogenic sources to the total excess deaths through long-term ambient $PM_{2.5}$ air pollution exposure.

We reiterate that the data used for China are associated with substantial uncertainty, and underly the assumption that comorbidity and mortality from air pollution in COVID-19 are the same as in SARS. Nonetheless, using these data does not change the results, providing confidence in the robustness of our findings. We emphasize that the data relevant to the present study are from upper-middle and high-income countries, and the representativeness of our results for low-income countries may be limited, and uncertainties are likely to exceed the 95% confidence intervals. It is expected that in countries with high levels of aeolian dust, e.g. in Africa and West Asia, $PM_{2.5}$ pollution is also a cofactor but with less contribution from human activities. Household air pollution is also likely to be important, being of particular relevance in low-income countries.[61] It will be critical to collect epidemiological evidence from many regions with different socio-economic and environmental conditions, to support analyses of the COVID-19 pandemic and investigate the role of environmental factors. The uncertainty ranges that accompany our results are considerable but, taking into account the biological plausibility of the relationship and the strong evidence of the impact of air pollution on conditions that are known to increase COVID-19 mortality, they can nevertheless inform policy decisions.

4.3 Short- and long-term health impacts

A new, though preliminary, finding of the present study is that a significant fraction of worldwide COVID-19 mortality is attributable to anthropogenic air pollution, of which ~50 – 60% is related to fossil fuel use (~70 – 80% in Europe, West Asia, and North America). This represents potentially avoidable, excess mortality. The links between economic activity, traffic, energy use, and public health have been illustrated by the strong reduction of air pollution in many locations during the lockdown measures.[62,63] There is ample evidence for a relationship between short-term exposure to $PM_{2.5}$ and adverse health effects, including excess mortality from cardiovascular and respiratory diseases.[55] While it is in principle possible to disentangle the acute from the chronic outcomes from short- and long-term exposure to air pollution,[64] at this stage it is difficult to make that distinction for $PM_{2.5}$-induced comorbidity and mortality from COVID-19. Generally, short-term associations between air pollution and mortality are substantially less than those from long-term exposure, due to the more persistent, cumulative effects from the latter.[65] By relating air pollution anomalies to short-term health outcomes during the COVID-19-induced societal lockdown, it was found that in China alone >4600 excess deaths may have been avoided.[62] This can be viewed as a health co-benefit from the containment measures, which may reduce air pollution-induced COVID-19 mortality. Such benefits could also be achieved after the COVID-19 lockdown. Both perspectives of air pollution during the pandemic underscore the important role of fossil fuel-related and other anthropogenic emissions.

4.3 Future directions

Our results suggest the potential for substantial benefits from reducing air pollution exposure even at relatively low $PM_{2.5}$ levels. Refinement of the exposure–response relationship and reducing uncertainties will require additional data analyses, including from large cohort studies as the COVID-19 pandemic evolves, but may appear too late to guide

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decision-making. A lesson from our environmental perspective of the COVID-19 pandemic is that the quest for effective policies to reduce anthropogenic emissions, which cause both air pollution and climate change, needs to be accelerated. The pandemic ends with the vaccination of the population or with herd immunity through extensive infection of the population. However, there are no vaccines against poor air quality and climate change. The remedy is to mitigate emissions. The transition to a green economy with clean, renewable energy sources will further both environmental and public health locally through improved air quality and globally by limiting climate change.

Supplementary material

Supplementary material is available at *Cardiovascular Reseach* online.

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Conflict of interest: none declared.

Data availability

The data underlying this article will be shared upon reasonable request to the corresponding author.

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Translational perspective

COVID-19 infections and air pollution cause excess mortality from cardiovascular and pulmonary diseases. We estimated the fraction of COVID-19 mortality attributable to the long-term exposure to ambient fine particulate air pollution ($PM_{2.5}$). Global exposure to $PM_{2.5}$ was characterized based on satellite data, and the anthropogenic fraction was calculated with an atmospheric chemistry model. $PM_{2.5}$ contributed ~15% to COVID-19 mortality worldwide, 27% in East Asia, 19% in Europe, and 17% in North America. Globally ~50–60% of the attributable, anthropogenic fraction is related to fossil fuel use, and 70–80% in Europe/West Asia/North America, indicating the potential for substantial health benefits from reducing air pollution exposure.

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ANNEXURE B (colly)
17

After studies, it's clear that air pollution contributes to Covid mortality: ICMR

Mint 27 October 2020, Edited By Aparna Banerjea

- According to a study, scientists have estimated that about 15% of deaths worldwide from COVID-19 could be attributed to long-term exposure to air pollution
- Furthering on the development of the Covid-19 vaccines in India and its distribution, Dr Bhargava informed that three vaccine candidates are in different stages of clinical testing

Amid coronavirus pandemic and the onset of winters in the country, the Indian Council of Medical Research (ICMR) on Tuesday said that studies have proven that long-term exposure to air pollution has been linked to an increased risk of dying from Covid-19.

"There have been studies from Europe and US, where they have looked at polluted areas and have compared mortality during lockdown and correlation with pollution. It is found that pollution is contributing to mortality in COVID, that's well established by studies," said Dr Balram Bhargava, DG ICMR, in a health ministry briefing today.

According to a study, published in Cardiovascular Research on Tuesday, scientists estimated that about 15% of deaths worldwide from COVID-19 could be attributed to long-term exposure to air pollution. In Europe the proportion was about 19%, in North America it was 17%, and in East Asia about 27%.

In their CVR paper, the researchers write that these proportions are an estimate of "the fraction of COVID-19 deaths that could be avoided if the population were exposed to lower counterfactual air pollution levels without fossil fuel-related and other anthropogenic [caused by humans] emissions".

Moreover, speaking on the Covid-19 spread in the country among youngsters, Dr Bhargava added that overall the figure in India is that below the age of 17 years, only 8% are COVID-19 positive, and below the age of 5 years, that figure would be much less.

Furthering on the development of the Covid-19 vaccines in India and its distribution as soon as it's available, Dr Bhargava informed that three vaccine candidates in India are in different stages of clinical testing.

"Covaxin has got approval for phase III trials, Cadila also progressing with phase-II trials & Serum is completing phase 2b trial and has an ongoing trial in Brazil, South Africa and the US," he added.

Echoing the concern of availability and distribution in the country, V K Paul, Niti Aayog member, said, "We've requested state governments to wait for overall picture to become clear and to take a national approach towards engaging companies & deciding the criteria for vaccine. In order to deliver the vaccine to priority groups, there's no problems in terms of resources."

Meanwhile, air quality deteriorated in the national capital with the rise of pollutants in the atmosphere and overall Delhi's Air Quality Index (AQI) is in the "very poor" category, said the Delhi Pollution Control Committee data on Tuesday.

The Air Quality Index (AQI) was recorded at 346 in Rohini, 329 in RK Puram, 377 in Anand Vihar, and 363 in Mundka, all four in the 'very poor' category, as per Central Pollution Control Board (CPCB) data.

In an attempt to curb the increasing air pollution in the national capital, the Delhi government recently launched the 'Red Light On, Gaadi Off' campaign as part of its 'Yuddh Pradushan Ke Viruddh' (War Against Pollution) initiative.

Along with this, Delhi Environment Minister Gopal Rai had also announced the launch of a campaign starting on Monday to include the citizens of the capital in raising awareness on air pollution.

Source: https://www.livemint.com/news/india/after-studies-it-s-clear-that-air-pollution-contributes-to-covid-mortality-icmr-11603799525870.html; accessed on 3 November 2020

Air Pollution May Account for 15% of COVID-19 Deaths Worldwide, Says New Study

It indicates that in the absence of pollution, people with co-morbidities could have avoided the severity caused by the viral infection.

NewsClick, Sandipan Talukdar, 28 October 2020

The poor quality of air has long been a major medical concern, with a wide range clinical manifestations starting from increased hospital admission to increased risk of premature deaths.

On October 27, a new research relating air pollution to pandemic was published in the *Cardiovascular Research* (CVR) journal. COVID-19, primarily a respiratory disease at its severe form, has been speculated to worsen with poor air quality. The CVR study says that air pollution could have accounted for about 15% COVID-19 deaths worldwide.

The research brings bad news for people living in cities like Delhi amid the pandemic, who have been witnessing extremely poor air quality for many years now. This year too, Delhi's air quality has been poor since the onset of autumn. The forecast says that the air will remain poor in quality till October 31.

The study also deciphered the regional variation of COVID-19 deaths due to long term exposure to air pollution. It says in Europe, the proportion of death is about 19%, while in North America it is 17% and in East Asia it is about 27%.

According to the research paper, these proportions of deaths are an estimate of "the fraction of COVID-19 deaths that could be avoided if the population were exposed to lower counterfactual air pollution levels

without fossil fuel-related and other anthropogenic [human induced] emissions."

However, the estimation does not reflect a direct cause-effect relationship between air pollution and COVID-19 deaths. Rather, it indicates the fact that in the absence of pollution, people with co-morbidities could have avoided the severity caused by the viral infection.

For their estimation, the researchers used epidemiological data available from previous studies on US and China and the SARS outbreak of 2003. They also included additional data from Italy. With this data set, the researchers compared another data set that comprises global exposure to air pollution caused by particulate matter 2.5 (particles having diameter of 2.5 microns). The PM 2.5 air pollution dataset was from the satellite data of global exposure to PM 2.5, information of ground based networks for monitoring pollution. They then developed a model to estimate the fraction of COVID-19 deaths that could be attributed to long term exposure to PM2.5. The epidemiological data was collected till June.

Prof Jos Lelieveld of Max Planck Institute of Chemistry, Mainz, Germany, and a corresponding author of the study said—"Since the numbers of deaths from COVID-19 are increasing all the time, it's not possible to give exact or final numbers of COVID-19 deaths per country that can be attributed to air pollution. However, as an example, in the UK there have been over 44,000 coronavirus deaths and we estimate that the fraction attributable to air pollution is 14%, meaning that more than 6,100 deaths could be attributed to air pollution. In the USA, more than 220,000 COVID deaths with a fraction of 18% yields about 40,000 deaths attributable to air pollution."

On the mechanism of how PM 2.5 can aggravate the respiratory disease, Prof. Thomas Munzel of Gutenberg University, Germany, said—"When

people inhale polluted air, the very small polluting particles, the PM2.5, migrate from the lungs to the blood and blood vessels, causing inflammation and severe oxidative stress, which is an imbalance between free radicals and oxidants in the body that normally repair damage to cells. This causes damage to the inner lining of arteries, the endothelium, and leads to the narrowing and stiffening of the arteries. The COVID-19 virus also enters the body via the lungs, causing similar damage to blood vessels, and it is now considered to be an endothelial disease."

"If both long-term exposure to air pollution and infection with the COVID-19 virus come together then we have an additive adverse effect on health, particularly with respect to the heart and blood vessels, which leads to greater vulnerability and less resilience to COVID-19. If you already have heart disease, then air pollution and coronavirus infection will cause trouble that can lead to heart attacks, heart failure and stroke," he further added.

The study also shows a country wide estimation of COVID-19 deaths attributable to long term air pollution exposure. According to it, Czech Republic has a share of 29%, China 26%, Germany 22%, Italy 15% and so on. New Zealand has a very low share of 1%.

Source: https://www.newsclick.in/air-pollution-account-15-per-COVID-19-deaths-worldwide-new-study; accessed on 3 November 2020

ANNEXURE C (Colly) 23

राजस्थान सरकार
गृह (ग्रुप–9) विभाग

क्रमांकः प. 2(1) गृह–9/2012 जयपुर, दिनांकः 02/11/2020.

परामर्शदात्री

वर्तमान में सम्पूर्ण भारत वर्ष में वैश्विक महामारी कोविड–19 (कोरोना वाइरस डिजीज –2019) फैली हुई है। इसी वजह से राज्य सरकार ने राजस्थान महामारी अध्यादेश, 2020 दिनांक 1 मई, 2020 को जारी किया एवं उक्त अध्यादेश की धारा 3 में अधिसूचना जारी कर कोविड–19 को सम्पूर्ण राज्य के लिए महामारी अधिसूचित किया। राज्य में कोविड–19 के रोगियों की संख्या दिन प्रतिदिन बढ रही हैं।

कोविड–19 से प्रभावित व्यक्तियों की श्वसनक्रिया प्रभावित होती है, इसलिये यह आवश्यक है कि वायुमण्डल प्रदूषण रहित हो।

राज्य सरकार के सलाहकार समूह (कोविड 19) द्वारा भी एसएमएस मेडिकल कॉलेज जयपुर के विशेषज्ञों द्वारा प्रस्तुत रिपोर्ट के आधार पर यह अवगत कराया है कि पटाखों के चलन से होने वाले वायु प्रदूषण (धुंए) से श्वसन तंत्र विशेषकर फेफड़ों में खराबी होने की संभावना होती है, प्रतिरोधक क्षमता कमजोर होती है। पटाखों के धुओं से वृद्धजन, बीमार व्यक्ति, सीओपीडी, अस्थमा, और कोविड–19 के रोगियों के पश्चातवर्ती प्रभाव विपरीत रूप से प्रभावित होते है। कमेटी ने अपनी रिपोर्ट में विभिन्न प्रकार के शोध प्रकाशनों, का हवाला भी दिया है। उक्त आधारों पर सलाहकार समूह ने दीपावली के अवसर पर आतिशबाजी का इस्तेमाल नही करने की अनुशंसा की है।

राज्य में कोविड–19 से ग्रसित व्यक्तियों के स्वास्थ्य की एवं श्वसन–रोगों से पीड़ित नागरिको के स्वास्थ्य की रक्षार्थ तुरन्त प्रभाव से दिनांक 31 दिसम्बर 2020 तक आतिशबाजी पर प्रतिबन्ध लागू किया जाना आवश्यक हो गया है।

अतः राज्य सरकार विस्फोटक अधिनियम, 1884 सपठित विस्फोटक नियम, 2008 में आतिशबाजी की अनुज्ञापत्र जारी करने के लिए प्राधिकृत अनुज्ञापन प्राधिकारी (Licencing Authority) को यह परामर्श देती है कि वे राज्य में कोविड–19 (कोरोना वाइरस डिजीज –2019) से ग्रसित व्यक्तियों के स्वास्थ्य को दृष्टिगत रखते हुए राज्य में आतिशबाजी के अस्थायी अनुज्ञापत्र जारी न करें।

इसकी कठोरता से पालना सुनिश्चित की जावें।

आज्ञा से,

(अभय कुमार)
प्रमुख शासन सचिव गृह

प्रतिलिपि निम्न को सूचनार्थ एवं पालनार्थ प्रेषित हैः–
1.महानिदेशक पुलिस, राजस्थान जयपुर।
2.महानिदेशक पुलिस (अपराध) राजस्थान जयपुर।
3.प्रमुख सचिव, माननीय मुख्यमंत्री।
4.संभागीय आयुक्त, समस्त।
5. महानिरीक्षक रेंज, समस्त।
6.पुलिस आयुक्त, जयपुर/ जोधपुर।
7. जिला मजिस्ट्रेट, समस्त।
8. जिला पुलिस अधीक्षक, समस्त।
9. निदेशक जनसम्पर्क विभाग, जयपुर।
10.रक्षित पत्रावली ।

02/11/2020
संयुक्त शासन सचिव, गृह

सत्यमेव जयते

राजस्थान राजपत्र विशेषांक	RAJASTHAN GAZETTE Extraordinary
साधिकार प्रकाशित	***Published by Authority***
कार्तिक 12, मंगलवार, शाके 1942–नवम्बर 3, 2020 *Kartika 12, Tuesday, Saka 1942–November 3, 2020*	

भाग 4 (ग)
उप–खण्ड (II)
राज्य सरकार तथा अन्य राज्य प्राधिकारियों द्वारा जारी किये गये
कानूनी आदेश तथा अधिसूचनाएं।

Home (Gr.V) Department
Notification
Jaipur, November 03, 2020

S.O.402 :-In continuation of this department's notification even number dated 03.05.2020, 12.05.2020, 21.05.2020, 27.07.2020 and 17.10.2020, in exercise of the powers conferred by section 11 of the Rajasthan Epidemic Diseases Act, 2020 (Act No. 21 of 2020), the State Government hereby authorizes all Executive Magistrates, all Police Officers not below the rank of Assistant Sub-Inspector, all officers of Municipal Corporation/ Council/Board not below the rank of Revenue Inspector, all Chief Executive Officers of Zila Parisad and all Block Development Officers, within their respective jurisdiction, to compound the offences committed under section 4 of the said Act, by violating the order or regulation prohibiting the actions specified in column 2 of the schedule given below for the amount specified against each of them in column 3 of the said schedule.

Schedule

S.No.	Offence	Amount in Rupees for which the offence is to be compounded
1	2	3
1.	Any shopkeeper selling any kind of fireworks.	Rs. 10,000/-
2.	Any person found using or allow the firing of any kind of fireworks.	Rs. 2000/-

[No.F. 9(16) Home-5/2020]

By order of the Governor,
Abhay Kumar,
Principal Secretary to the Government.

766
Government Central Press, Jaipur.

ANNEXURE D

Government of Odisha

Office of Special Relief Commissioner

No. 6218 /R&DM(DM) Date: 03-11-2020
RDM-RLF-MISC-0290-2020

ORDER

Whereas, the State is passing through a critical stage of COVID-19 pandemic;

And whereas, the winter season is approaching during which the elderly, children, persons with co-morbidities and others develop respiratory problems;

And whereas, the Deepavali and Kartika Purnima festivals are approaching and people usually burn fire crackers during such occasions;

And whereas, it is a well-known fact that burning of the fire crackers releases copious amounts of harmful chemicals, which have severe impact on the respiratory health of vulnerable groups and such pollutants can further aggravate health conditions of COVID-19 positive persons besides persons staying in home isolation;

And whereas, the Technical Expert Committee of the State Government has recommended for prohibition of burning of fire crackers to protect the vulnerable groups like elderly, children, persons with co-morbidities and others;

And whereas, considering the potentially harmful consequences of burning of crackers amidst COVID-19 pandemic situation and approaching winter, the State Government have directed to prohibit the sale and use of fire crackers from 10th to 30th of November, 2020 in public interest;

Now, therefore, in exercise of the powers conferred under section 24(I) of the Disaster Management Act, 2005 read with rule 8(1) of the Odisha Disaster Management Rules, 2010, the undersigned hereby directs that the sale and use of fire crackers shall remain prohibited in all parts of the State from 10th to 30th of November, 2020.

Any person found violating this order shall be punished under the provisions of the Disaster Management Act, 2005 and other relevant laws.

Chief Secretary, Odisha

ANNEXURE E 26

Report on Ambient Noise Levels & Ambient Air Quality during Deepawali Festival 2018 & 2019.



CENTRAL POLLUTION CONTROL BOARD
Ministry of Environment, Forest & Climate Change
Website: www.cpcb.nic.in

PART-II

Ambient Air Quality during Deepawali festival 2019

REPORT ON AMBIENT AIR QUALITY DURING DEEPAWALI FESTIVAL 2019

1.0 Background

Hon'ble Supreme Court in its order dated October 23, 2018 in the matter of Arjun Gopal and Others Versus Union of India and Others Writ Petition (Civil) No. 728 of 2015, directed as follows:

"CPCB and respective State Pollution Control Boards/Pollution Control Committees (SPCBs/PCCs) of the States and Union Territories shall carry out short –term monitoring in the cities for 14 days (commencing from 7 days prior to Deepawali and ending 7 days after Deepawali) for parameters namely Aluminium, Barium, Iron apart from the regulatory parameters against the short-term Ambient Air Quality Criteria Values (AAQCVs) proposed by CPCB with regard to bursting of firecrackers. This will help in generation of data on pollution caused by the bursting of firecrackers and would be helpful for regulation and control quantity of Aluminium, Barium and Iron used in the manufacture of firecrackers".

In compliance of above, like last year (2018) this year also CPCB conducted monitoring at seven cities namely Delhi (CPCB Head Quarter) and Agra, Bhopal, Bengaluru, Kolkata, Lucknow and Vadodara where its Regional Directorates are situated and Deepawali is widely celebrated. 15 days monitoring (20th October to 3rd November); 7 days prior (21st October to 26th October – Pre-Deepawali period); Deepawali day (27th October) and 7 days after Deepawali (28th October to 3rd November – Post-Deepawali period); was conducted by CPCB.

In addition to the NAAQS parameters (PM_{10}, $PM_{2.5}$, SO_2 and NO_2 and metals such as Pb, Ni & As in PM_{10}) and elements (Al, Ba, and Fe) used in composition of firecrackers, which may have harmful effects on inhalation, are also included in monitoring plan. Al, Ba, and Fe are monitored in $PM_{2.5}$ fraction as proposed in AAQCVs.

2.0 Monitoring locations

City wise locations covered for monitoring is presented in Table 1.

Table 1: Locations Covered in Deepawali Special Monitoring

S. No.	States	City	Name of the location	Parameters covered
01	Delhi	Delhi NCT	1) Pitampura 2) Janakpuri,	Regulatory Parameters like PM_{10}, $PM_{2.5}$, SO_2, NO_2, Metals (Pb, Ni, As in PM_{10}) and parameters related to AAQCVs (Al, Fe and Ba in $PM_{2.5}$)
02	Gujarat	Vadodara	1) Hari Nagar 2) M.S. University Campus	
03	Karnataka	Bengaluru	1) Rajarajeshwari Nagar 2) Basaveshwara Nagar	
04	Madhya Pradesh	Bhopal	1) North T.T.Nagar, 2) Nehru Nagar	
05	Uttar Pradesh	Agra	1) Taj Mahal	
		Lucknow	1) Viksh Khand, Gomt Nagar, 2) Mayur Vihar, Indira Nagar	
06	West Bengal	Kolkata	1) Kasba 2) Behala 3) North avenue	

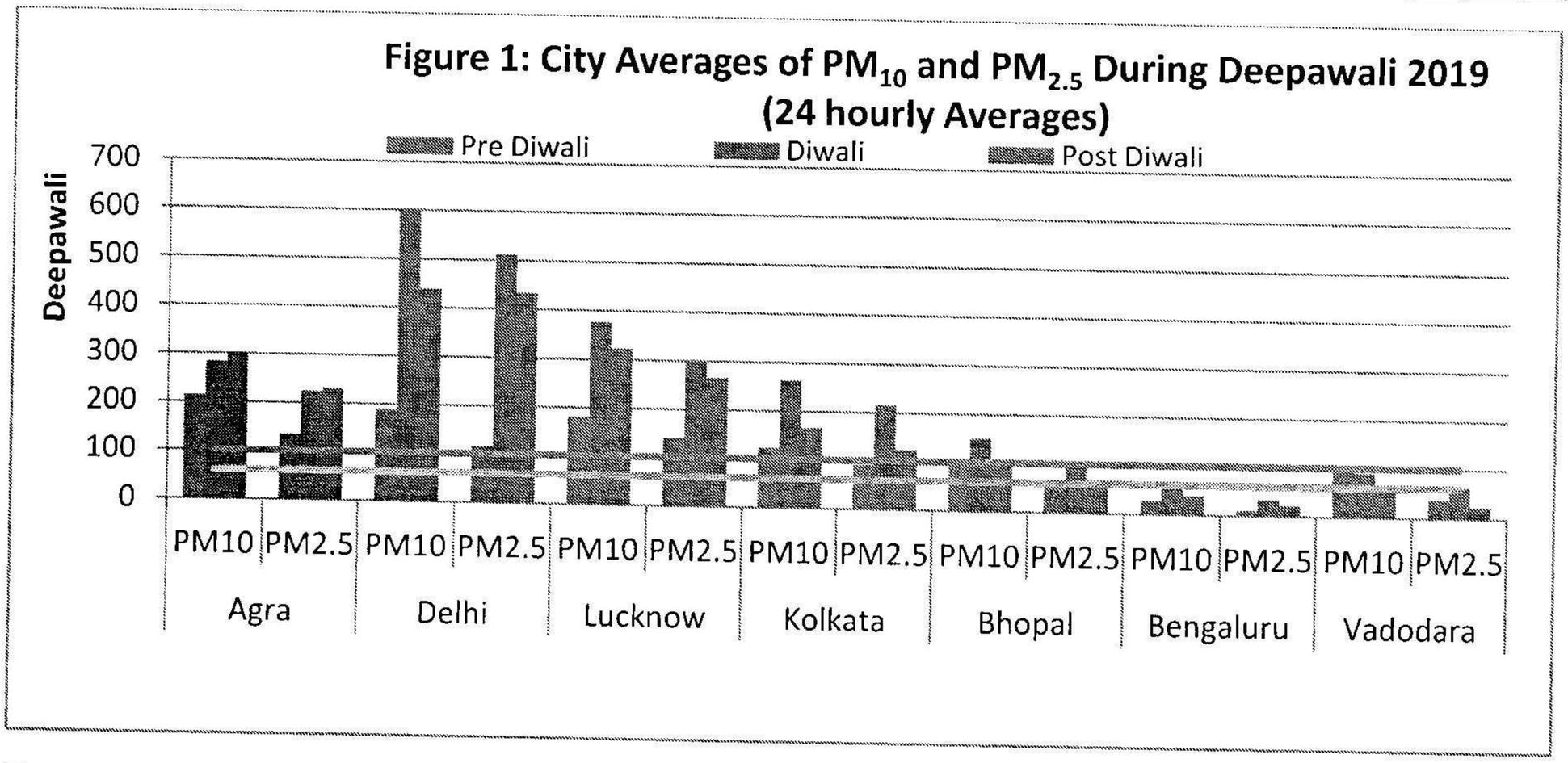
3.0 Results and Discussion

Data were analysed for Pre-Deepawali (20th October to 26th October, Deepawali (27th October and Post Deepawali period (28th October to 03rd November). Parameter-wise results are discussed as under:

3.1 NAAQS parameters (PM_{10}, $PM_{2.5}$, SO_2, NO_2 and metals (Pb, Ni & As) in PM_{10}

a) **Particulate Matter (PM_{10} and $PM_{2.5}$)**

PM_{10} and $PM_{2.5}$ data of representative stations in respective cities are averaged to assess the overall air quality of the city with respect to Particulate matter during pre-Deepawali, Deepawali day and post Deepawali is depicted in Figure 1.



From Figure 1 it may be seen that PM_{10} was above the NAAQS (National Ambient Air Quality Standard, i.e 100 $\mu g/m^3$ 24 hourly averages) in Agra, Delhi, Lucknow and Kolkata; however, $PM_{2.5}$ was above prescribed standards in all cities except Bengaluru and Vadodara on pre-Deepawali days. On Deepawali day $PM_{2.5}$ was found above 60 $\mu g/m^3$ (above 24 hourly NAAQS) in all cities except Bengaluru.

Post Deepawali Monitoring has revealed that particulates (both PM_{10} and $PM_{2.5}$) in all the cities except Agra declined. It was also evident that the northern Indian cities are behaving similarly in dispersion pattern of Deepawali effect due to changes in weather conditions and perhaps additions of transported pollution as Delhi is facing during post Deepawali days.

City-wise increase/decrease in PM_{10} and $PM_{2.5}$ on Deepawali day is presented in Table 2.

Table 2: City-wise increase in PM_{10} and $PM_{2.5}$ on Deepawali day compared to Pre-Deepawali period (in %)

	Agra	Delhi	Kolkata	Bengaluru	Bhopal	Lucknow	Vadodara
PM_{10}	33	247	112	83	59	107	-9.0
$PM_{2.5}$	68	592	137	218	57	113	64

PM_{10} was increased in all the cities except Vadodara where torrential rain falls perhaps wiped out coarser particulates. The increase in PM_{10} was recorded by 33% to 247% on 27th October 2019 (Deepawali day) compared to Pre-Deepawali period among various cities monitored. Highest increment in PM_{10} on Deepawali day was

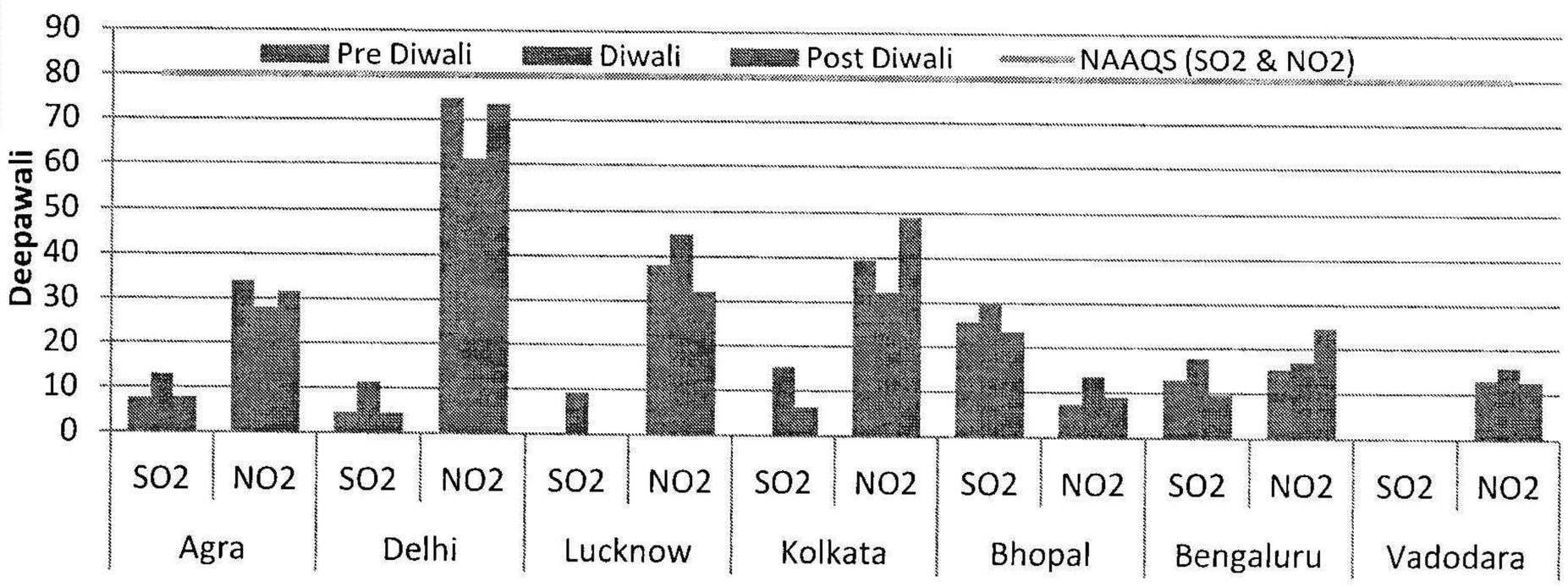
reported in Delhi (247%) followed by Kolkata (112%) and Lucknow (107%). PM_{10} in Vadodara was declined by (9%) on Deepawali day.

On Deepawali day, $PM_{2.5}$ was increased by 64 – 592% compared to Pre-Deepawali period among the various cities monitored. Highest increment was recorded in Delhi (592%), followed by Bengaluru (218%) Kolkata (137%) and Lucknow (113%). Minimum increase (57%) was reported in Bhopal this year.

b) **Sulphur di oxide (SO_2) and Nitrogen di oxide (NO_2)**

Fig 2 depicts the concentrations of criteria gaseous pollutants (SO_2 and NO_2) at all cities. SO_2 was found always within the prescribed 24 hourly NAAQS (80µg/m^3) throughout the monitoring period including Deepawali day. Increase in SO_2 concentration on Deepawali day at all cities are evident. Increase on Deepawali day may be attributed to oxidation of sulphur due to bursting of cracker.

Figure 2: City Averages of SO_2 and NO_2 During Deepawali 2019 (24 hourly Averages)



NO_2 was reported within prescribed 24 hourly NAAQS (80µg/m^3) in all the cities during Pre-Deepawali and Deepawali. On Deepawali day NO_2 was found to increase at 5 out of 7 cities. Agra, Kolkata and Vadodara have reported decline in NO_2 on Deepawali day compared to Pre-Deepawali period.

3.2 Metals in PM_{10} (NAAQS Parameters)

Lead Nickel and Arsenic (Pb, Ni and As) concentrations are prescribed in NAAQS 2009. The value of these metals found during Deepawali 2019 is presented in Table 3.

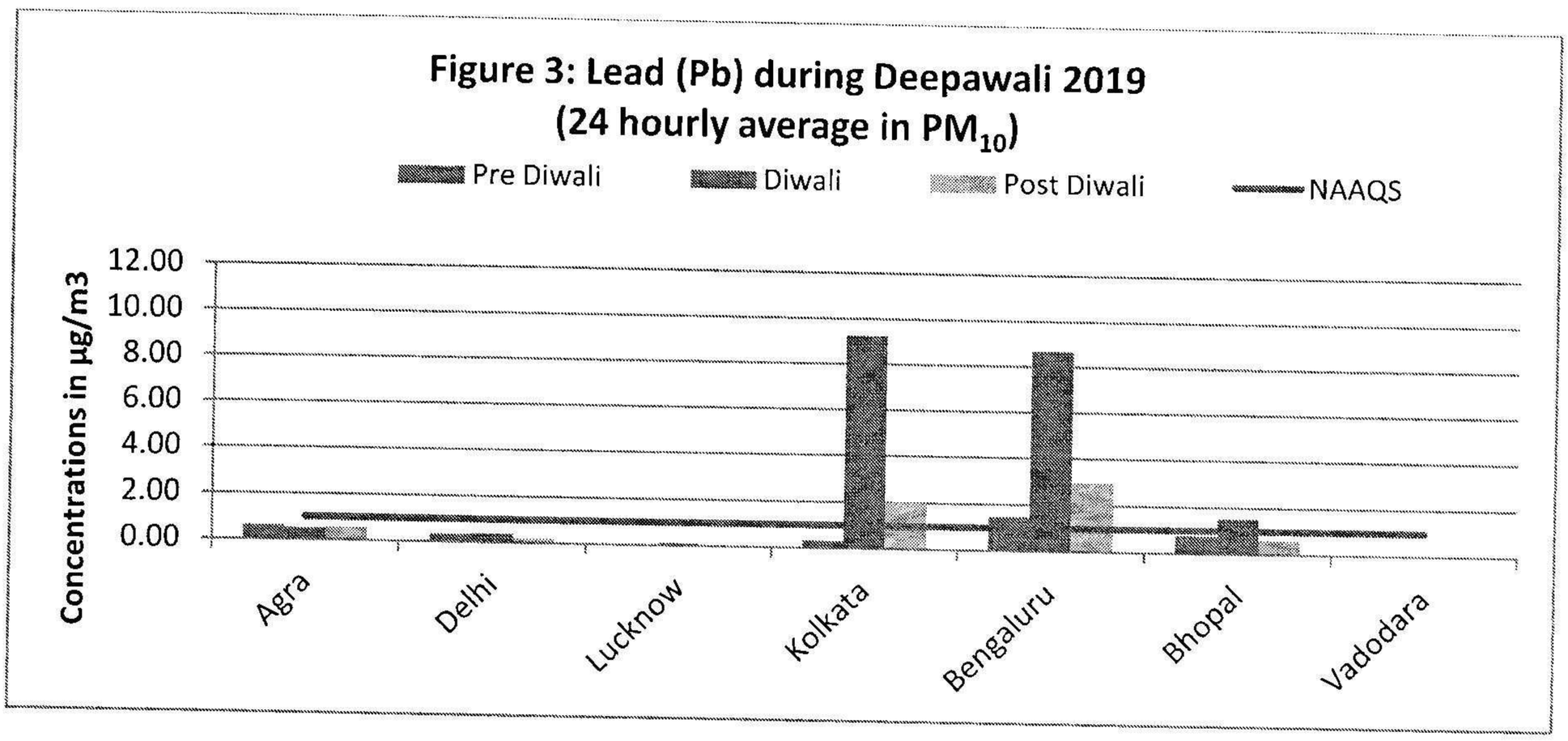
Table 3: Lead Nickel and Arsenic in PM_{10} in Delhi during Deepawali - 2019

	Nickel (Ni)	Lead (Pb)	Arsenic (As)
Pre - Deepawali	6	360	5
Deepawali	6	328	9
NAAQS	20	1000	6

Notes: (i) All values are in ng/m^3 (ii) Ni and As has only annual standard and (iii) Pb have both 24 hourly (1000 ng/m^3) and annual standards (500 ng/m^3)

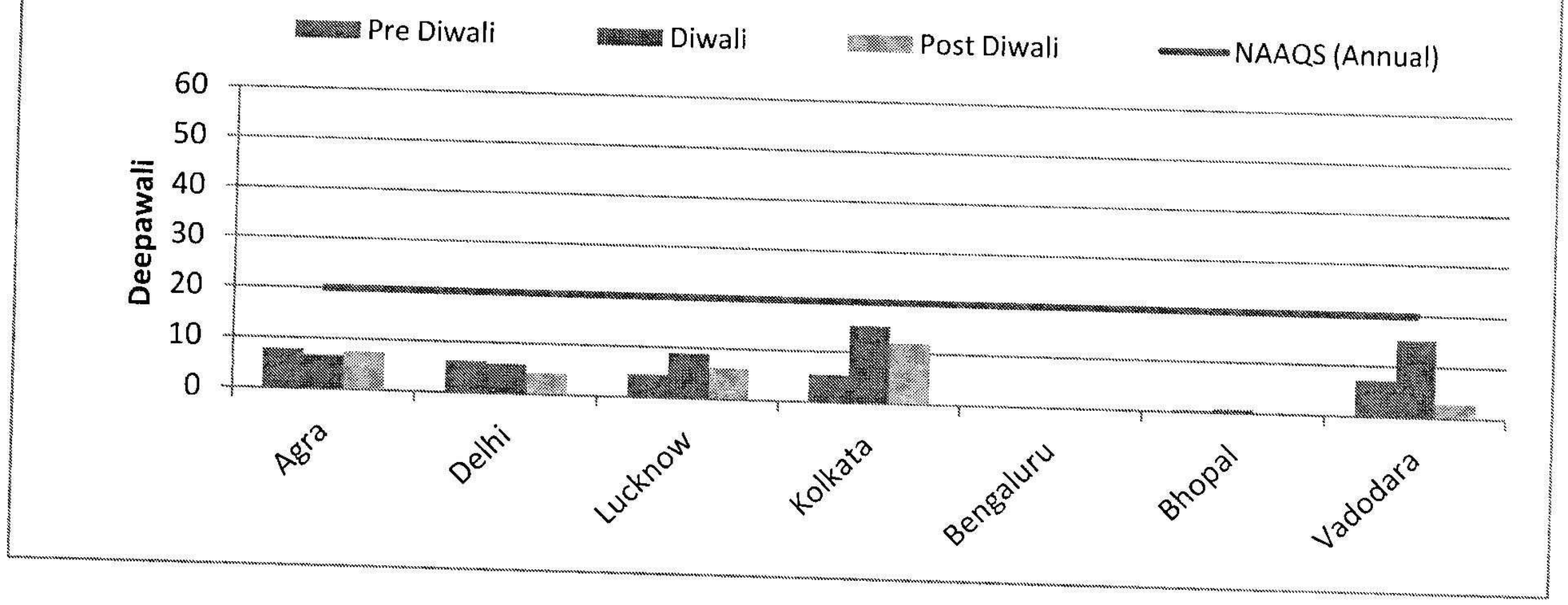
Lead (Pb), Nickel (Ni) and Arsenic in ambient air (PM_{10}) in various cities during the study period are depicted in Figure 3, Figure 4 and Figure 5.

Figure 3: Lead (Pb) during Deepawali 2019 (24 hourly average in PM_{10})



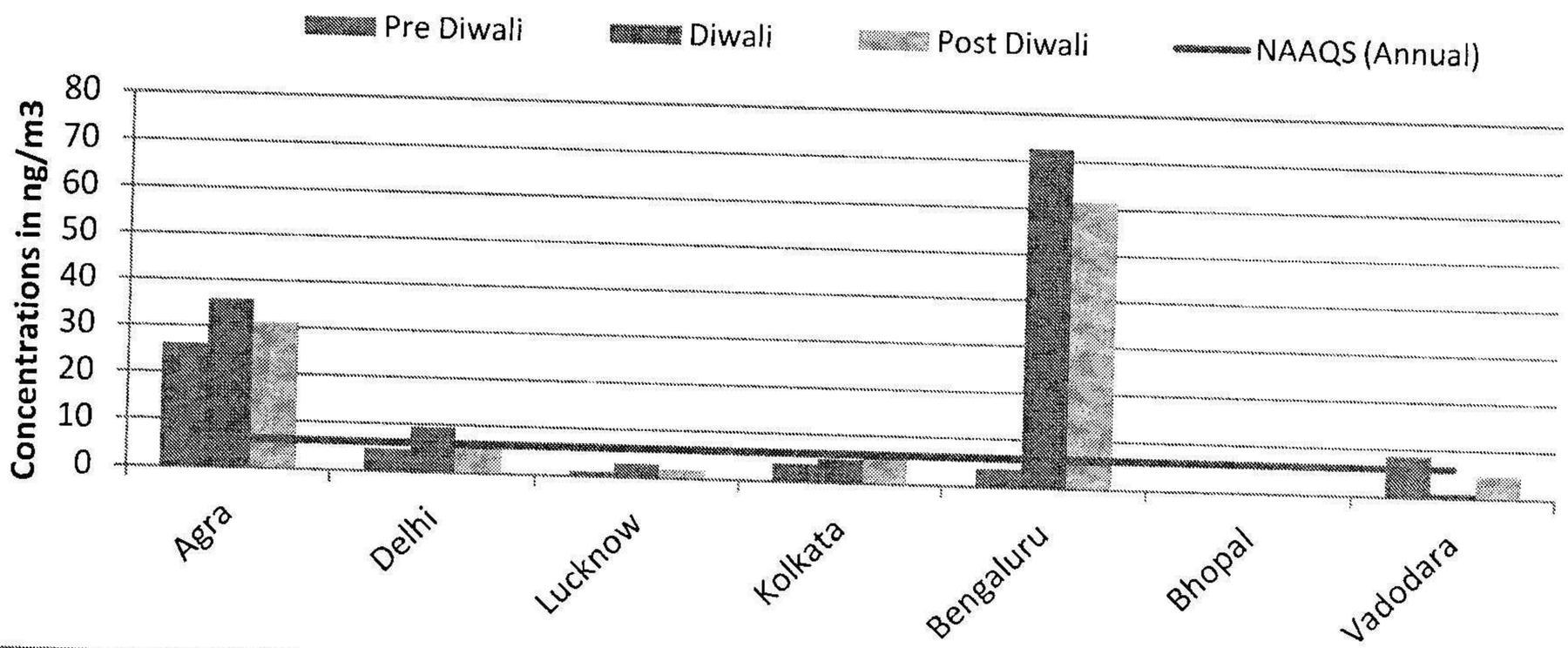
Lead (Figure 3) found to cross 24 hourly prescribed NAAQS limit on Deepawali day in Bhopal, Bengaluru and Kolkata. Bengaluru and Kolkata witnessed substantial increase in lead on Deepawali day and it remained in air during post Deepawali days. Higher lead concentrations in Bengaluru and Kolkata in pre and post Deepawali period may be a matter of further investigation.

Figure 4: Nickel (Ni) during Diwali 2019 (24 hourly average in PM_{10})



Nickel (Ni): As depicted in Figure 4 concentration of Nickel was increased in Lucknow, Kolkata and Vadodara; however it remained always within 20 ng/m^3 (NAAQS – Annual average value).

Figure 5: Arsenic (As) during Deepawali 2019 (24 hourly average in PM_{10})



Arsenic was found to increase and crossed the prescribed annual concentration limit on Deepawali day. It may not be considered as an exceedence as these are 24 hourly values.

3.3 Elements in $PM_{2.5}$

Three parameters (Aluminium, Barium and Iron) used in manufacturing of firecrackers for which proposed short term Ambient Air Quality Criteria Values (AAQCVs) were proposed due to possible health impact. City-wise summary of 15 days' data of prescribed elements in $PM_{2.5}$ for Pre-Deepawali period, Deepawali day and Post Deepawali period is presented in Table 3.

Table 3: Comparison of Metal concentrations in $PM_{2.5}$ at various Indian Cities during Deepawali 2019

	Agra			Bhopal			Bengaluru			Delhi		
	Al	Ba	Fe	Al	Ba	Fe	Al	Ba	Fe	Al	Ba	Fe
Pre Deepawali	0.97	0.05	0.93	0.55	0.03	0.53	0.02	0.01	0.13	1.30	0.27	0.59
Deepawali	14.45	8.67	0.81	9.16	6.04	0.40	4.17	2.63	0.25	32.87	18.77	1.12
Post Deepawali	3.38	1.55	0.82	1.09	0.42	0.47	0.97	0.49	0.24	2.66	0.86	0.51
	Kolkata			Lucknow			Vadodara					
	Al	Ba	Fe	Al	Ba	Fe	Al	Ba	Fe			
Pre Deepawali	1.05	0.52	0.67	0.85	0.23	0.44	0.53	0.15	0.41			
Deepawali	19.44	20.03	0.53	23.63	15.08	0.81	2.63	1.60	0.20			
Post Deepawali	4.03	3.21	0.84	4.60	2.60	0.54	0.62	0.42	0.25			

Note: (a) All Values are in µg/m³ in $PM_{2.5}$ (b) Short Term Critical Ambient Air Quality Critical Values (CAAQVs) are: Al - 40 µg/m³; Ba - 4.0 µg/m³ and Fe - 40.0 µg/m³ (All these are given for 24 hourly averages)

From the above Table it is evident that Aluminium and Iron in $PM_{2.5}$ fraction are well within the prescribed short term AAQCVs in all cities; however, the main violation occurred in Barium. Barium exceeded AAQCVs (4.0 µg/m³) in Delhi, Kolkata, Agra, Bhopal and Lucknow. This year with the promotion of Green Cracker and new formulation crackers increase in Barium concentration was not expected.

Year wise comparison (2016 – 2019) of Deepawali day's data of Delhi is presented in Table 4. Aluminium was increased this year compared to 2018 in Delhi; however, the level was far less than 2016 and 2017 data Deepawali. Except Barium other elements (Aluminium and Iron) was within proposed AACQVs concentrations; however, Barium in $PM_{2.5}$ got reduced by about three times this year on Deepawali day.

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Table 4: Comparison of $PM_{2.5}$ and elements in $PM_{2.5}$ in Delhi during Deepawali 2016, 2017 and 2018

All Concentrations are in $\mu g/m^3$

	$PM_{2.5}$				Aluminum (Al)				Barium (Ba)				Iron (Fe)			
	2016	2017	2018	2019	2016	2017	2018	2019	2016	2017	2018	2019	2016	2017	2018	2019
Pitampura	1238	677	831	513	183	165	3.09	25.8	95.9	34.5	53.7	16.3	3.2	1.49	1.44	1.0
Janakpuri	842	638	988	511	180	177	3.82	39.9	65.34	45.7	56.5	21.2	2.76	1.51	1.52	1.2
Parivesh Bhawan	958	496	990	NM	166	136	4.37	NM	60.92	23.7	52.2	NM	2.02	1.1	1.27	NM
City Average	1013	604	936	512	176	159	3.8	32.9	74	34.7	54.2	18.8	2.66	1.37	1.41	1.1

Notes: a) NM - Not Measured and b) AAQCVs: Al – 40 $\mu g/m^3$, Ba – 4.0 $\mu g/m^3$ and Fe – 40 $\mu g/m^3$

3.4 Trend of Particulate matter during Deepawali fortnight (7 days before and 7 days after Deepawali in Delhi

Comparative data collected by CAAQMS since 2016 is presented in Figure 6 and Table 5. From the data and Figure it is evident that the after effects of Deepawali celebration depend on date (week) of Deepawali celebration. It is clearly evident that in 2016 (Deepawali on 30th October) and 2019 (Deepawali on 27th October) the after effect of Deepawali was similar as it coincides with peak period of stubble burning.

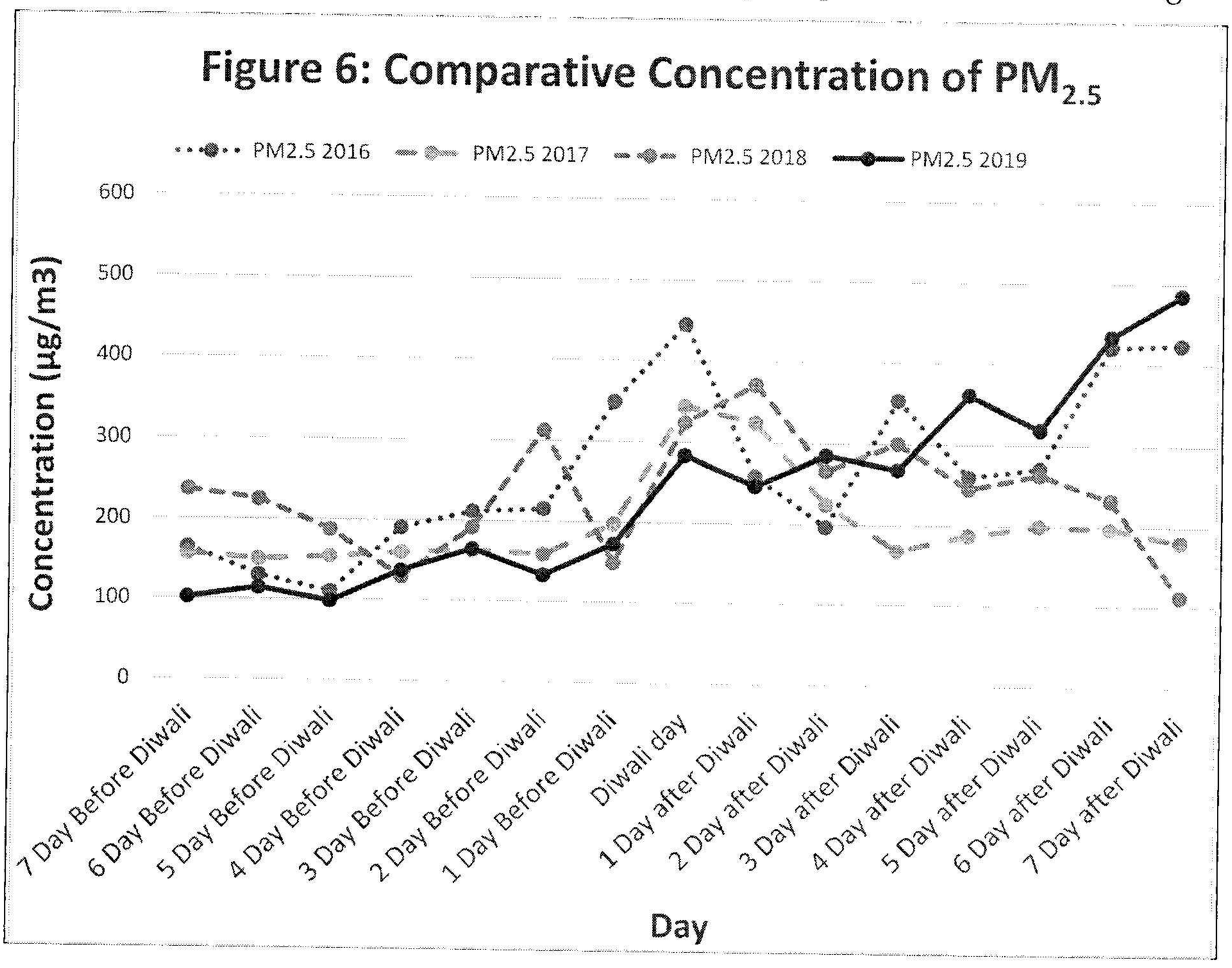


Table 5: Comparative Concentration of $PM_{2.5}$ & PM_{10} (Based on Real time data) During Deepawali days (2016, 2017, 2018 & 2019)

Year/Day	2016			2017			2018			2019		
	DATE	$PM_{2.5}$	PM_{10}	DATE	$PM_{2.5}$	PM_{10}	DATE	$PM_{2.5}$	PM_{10}	DATE	$PM_{2.5}$	PM_{10}
7 Day Before Deepawali	23-Oct	165	399	12-Oct	157	356	31-Oct	237	430	20-Oct	102	208
6 Day Before Deepawali	24-Oct	130	380	13-Oct	150	353	1-Nov	225	403	21-Oct	114	232
5 Day Before Deepawali	25-Oct	110	304	14-Oct	154	312	2-Nov	188	355	22-Oct	98	231
4 Day Before Deepawali	26-Oct	191	411	15-Oct	160	369	3-Nov	129	254	23-Oct	137	305
3 Day Before Deepawali	27-Oct	212	507	16-Oct	163	394	4-Nov	192	293	24-Oct	165	326
2 Day Before Deepawali	28-Oct	216	491	17-Oct	159	361	5-Nov	313	454	25-Oct	133	289
1 Day Before Deepawali	29-Oct	349	600	18-Oct	198	414	6-Nov	149	290	26-Oct	173	315
Deepawali day	30-Oct	445	862	19-Oct	344	445	7-Nov	324	432	27-Oct	284	391
1 Day after Deepawali	31-Oct	259	766	20-Oct	325	628	8-Nov	371	532	28-Oct	247	386
2 Day after Deepawali	1-Nov	197	674	21-Oct	225	520	9-Nov	267	411	29-Oct	286	455
3 Day after Deepawali	2-Nov	354	945	22-Oct	168	373	10-Nov	301	477	30-Oct	269	446
4 Day after Deepawali	3-Nov	261	716	23-Oct	188	434	11-Nov	246	433	31-Oct	361	560
5 Day after Deepawali	4-Nov	272	632	24-Oct	200	426	12-Nov	264	466	1-Nov	319	511
6 Day after Deepawali	5-Nov	421	1031	25-Oct	197	466	13-Nov	233	393	2-Nov	434	592
7 Day after Deepawali	6-Nov	424	1231	26-Oct	181	435	14-Nov	112	196	3-Nov	486	557

4.0 Conclusion

1) On Deepawali day $PM_{2.5}$ concentrations were found to be 0.5 to 6.0 times higher than pre-Deepawali average levels across various cities. Maximum increase was observed in Delhi (6.0 times) followed by Bengaluru (2.2 times), Kolkata (1.4 times) and Lucknow (1.1 times). Bhopal recorded minimum increase in PM2.5.
2) SO_2 was found within prescribed NAAQS (80 $\mu g/m^3$) limits during the entire monitoring period including 27th October, 2019 (Deepawali day).
3) Similarly, NO_2 was also found to be within prescribed NAAQS limit in all the cities during monitoring period.
4) During post Deepawali period PM_{10} concentration was reduced by 14 - 42% in different cities compared to Deepawali day level. Agra has recorded 7% increase in PM_{10} during post Deepawali period. Maximum reduction was observed in Vadodara (42.5%) and minimum at Lucknow (14%). In Delhi PM_{10} was reduced by 27% in post Deepawali period compared to Deepawali peak.
5) $PM_{2.5}$ levels during post Deepawali declined by 11 - 62% in comparison with Deepawali day in different cities. Highest decrease was found in Vadodara (62%) and lowest in Lucknow (11%). In Delhi, $PM_{2.5}$ concentration was decreased by 15% during post Deepawali compared to Deepawali day concentration. Agra recorded little increase in $PM_{2.5}$ during post Deepawali. The reduction in particulates during post Deepawali also indicate that the prevailing meteorology is governing the scenario and in Indo Gangetic plain the particulates remained in suspension for more duration this year. Vadodara got heat by cyclonic depression and the PM concentrations reduced substantially due to high wind speed and rain.
6) Barium exceeded AAQCVs (4.0 $\mu g/m^3$) in Delhi, Kolkata, Agra, Bhopal and Lucknow. This year with the promotion of Green Cracker and new formulation crackers increase in Barium concentration was not expected.

7) The concentration of Iron in $PM_{2.5}$ was found well within the AAQCVs (40 $\mu g/m^3$) in all the cities monitored by CPCB.
8) Aluminium levels were also found within AAQCVs (40 $\mu g/m^3$).
9) In Delhi Barium in $PM_{2.5}$ got reduced by about three times this year on Deepawali day. It is also pertinent to mention that with the introduction of Green Cracker and banning of Barium in fireworks as directed by Hon'ble Supreme Court, Barium concentration was not supposed to be elevated from pre-Deepawali level on Deepawali day.



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 bring into one place 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.

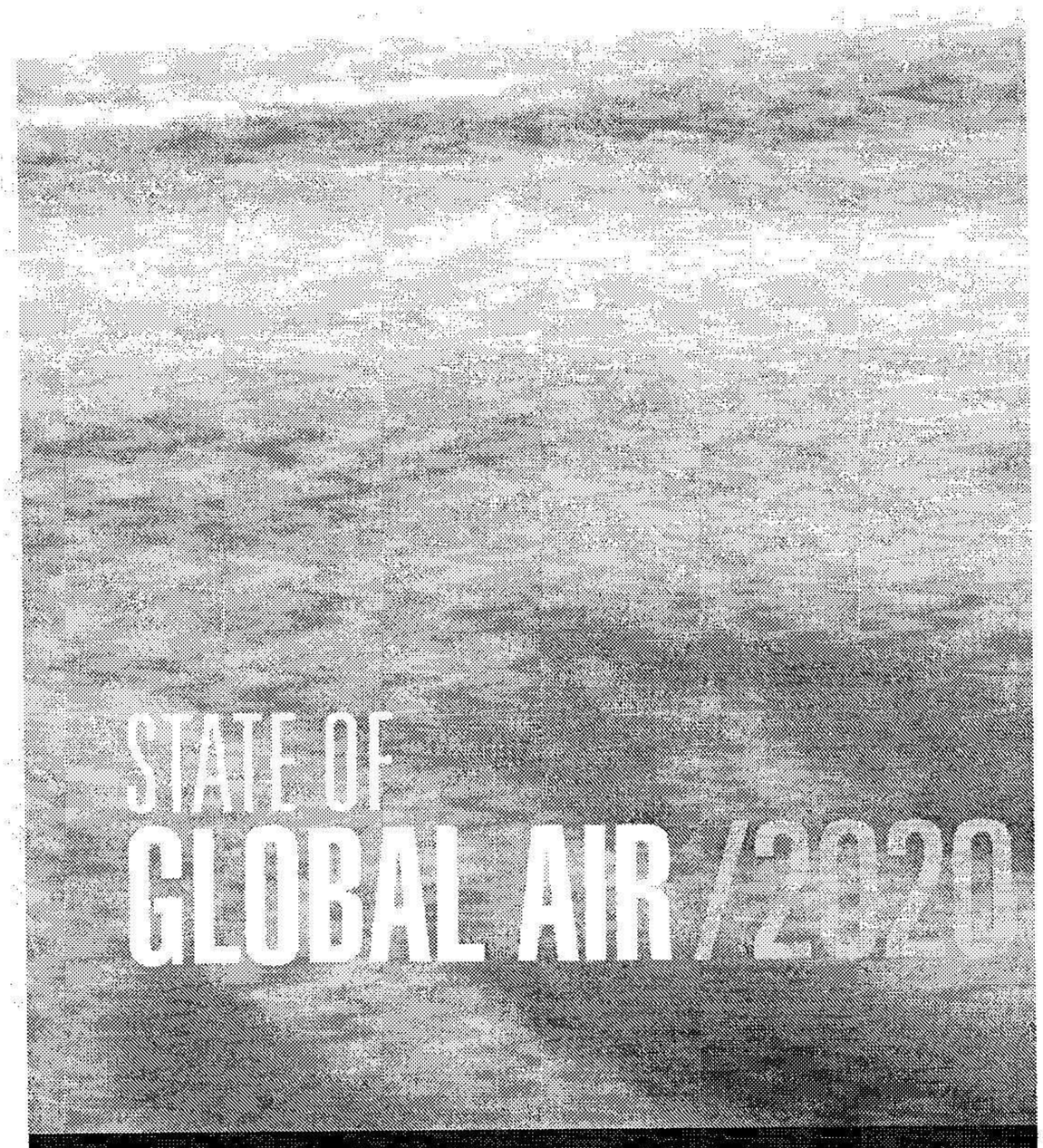
WHO IS IT FOR?

The report and website are designed to give citizens, journalists, policy makers, 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 reflecting the latest air pollution levels and associated burden of disease. 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 stateofglobalair.org.

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INTRODUCTION

As a result of the COVID-19 pandemic, public health has rocketed to the forefront of our collective concerns. We are continuing to learn about the damaging effects of COVID-19 infection, an invisible threat to our respiratory and cardiovascular health carried through the air we breathe. At the same time, the pandemic has brought renewed attention to another global airborne threat to public health, not entirely invisible, but one that continues to be ignored in many parts of the world — air pollution. While COVID-19's effects may appear in a few short weeks, the health consequences of air pollution may take years to manifest themselves in the form of chronic diseases. And yet, as we have learned in recent months, the underlying toll that air pollution has taken on respiratory and cardiovascular health over time has made individuals more vulnerable to the effects of COVID-19.

The drastic shifts that economic shutdowns required have made more visible the impacts of our own human activities on air pollution. Just as the COVID-19 crisis has demonstrated the need for multiple strategies to manage the pandemic, it has also provided an unexpected opportunity to understand what we can do better to address air pollution. Solutions to air pollution will require multifaceted ongoing efforts to bring attention to its health threats, to identify the policy changes necessary to control it, and to monitor progress over time.

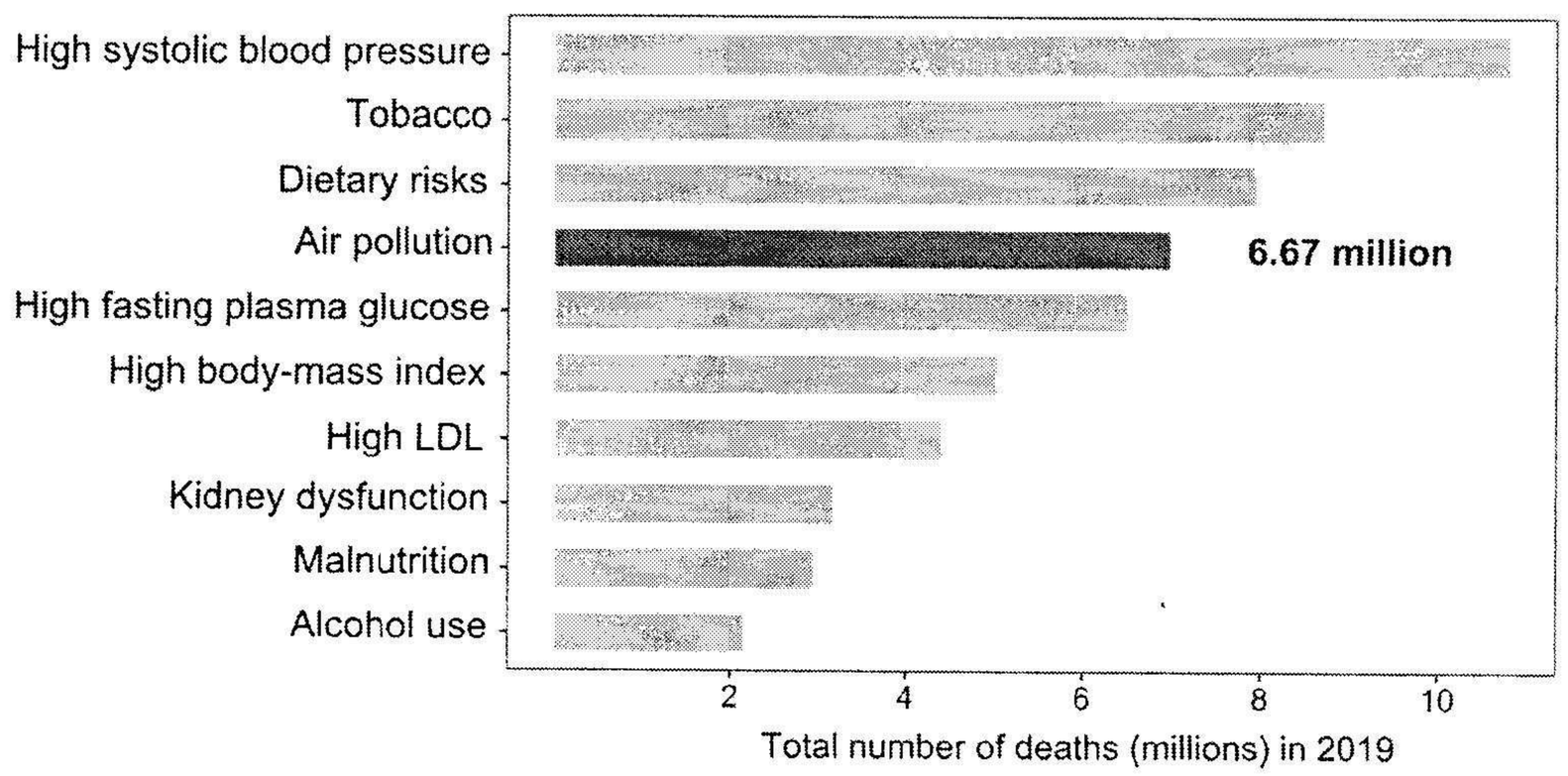
The *State of Global Air* supports these efforts by providing a global report card on the current status of air pollution and health worldwide, the progress that has been made, and where problems

Air pollution was the 4th leading risk factor for early death worldwide in 2019, surpassed only by high blood pressure, tobacco use, and poor diet.

persist or are getting worse. Since we first launched the *State of Global Air* nearly five years ago, air pollution has risen to the top of environmental concerns worldwide. In 2019, air pollution moved up from the 5th to the 4th leading risk factor for death globally, continuing to exceed the impacts of other widely recognized risk factors for chronic disease like obesity (high body-mass index), high cholesterol, and malnutrition (Figure 1). An important factor behind this shift is that the calculations now, for the first time, include air pollution's effects on the health of babies in their first month of life. And over the last several decades scientists have continued to build an extensive body of evidence on the risks that breathing poor-quality air poses to human health and our environment, perhaps the most extensive evidence that exists for any environmental risk factor.

Despite all that is known about the effects of air pollution on health, the findings in 2019 show that little or no progress has been made in many parts of the world. Major disparities continue to exist; air quality has improved in many high-income countries over the past

FIGURE 1 Global ranking of risk factors by total number of deaths from all causes in 2019.



several decades, while dangerous levels of air pollution persist in low- and middle-income countries. And evidence is mounting that air pollution can cause harm at much lower levels than previously thought, suggesting that even high-income countries need to continue their efforts to reduce exposure and to ensure that the progress achieved is not lost over time. Systematic and consistent efforts to track progress toward reducing air pollution and the impacts it has on human health remain essential.

What differentiates the *State of Global Air* from the near-daily updates on air pollution in the news? We work with the Institute for Health Metrics and Evaluation's (IHME's) Global Burden of Disease (GBD) project, a unique resource, where high-quality and internally consistent state-of-the-art methods have been applied to estimate current status and yearly trends in exposures and burden of disease from 87 risk factors or groups of factors in 204 countries and territories. Updated annually, this comparative risk assessment approach gives scientists, citizens, and policy makers the opportunity to understand both the absolute and relative importance of the multiple risks that contribute to burden on public health, putting air pollution into perspective.

This year's *State of Global Air* report focuses on key takeaways on the levels and trends in air pollution for the world's major regions and most populous countries. However, a much larger trove of data — with detailed statistics for every country in the world, tools for generating custom data tables and graphs, and factsheets for selected countries — is available at stateofglobalair.org.

WHAT'S NEW THIS YEAR?

Every year, the GBD project incorporates the latest scientific evidence and methods to refine estimates of the burden of disease — or impacts on population health — from air pollution and other risk factors. These are the primary updates for 2019:

Inclusion of air pollution's effects on adverse birth outcomes. Over the past decade, a growing body of scientific evidence has indicated that women who are chronically exposed to particulate air pollution are more likely to have babies born too small (low birth weight) or too early (preterm birth). These children are at greater risk of a range of health effects, which are now reflected in the health burden estimates for babies in their first month of life.

Improvements to $PM_{2.5}$ exposure estimates. The database of ground measurements of $PM_{2.5}$ (particles measuring less than 2.5 micrometers in aerodynamic diameter) has been expanded from 9,960 to 10,408 sites in 116 countries.

Exclusion of smoking studies from particulate matter exposure–response functions. In previous years, the integrated exposure–response functions for particulate matter and lung cancer, chronic obstructive pulmonary disease (COPD), lower-respiratory infections, type 2 diabetes, heart disease, and stroke had to rely on evidence from active smoking data to characterize risks at higher levels of exposure. With the availability of new studies of high air pollution conditions in China and South Asia and the new exposure–response modeling approach, the use of evidence from active smoking data is no longer necessary.

Revisions to exposure–response relationships. Using a methodology designed to improve the selection and modeling of all exposure–response relationships, GBD scientists revised the exposure–response functions for 10 risk–outcome pairs within air pollution: particulate matter pollution (ambient and household) and birthweight, preterm birth, lung cancer, COPD, lower-respiratory infections, type 2 diabetes, ischemic heart disease, and stroke; ozone and COPD; and household air pollution and cataracts.

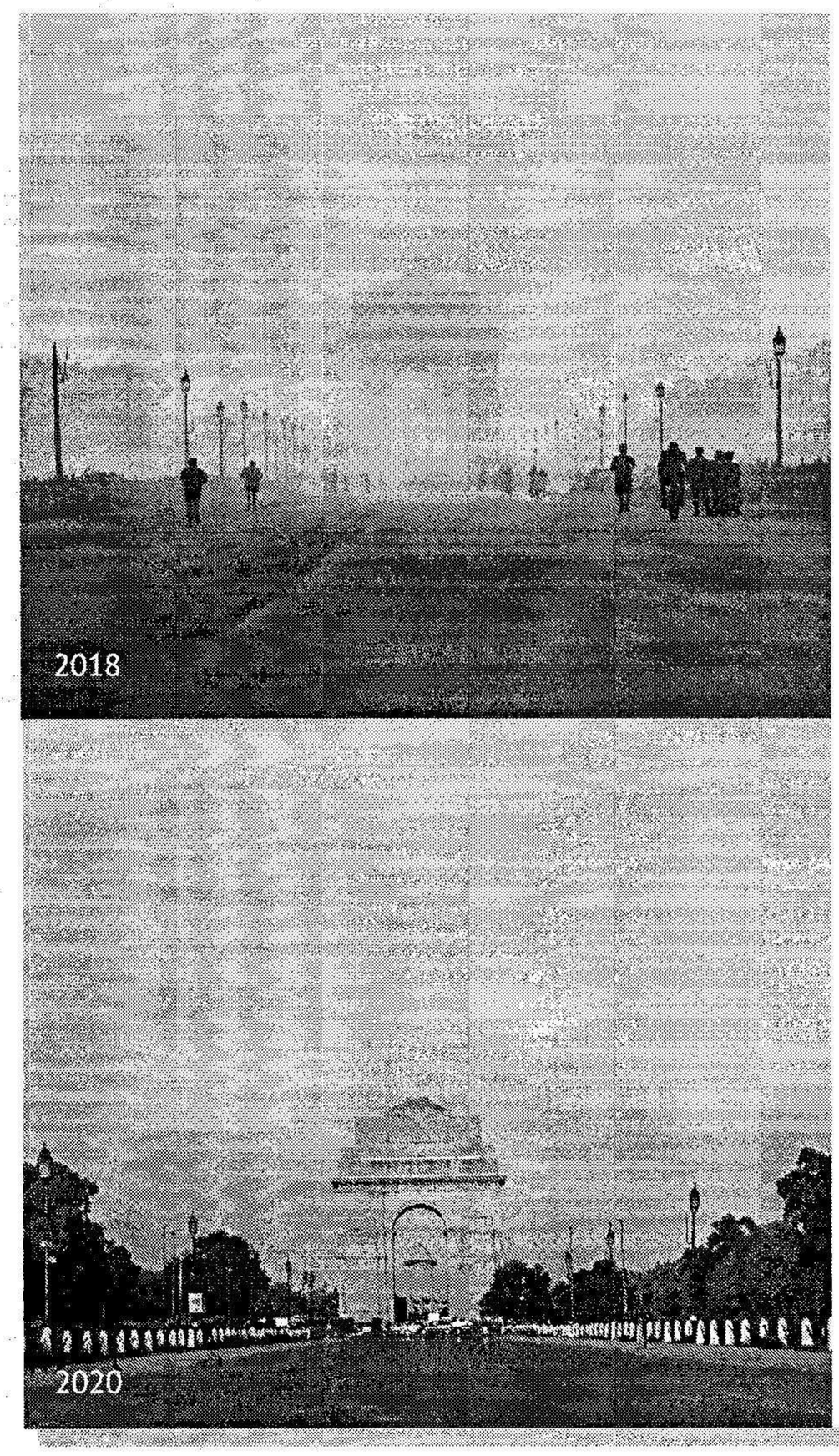
Improvements to estimates of exposure to household air pollution. GBD scientists developed a new method to translate data on the proportion of households in a country using solid fuels for cooking into the proportion of individuals exposed to household $PM_{2.5}$ and their levels of exposure. This new method improves the ability to estimate the burden of disease attributable to household air pollution.

Improvements to ozone exposure estimates. The ozone exposure estimates were improved by doubling the number of monitoring sites from 4,400 to 8,800, combining their data with additional chemical transport models, and improving the spatial resolution of the estimates.

EXPOSURE TO AIR POLLUTION

The *State of Global Air* presents a comprehensive analysis of three types of air pollution known to impact human health: ambient (outdoor) fine particle pollution, ambient tropospheric ozone, and household air pollution. Drawing from the World Health Organization's city-level air quality monitoring database and other key sources, GBD scientists use a systematic approach to estimating exposure to air pollution that is internally consistent — making historical estimates comparable to today's — while taking advantage of the most recent data and advanced modeling and analysis methods. The results, reported here, offer both a comprehensive accounting of exposures and a foundation for informing decisions and actions toward a cleaner world.

The focus of this report is on long-term exposures to each of these air pollutants — exposures that occur over multiple years and that have been shown by studies to be the strongest determinants of the heavy burden from chronic diseases, diseases that persist for a long time and can take several years to develop.



Amit kg/shutterstock.com

Clean Air Collective, India

COVID-19

How Has COVID-19 Affected Air Quality?

The COVID-19 pandemic led to unprecedented restrictions that dramatically reduced global and local travel, shut down schools and businesses, and halted some industrial activity. While there have been significant societal and personal costs, many countries around the world have experienced blue skies and starry nights, often for the first time in many years. Satellite and ground-based air quality monitoring data have shown substantial reductions in concentrations of pollutants such as nitrogen dioxide (NO_2) and, in some cases, modest reductions for other pollutants such as $PM_{2.5}$. At the same time, levels of ozone appear to have increased, in part due to the reductions in NO_2 and changes in meteorological factors including temperature.

As evidence from some countries shows, these changes are only temporary. As restrictions have lifted, emissions have risen — quickly erasing any gains in air quality. Since air pollution's most substantial health burdens arise from chronic, long-term exposure, COVID-19 has offered only a temporary respite from air pollution.

Nonetheless, the blue skies have offered a reminder of what pollution takes away, and actions to restrict the spread of COVID-19 offered only a temporary solution, inspiring renewed demands for cleaner air in the longer term.

The sky in Rajpath, New Delhi, India, in 2018 and during the COVID-19 lockdown in 2020.

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. Although exposures to both smaller and larger airborne particles can also be harmful, studies have shown that exposure to high average concentrations of $PM_{2.5}$ over the course of several years has been the most consistent and robust predictor of mortality from cardiovascular, respiratory, and other types of diseases.

Ambient $PM_{2.5}$ concentrations are measured in micrograms of particulate matter per cubic meter of air, or $\mu g/m^3$. Understanding the concentrations individuals actually experience — their *exposure* — is crucial to estimating the burden of disease associated with $PM_{2.5}$ pollution. The GBD project estimates exposure at the country level as the *population-weighted annual average concentration*, the concentration to which most of a country's population is exposed. (See "How $PM_{2.5}$ Exposure Is Estimated" on page 8.)

Global Patterns in Ambient $PM_{2.5}$ Exposure

In 2019, over 90% of the world's population experienced annual average $PM_{2.5}$ concentrations that exceeded the WHO Air Quality Guideline of 10 $\mu g/m^3$. The highest annual average exposures were seen in Asia, Africa, and the Middle East (Figure 2). The 10 countries with the highest exposures worldwide are in these regions (Table 1), though given uncertainty in the estimates, the rankings are not absolute. The 10 countries with the lowest exposures (i.e., population-weighted annual average concentrations less than 8 $\mu g/m^3$) are Australia, Brunei Darussalam, Canada, Estonia, Finland, Iceland, New Zealand, Norway, Sweden, and the United States.

Countries in Asia, Africa, and the Middle East continue to experience the highest levels of ambient $PM_{2.5}$.

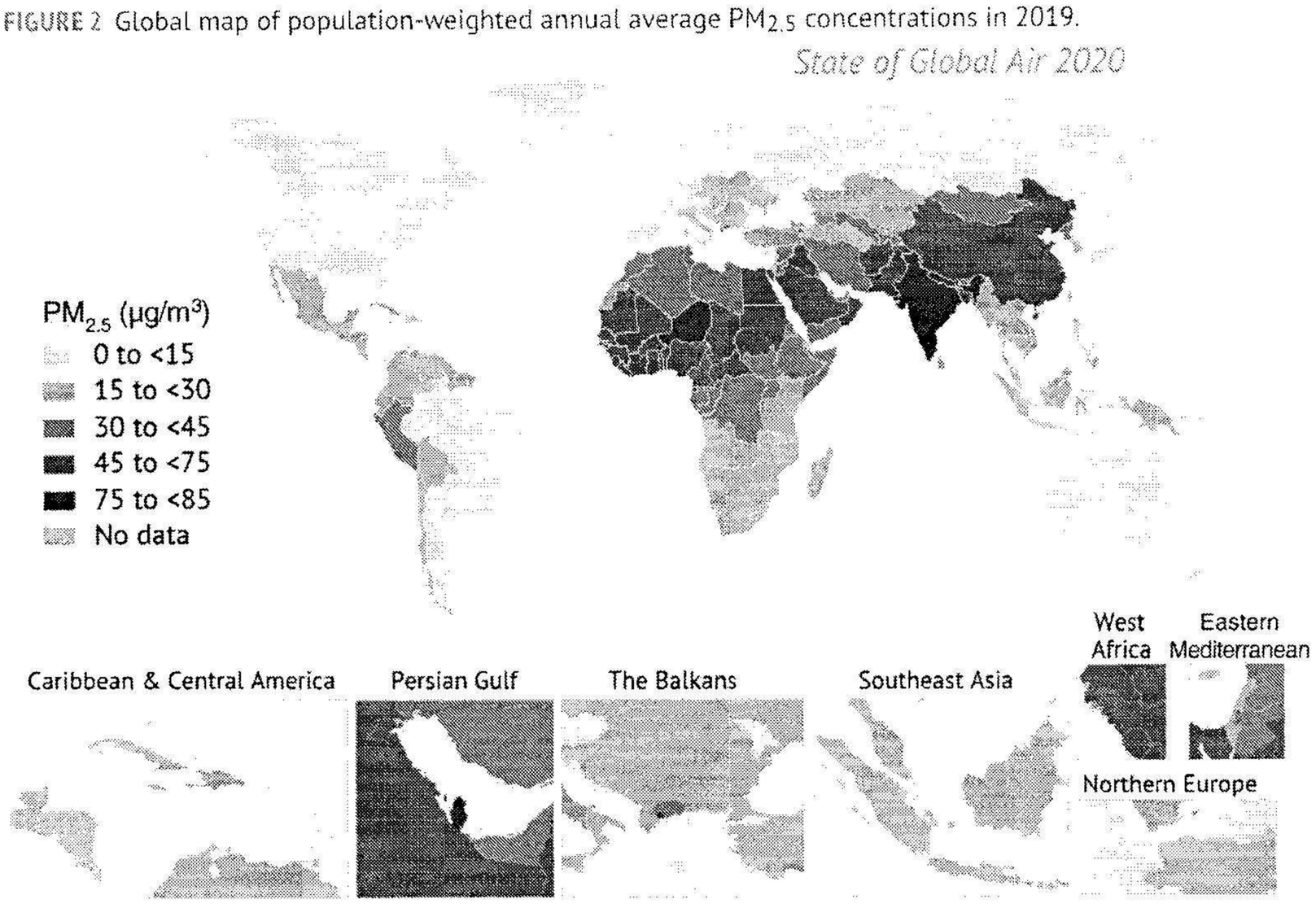
TABLE 1 Top 10 countries with the highest population-weighted annual average $PM_{2.5}$ exposures in 2019

Country	$PM_{2.5}$ Concentration ($\mu g/m^3$)	95% Uncertainty Intervals*
India	83.2	76.1 to 90.7
Nepal	83.1	62.9 to 107
Niger	80.1	42.2 to 145
Qatar	76.0	59.2 to 96.6
Nigeria	70.4	45.4 to 105
Egypt	67.9	47.8 to 92.8
Mauritania	66.8	37.6 to 108
Cameroon	64.5	43.8 to 92.6
Bangladesh	63.4	55.1 to 73.8
Pakistan	62.6	49.9 to 77.5

* The 95% uncertainty intervals are a measure of scientific uncertainty. They reflect a range of values, from the 2.5th to the 97.5th percentile of a possible distribution of values, within which the true concentration is likely to fall.

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 day to day or in certain seasons, especially around cities or major pollution sources. Although short-term exposure spikes can affect health, it is long-term exposures that contribute most to the burden of disease and mortality from air pollution, and therefore are the focus of the GBD project.

FIGURE 2 Global map of population-weighted annual average $PM_{2.5}$ concentrations in 2019.



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

Trends in Ambient $PM_{2.5}$ Exposure

Although $PM_{2.5}$ levels have shown modest improvements in some regions, there has been little or no sustained progress in the most polluted regions.

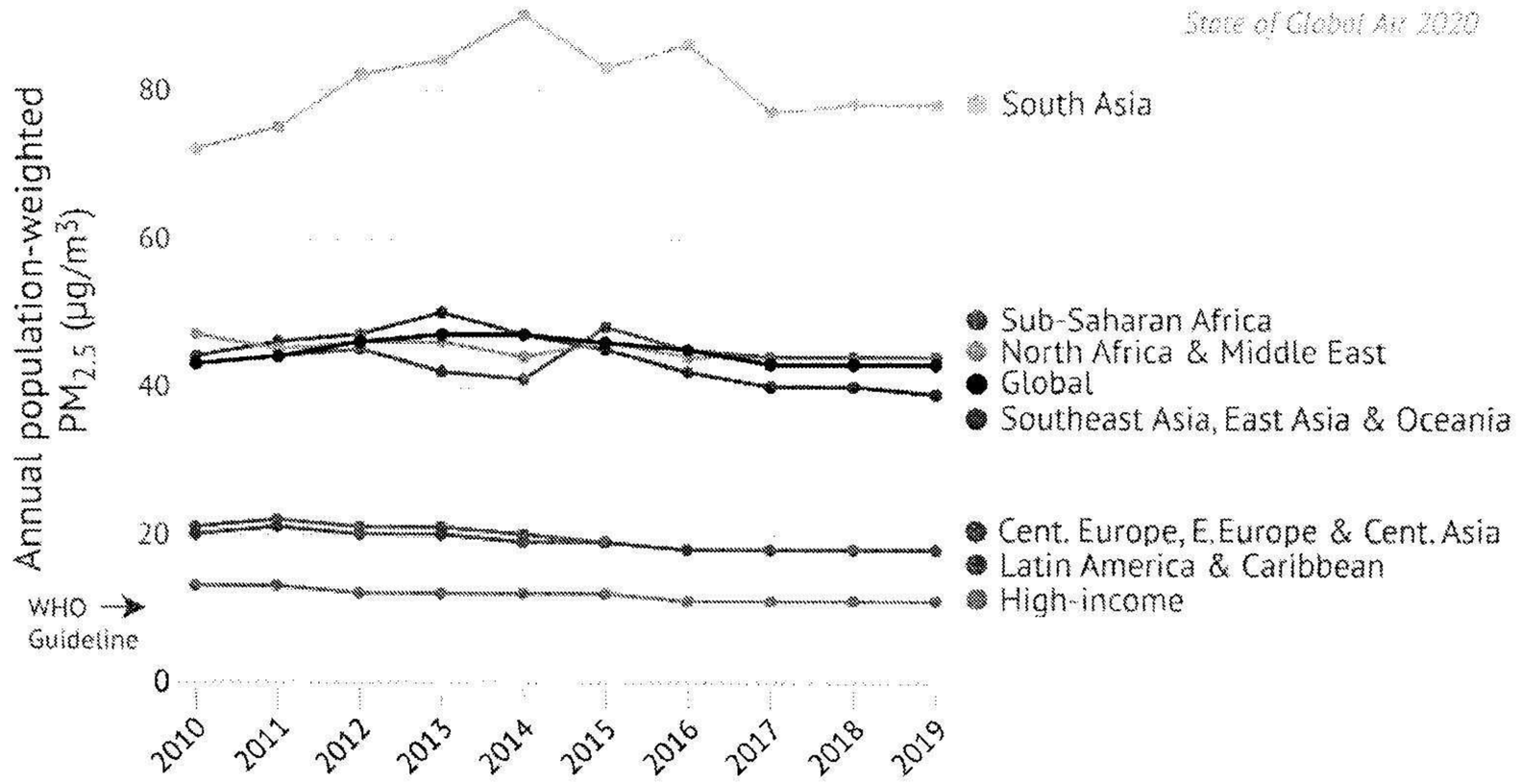
On average, global $PM_{2.5}$ exposures declined slightly from 2010 to 2019 but reflect very different experiences across the GBD Super Regions (countries grouped by similar cause-of-death patterns; Figure i). Some regions have seen improvements, notably Southeast Asia, East Asia, and Oceania, led by China, Vietnam, and Thailand. However, others — in particular North Africa, the Middle East, and sub-Saharan Africa — have experienced little or no progress or even have seen increases in exposures (Figure 3). The disparities in exposure to $PM_{2.5}$ across these regions have largely remained constant over the past decade, with South Asia consistently seeing the highest exposures. In large part, these regional trends track closely with socioeconomic development and national policy actions.

With the exception of the High-Income Super Region, exposures in all regions continue to exceed the WHO guideline of 10 µg/m³. In fact, four of the seven Super Regions continue to experience $PM_{2.5}$ exposures that exceed even the least-stringent intermediate goal set by the WHO, Interim Target 1, which is 35 µg/m³.

The world's 20 most populous countries collectively represent 70% of the world's population. The good news is that 14 of these 20 countries have seen declines in annual average $PM_{2.5}$ exposures, ranging from a slight decrease of 2.9 µg/m³ (from 22.3 to 19.4 µg/m³) in Indonesia to a substantial decline of 10.6 µg/m³ (from 78.5 to 67.9 µg/m³) in Egypt over the past decade (Figure 4). Germany and the United States, grouped within the High-Income Super Region, experienced modest reductions since 2010. Japan, another country in the High-Income Super Region, saw a modest increase in $PM_{2.5}$ levels (11.5 to 13.5 µg/m³), which may in part reflect increased emissions from power plants that burn fossil fuel, which replaced nuclear plants after the Fukushima nuclear accident in 2011.

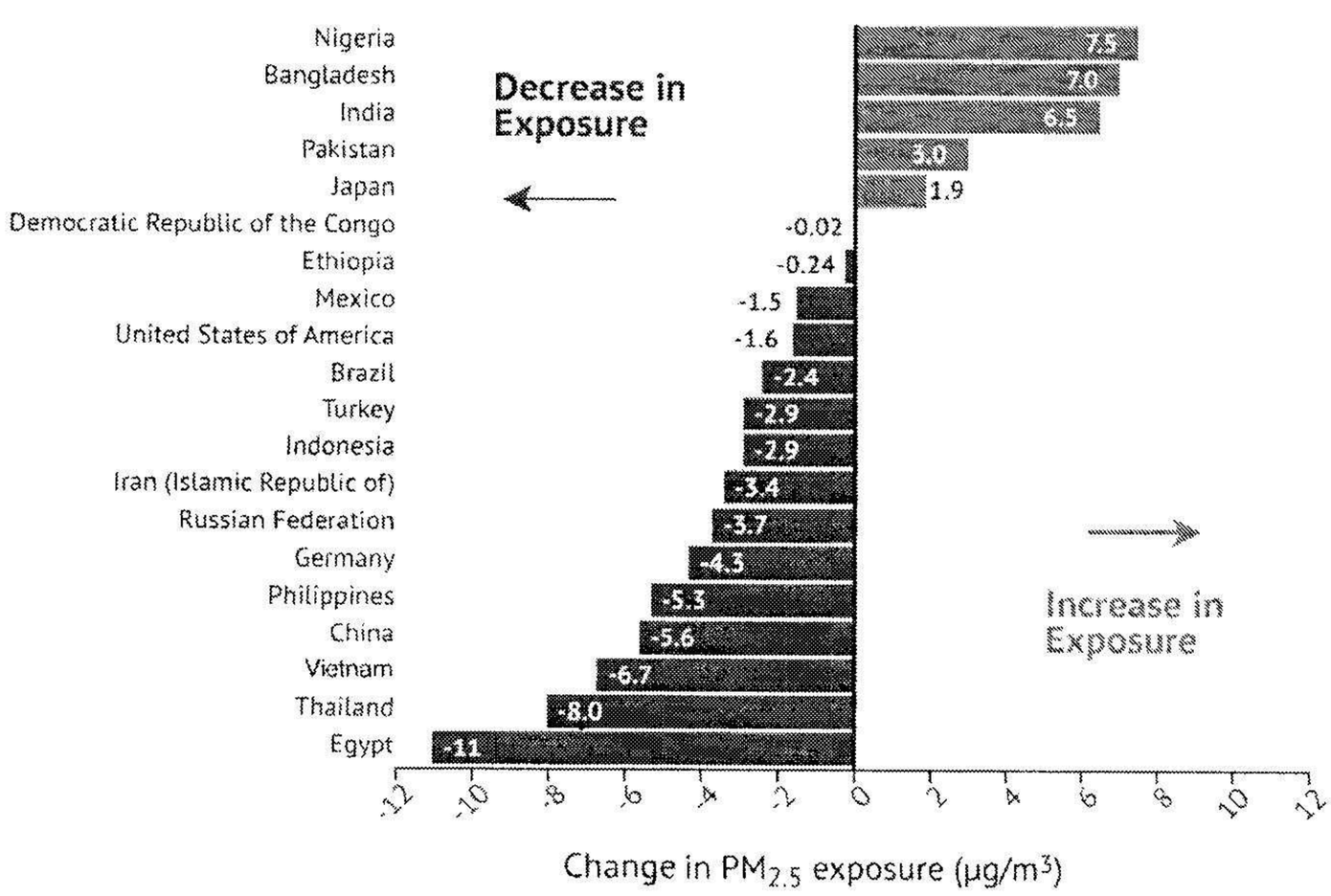
At the other end of the spectrum, Nigeria experienced an increase of 7.5 µg/m³ in the level of $PM_{2.5}$, from 62.9 µg/m³ (95% uncertainty interval [UI]: 41.1 to 92.4) in 2010 to 70.4 µg/m³ (95% UI: 45.4 to 105.2) in 2019. Countries with some of the highest exposures in the world — India, Pakistan, and Bangladesh — continue to see increases.

FIGURE 3 Trends in population-weighted annual average $PM_{2.5}$ concentrations globally and in the GBD Super Regions, 2010–2019.



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

FIGURE 4 Change in population-weighted annual average $PM_{2.5}$ exposure in the 20 most populous countries, 2010–2019.



How $PM_{2.5}$ Exposure Is Estimated

Many of the world's high- and middle-income countries measure $PM_{2.5}$ concentrations through extensive networks of reference-grade monitoring stations concentrated around urban areas. These stations offer a rich source of data that has served as the foundation for most studies of the health effects of air pollution and changes in air quality over time. In addition to these sources of data, GBD estimates incorporate data from the World Health Organization (WHO) air quality database, which serves as a repository for monitoring data for many individual cities around the world. In 2019, the GBD project added particulate matter measurements (PM_{10} and $PM_{2.5}$) from an additional 448 ground monitors, bringing the total to 10,408 ground monitors from 116 countries.

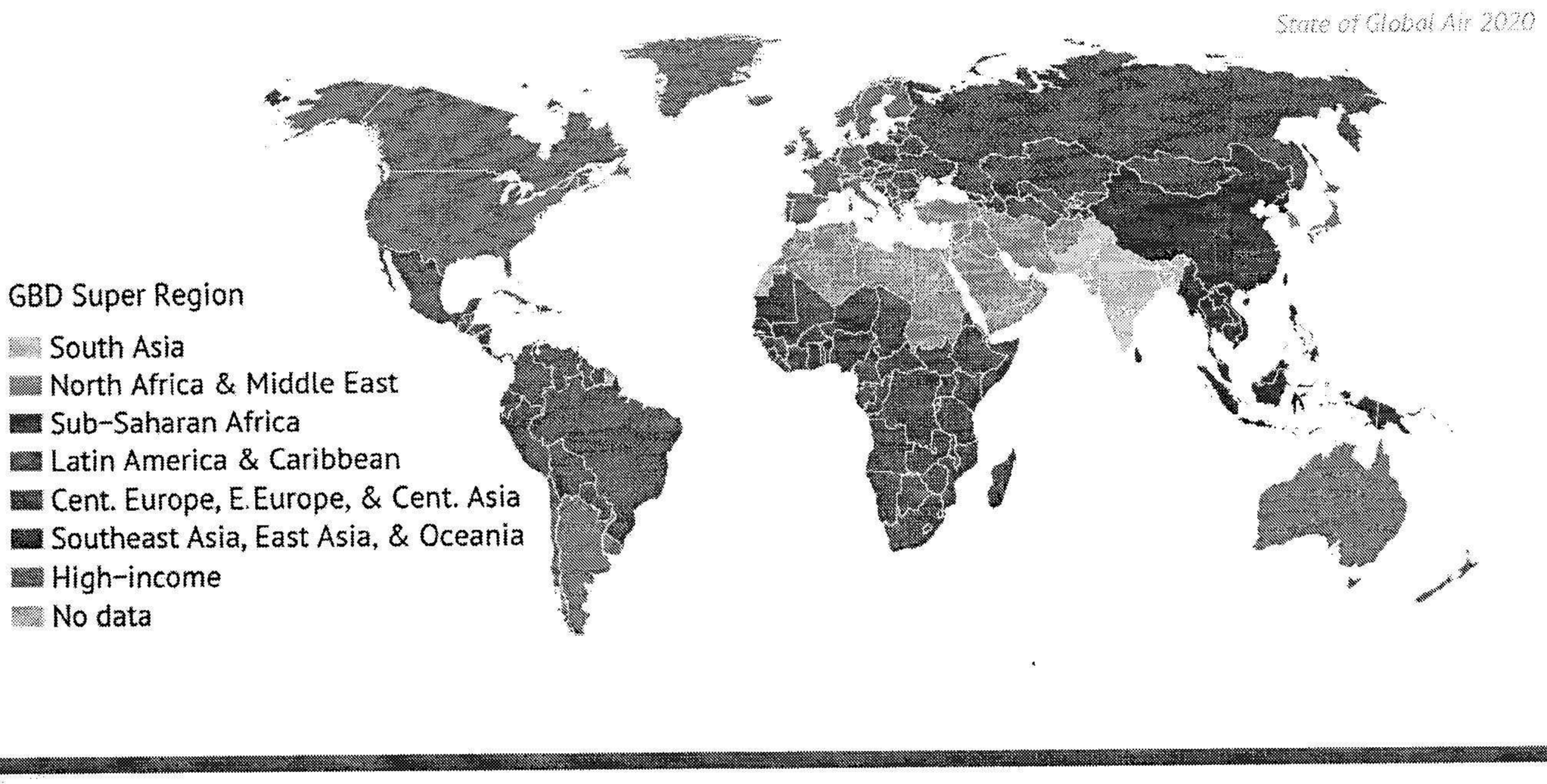
Although these data sources are valuable, on-the-ground air quality monitoring stations are few and far between in many regions of the world, particularly in countries at low and middle levels of development. To fill the gaps and to provide a consistent view of air pollution levels around the world, GBD scientists use sophisticated techniques to combine available ground measurements of particulate matter with observations from satellites and predictions from global chemical transport models. They update their estimates each year using improved methods and new ground-level and satellite measurements.

Extensive comparisons of these predictive methods (satellite and modeling approaches) with ground-level measurements demonstrate that they are reasonably accurate, and thus reliable indicators of $PM_{2.5}$ where ground monitors do not exist or data are not made publicly available.

Using this combined approach, GBD scientists systematically estimate annual average concentrations of $PM_{2.5}$, along with the 95% uncertainty interval (UI) for each estimate, 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, GBD scientists link the concentrations in each block with the number of people living within each block to produce a *population-weighted annual average concentration*. Population-weighted annual average concentrations are better estimates of population exposures than simple averages across monitors, for example, because they give greater weight to the pollutant concentrations experienced where most people live. *Gridded data are available on request.*

Throughout the report, we present results for the GBD Super Regions — countries grouped by similar cause-of-death patterns (Figure i) — and the 20 most populous countries.

FIGURE I Countries included in the seven GBD Super Regions.



AMBIENT OZONE AIR 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 and volatile organic compounds in the presence of sunlight. Nitrogen oxides and volatile organic compounds are both produced by a variety of human activities. Nitrogen oxides 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, as well as by oil and gas extraction and processing and other industrial activities. Certain types of volatile organic compounds can also be emitted from natural sources, such as trees.

Studies suggest that ozone levels today are 30% to 70% higher than they were 100 years ago. This increase reflects rising emissions of the chemicals that form ozone, as well as increases in global and local temperatures, which can accelerate ozone formation. Ozone is also a greenhouse gas, contributing to the warming on which it thrives. 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 pollution is accelerated by — and contributes to — climate change.

Ozone concentrations are measured in parts per billion (ppb). When assessing human exposure to ozone, GBD scientists focus on measurements taken in the warm season in each region, when ozone concentrations tend to peak in the mid-latitudes (where most epidemiological studies have been conducted to date). The GBD assessment evaluates human exposure in terms of the *average seasonal 8-hour daily maximum concentrations*, the measure of long-term exposure in the most recent epidemiological studies of ozone's health effects. Season is defined by the six-month period with the highest average ozone concentrations. Like $PM_{2.5}$ exposures, ozone exposures are estimated for each country as *population-weighted concentrations*. (See "How Ozone Exposure Is Estimated" on page 11.)

Tracking ozone concentrations systematically around the world and over time is vital to measuring progress and evaluating this pollutant's implications for human health and the environment. The GBD is continually improving the scientific basis for this tracking, bolstered by the addition of data from a large number of new monitoring sites, many in China; by improvements in the models used to estimate ozone concentrations where data are lacking; and in the statistical methods used to combine the information from monitors and models to improve confidence in the final estimates over geographical areas and over time.

Trends in Pollution Policy: How Do Key Countries Compare?

China implemented the first comprehensive five-year plan to improve air quality between 2013 and 2017 and subsequent plans have continued to address air pollution. Between 2010 and 2019, outdoor $PM_{2.5}$ levels in China decreased by 30%, largely due to actions undertaken in the past 5 to 7 years, including a shift from coal to gas in residential and industrial sectors and a reduction in industrial emissions. However, there are fears that the recent economic slowdown and related increases in coal-burning capacity will continue to pose challenges with respect to air pollution control.

India released its National Clean Air Programme in 2019 with a view to reducing outdoor $PM_{2.5}$ levels by 2024. While the program has been criticized for its lack of a legal mandate and its narrow focus on cities, it has led to increased engagement on the issue of air pollution at the state and local levels. In April 2020, the country initiated a switch to Bharat Stage VI (BS-VI) vehicle emission standards, which is likely to bring benefits over the next few years. However, the COVID-19 pandemic has raised concerns that the full implementation of the switch might be delayed.

Nigeria saw a 7% increase in outdoor $PM_{2.5}$ levels between 2010 and 2019. In 2019, the National Short-Lived Climate Pollutant Plan was launched, which aims to reduce $PM_{2.5}$ emissions by 75% by 2030. Among a list of 22 key measures, the actions to address $PM_{2.5}$ include regulation and enforcement of vehicle emission standards, switching to cleaner fuels for cooking, eliminating gas flaring, and reducing emissions from crop burning and livestock.

Pakistan lacks a coordinated national action plan on air pollution, although air quality is broadly addressed within the Pakistan Environmental Protection Act. Recent efforts, some of which are mandated through orders from the Supreme Court, have been focused on control of emissions from brick kilns, agricultural burning, and industry. The country still relies on Euro-II vehicle emissions norms, and emissions from large as well as smaller, informal industries are not regulated. Regional action plans (e.g., Punjab Clean Air Action Plan) have been announced, but progress is unclear.

Bangladesh released the draft Clean Air Bill in 2019, which sets the stage for preparation of the National Air Quality Management Plan as well as identification of critical air quality areas, among other measures. The country also undertook an extensive program (Clean Air and Sustainable Environment project) to address air pollution from brick kilns and the transportation sector between 2009 and 2019.

Global Patterns in Ozone Exposure

Global ozone exposures vary from a low of about 12.2 ppb to a high of 67.2 ppb across the globe (Figure 5). The 10 countries with the highest average ozone exposures in 2019 were in Asia and the Middle East (Table 2), although from the uncertainty intervals, the differences in the rankings are not always significant. Small island states, such as Micronesia and Papua New Guinea, were among the countries with the lowest concentrations.

How do these exposure levels compare with health-based standards? The WHO set a guideline for daily maximum 8-hour exposure to ozone at 50 ppb, a level exceeded by all of the top 10 countries. The U.S. National Ambient Air Quality Standard is 70 ppb and is calculated as the annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years. Neither is measured in exactly the same way as the GBD ozone levels; however, the steady increase in ozone levels in the last several decades is bringing them closer to levels of concern for public health in many regions of the world.

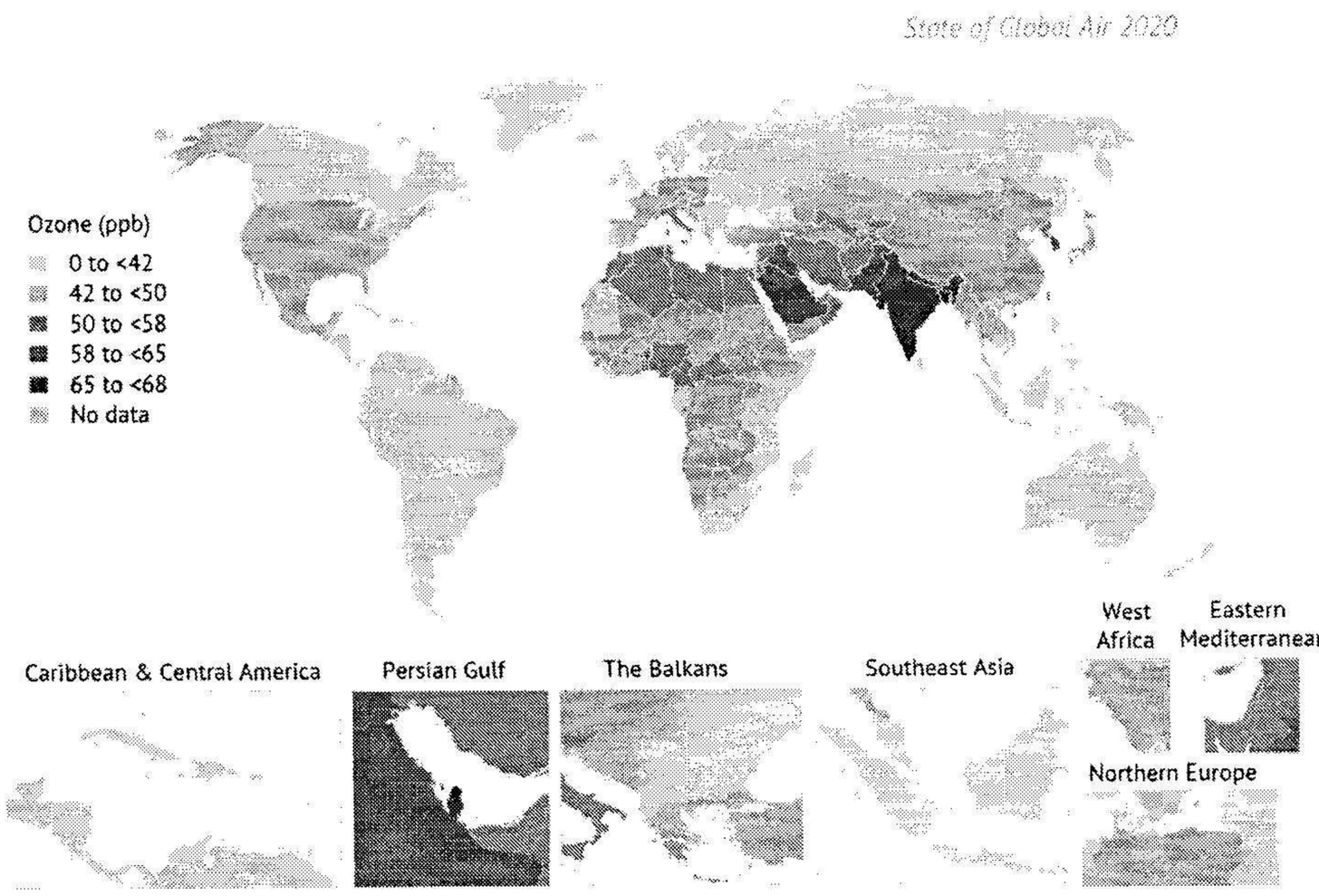
Global levels of ozone exposure have been slowly but steadily increasing over the past decade.

Trends in Ozone Exposure

On average, global exposure to ozone increased from about 47.3 ppb in 2010 to 49.5 ppb in 2019, although patterns across the GBD Super Regions vary (Figure 6). Countries in South Asia saw the steepest increase, while some countries in the High-Income, Central Europe, Eastern Europe, Central Asia and East Asia Regions experienced modest declines.

Figure 7 plots the absolute changes in population-weighted average seasonal 8-hour maximum ozone concentrations for the

FIGURE 5 Global map of population-weighted average seasonal 8-hour daily maximum ozone concentrations in 2019.



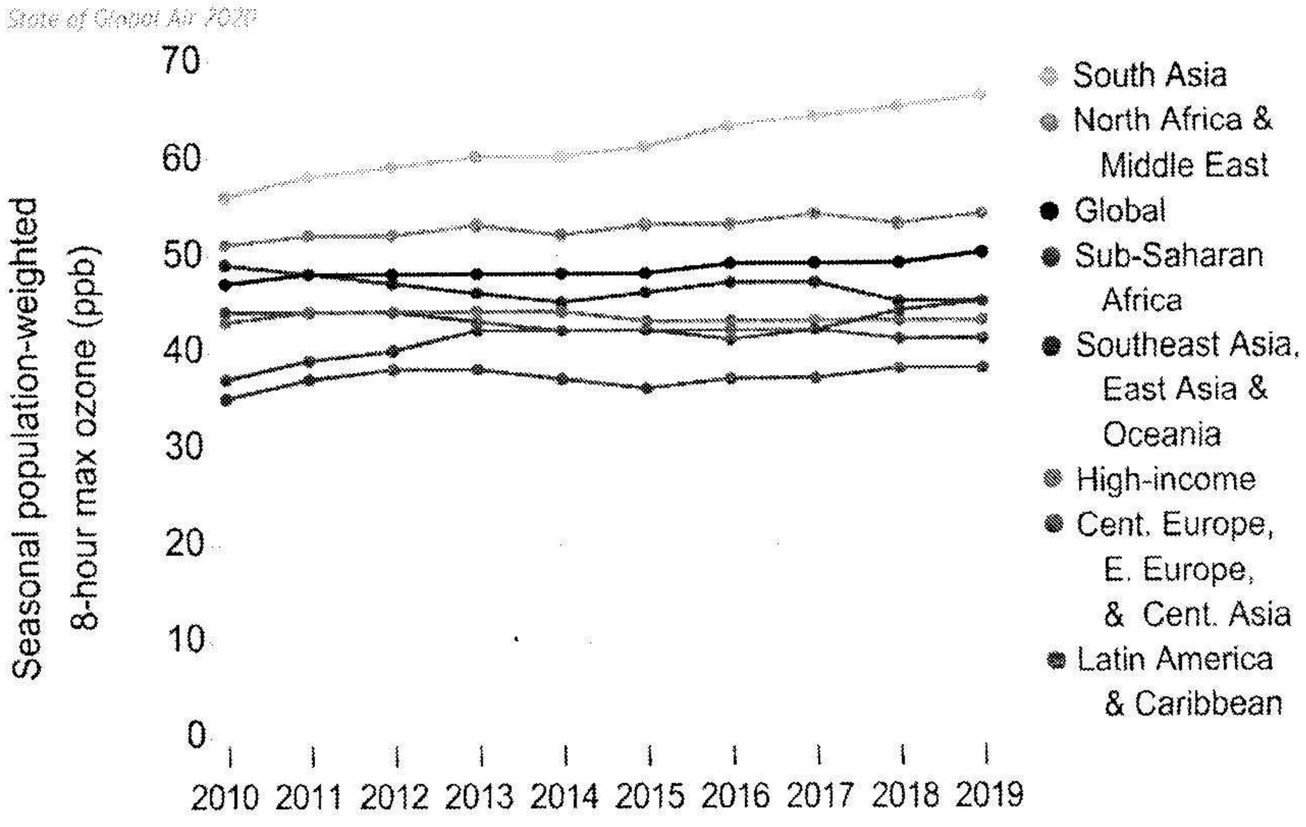
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TABLE 2 Top 10 countries with the highest ozone exposures globally in 2019.

Country	Tropospheric Ozone (ppb)	95% Uncertainty Intervals*
Qatar	67.2	62.3 to 72.4
Nepal	67.0	65.5 to 68.6
India	66.2	66.0 to 66.3
Bangladesh	64.6	63.9 to 65.3
Bahrain	64.0	51.7 to 75.9
Pakistan	63.3	62.8 to 63.8
Kuwait	62.1	57.6 to 67.1
Iraq (Islamic Republic of)	59.5	58.8 to 60.2
Republic of Korea	57.9	56.4 to 59.3
Saudi Arabia	58.2	57.7 to 58.6

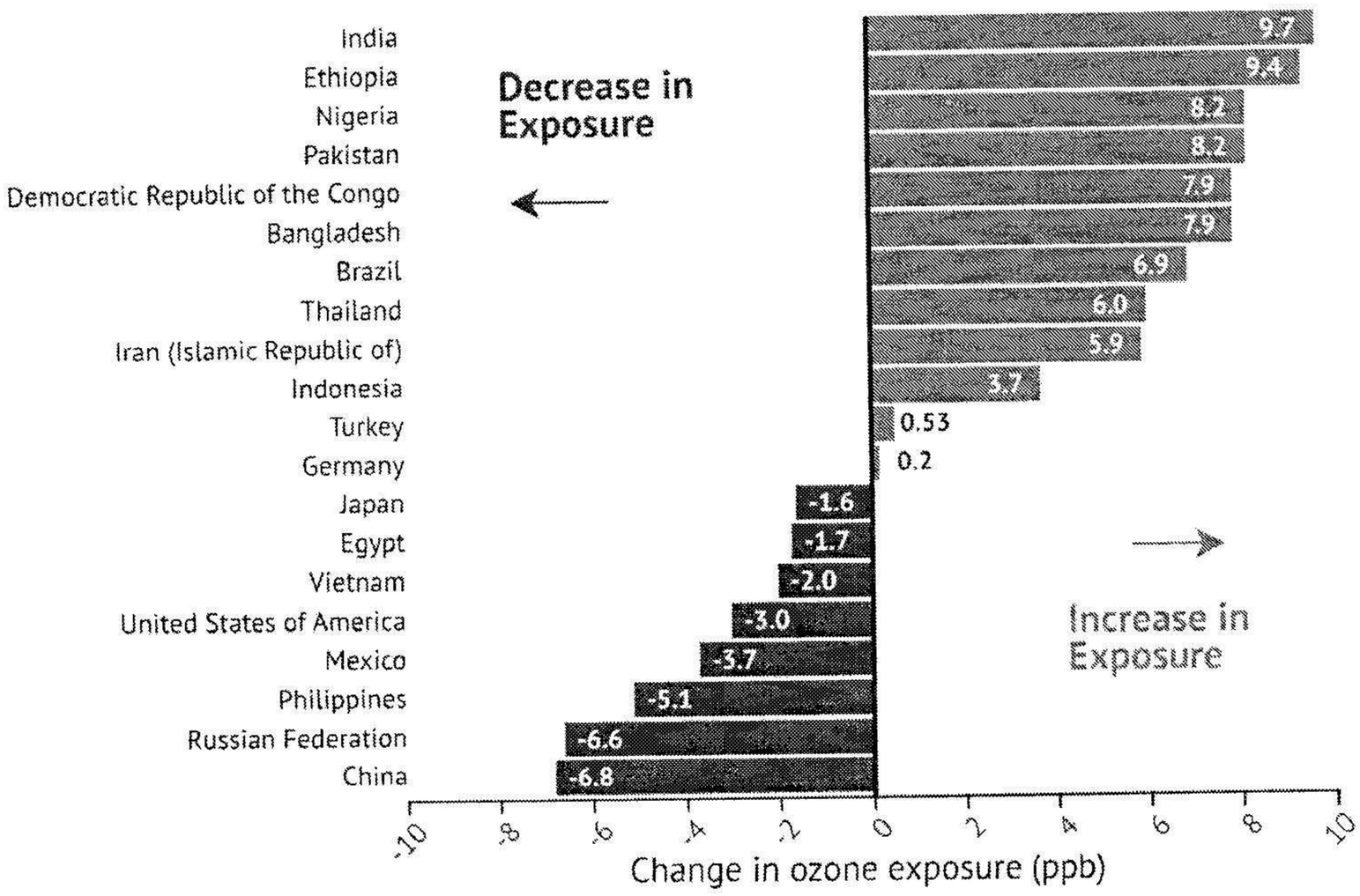
* The 95% uncertainty intervals are a measure of scientific uncertainty. They reflect a range of values, from the 2.5th to the 97.5th percentile of a possible distribution of values, within which the true concentration is likely to fall.

FIGURE 6 Trends in population-weighted average seasonal 8-hour maximum ozone concentration globally and in the GBD Super Regions, 2010–2019.



20 most populous countries from 2010 to 2019. Ethiopia, Nigeria, the Democratic Republic of the Congo, and Brazil experienced increases in ozone concentrations over this time frame. Ethiopia, for example, experienced a steep increase of 27% – from 34.9 ppb (95% UI: 34.5 to 35.3) in 2010 to 44.3 ppb (95% UI: 43.8 to 44.6) in 2019. Several of the most populous countries that already had the highest ozone concentrations in 2010 – India, Pakistan, and Bangladesh – have also seen some of the greatest increases. India, for example, experienced an increase of about 17% – from 56.5 ppb (95% UI: 56.3 to 56.6) in 2010 to 66.2 ppb (95% UI: 66.0 to 66.3) in 2019. Eight of the 20 countries saw a reduction in ozone levels over the past decade, ranging from a 1.6 ppb drop in Japan to a 6.8 ppb drop in China.

FIGURE 7 Change in population-weighted average seasonal 8-hour maximum ozone concentrations in the 20 most populous countries, 2010–2019.



OZONE

How Ozone Exposure Is Estimated

Like $PM_{2.5}$, ozone concentrations are measured in more-developed countries using extensive monitoring networks, but many parts of the world do not have such networks or have not made their data openly available to scientists. To characterize ozone concentrations and trends in a consistent way around the world – particularly for regions where monitoring data are sparse – scientists combine data from monitoring networks with outputs from atmospheric transport models. Using both approaches enables scientists to correct for differences between observed and modeled values and to estimate uncertainty in the model predictions.

This year the GBD project improved its methods for estimating ozone concentrations in several important ways. For the first time, in addition to data from the international scientific collaboration on ozone (see the Tropospheric Ozone Assessment Report [TOAR]), GBD scientists were able to obtain data from 1,565 surface ozone monitoring stations from the China National Environmental Monitoring Center network for the years 2013 to 2017, filling an important gap in global monitoring data. Along with the addition of other new stations globally, this network increased the number of observation locations from 4,400 to more than 8,800. Second, they expanded the combination of global atmospheric models used in their analysis from six to nine. Third, the team used improved methods to fuse, or combine statistically, the monitor observations and model results over both space and time, including for each year from 1990 to 2017. Finally, ozone concentrations were modeled at a finer spatial scale than in previous years. Together, these data and approaches led to greater confidence in the model predictions and estimates of human exposures. The annual trends were then extrapolated to the years 2018 and 2019.

Using this combined approach, the scientists are able to systematically estimate seasonal 8-hour maximum concentrations of ozone 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 exposures, or concentrations, that a population in a specific country is more likely to come into contact with, GBD scientists link the average seasonal 8-hour maximum concentrations in each block with the number of people living within each block to produce a *population-weighted average seasonal 8-hour maximum ozone concentration*. Population-weighted concentrations are better estimates of population exposures than simple averages because they give greater weight to the pollutant concentrations experienced where most people live. *Gridded data are available upon request.*

HOUSEHOLD AIR POLLUTION

Household air pollution results from the burning of various fuels (coal, charcoal, wood, agricultural residue, animal dung, and kerosene, among others) for heating or for cooking using open fires or cookstoves with limited ventilation. Burning these fuels produces an array of pollutants that may harm human health, including fine particulate matter ($PM_{2.5}$), black carbon, and carbon monoxide. The GBD focuses only on the role of burning solid fuels for cooking in its estimates of exposure to household air pollution. These exposures in homes are estimated in terms of $PM_{2.5}$ concentrations based on the proportion of a country's population that relies on solid fuel for cooking, combined with evidence from household and personal exposure measurement studies. (See "How Household Air Pollution Is Estimated" on page 14.) These estimates are likely to understate the total exposure and health burden in some locations because they do not include exposures related to use of solid fuels for heating and for hot water, or exposures from burning of liquid fuels such as kerosene.

Although this analysis focuses on the exposures experienced in the home only, household air pollution is a major contributor to ambient $PM_{2.5}$, and as we have reported elsewhere, it is sometimes a dominant source. However, these exposures are accounted for as part of exposures to ambient $PM_{2.5}$ presented in the previous section.

Global Patterns in Household Air Pollution Exposure

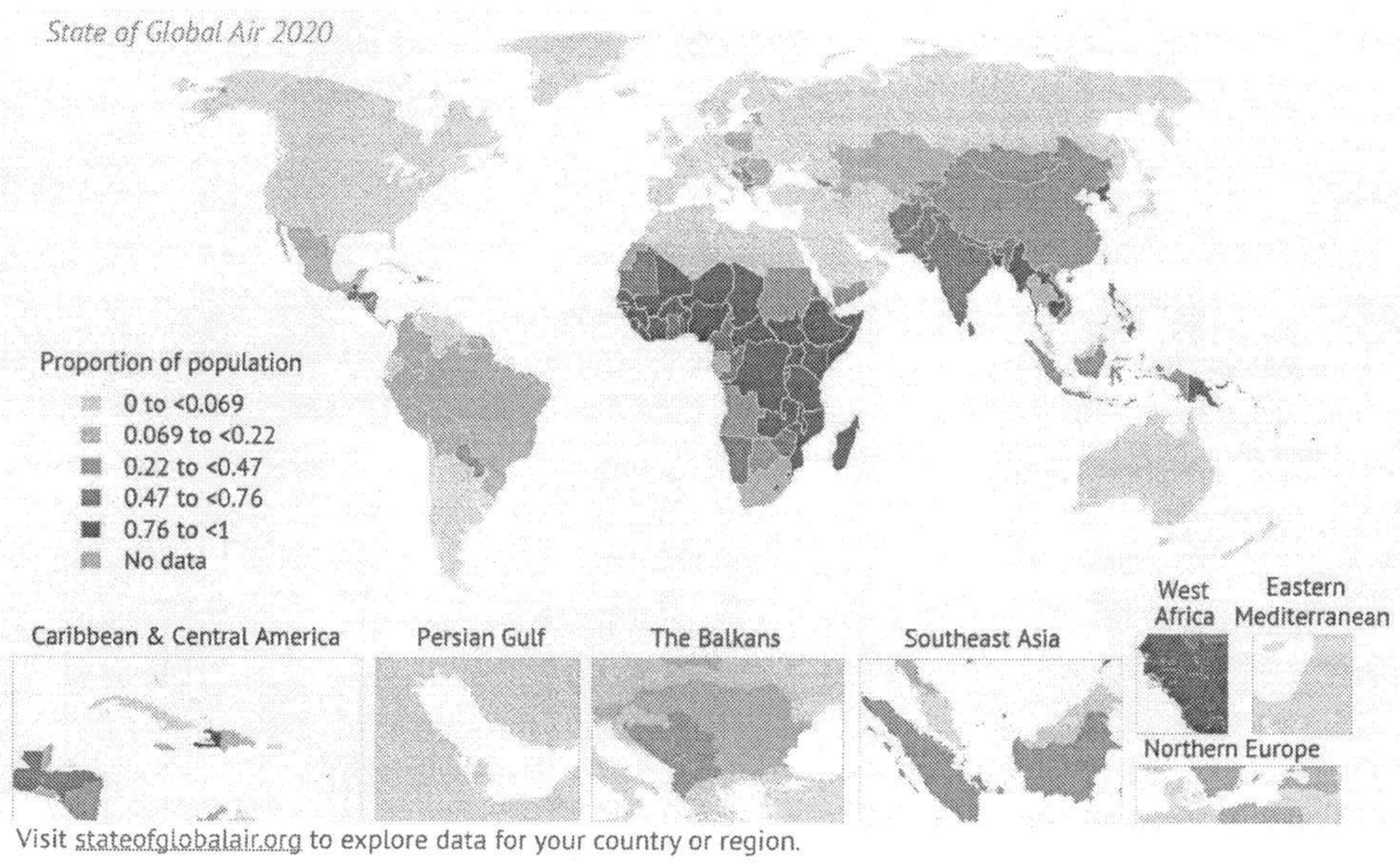
Exposures to household air pollution are most widespread in sub-Saharan Africa and in parts of Asia (Figure 8). The 10 countries with the highest proportion of households cooking with solid fuels are the Central African Republic, South Sudan, Rwanda, Burundi, Niger, Mali, Madagascar, Tanzania, Uganda, and Guinea-Bissau; in each, more than 97% of the country's population uses solid fuels for cooking.

Most people who rely on solid fuels for cooking live in Africa and Asia.

Trends in Household Air Pollution Exposure

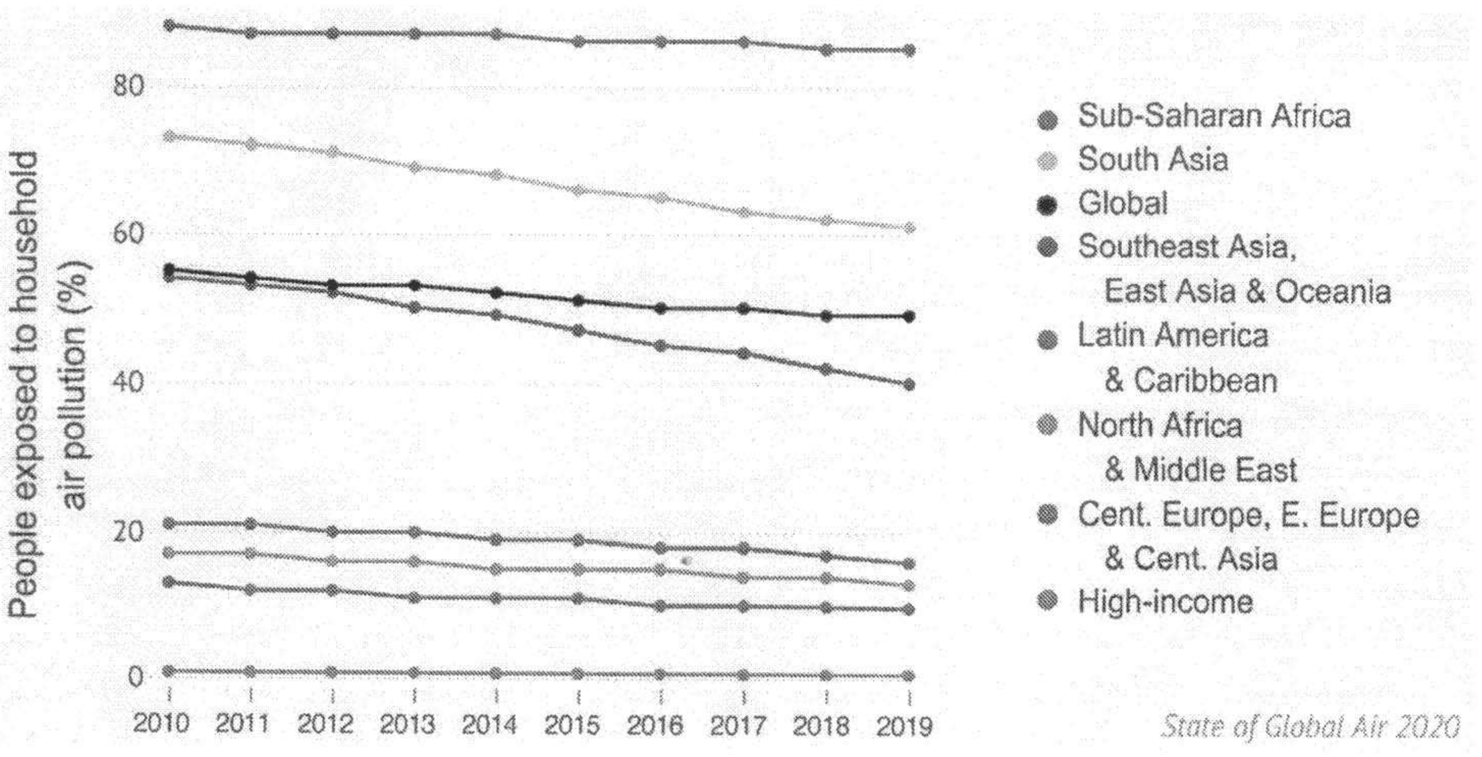
Since 2010, the use of solid fuels has fallen slowly and steadily in most regions, in particular in South Asia and in the Southeast Asia, East Asia, and Oceania Super Regions (Figure 9). Progress has been slower in sub-Saharan Africa. Declines in solid fuel use — reflecting years of efforts to move to cleaner energy sources as well as broader development and urbanization that have made that process easier — have led to an 11% overall reduction in the percentage of the global population relying on solid fuels for cooking. However, that still leaves 49% of the world's population — about 3.8 billion people — exposed to household air pollution from the burning of solid fuels. Most of them live in just 17 countries — those with over 50 million people and more than 10% of the population relying on solid fuels for cooking.

FIGURE 8 Global map of the proportion of each country's population cooking with solid fuels in 2019.



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

FIGURE 9 Trends in the proportion of each country's population cooking with solid fuels globally and in the GBD Super Regions, 2010–2019.

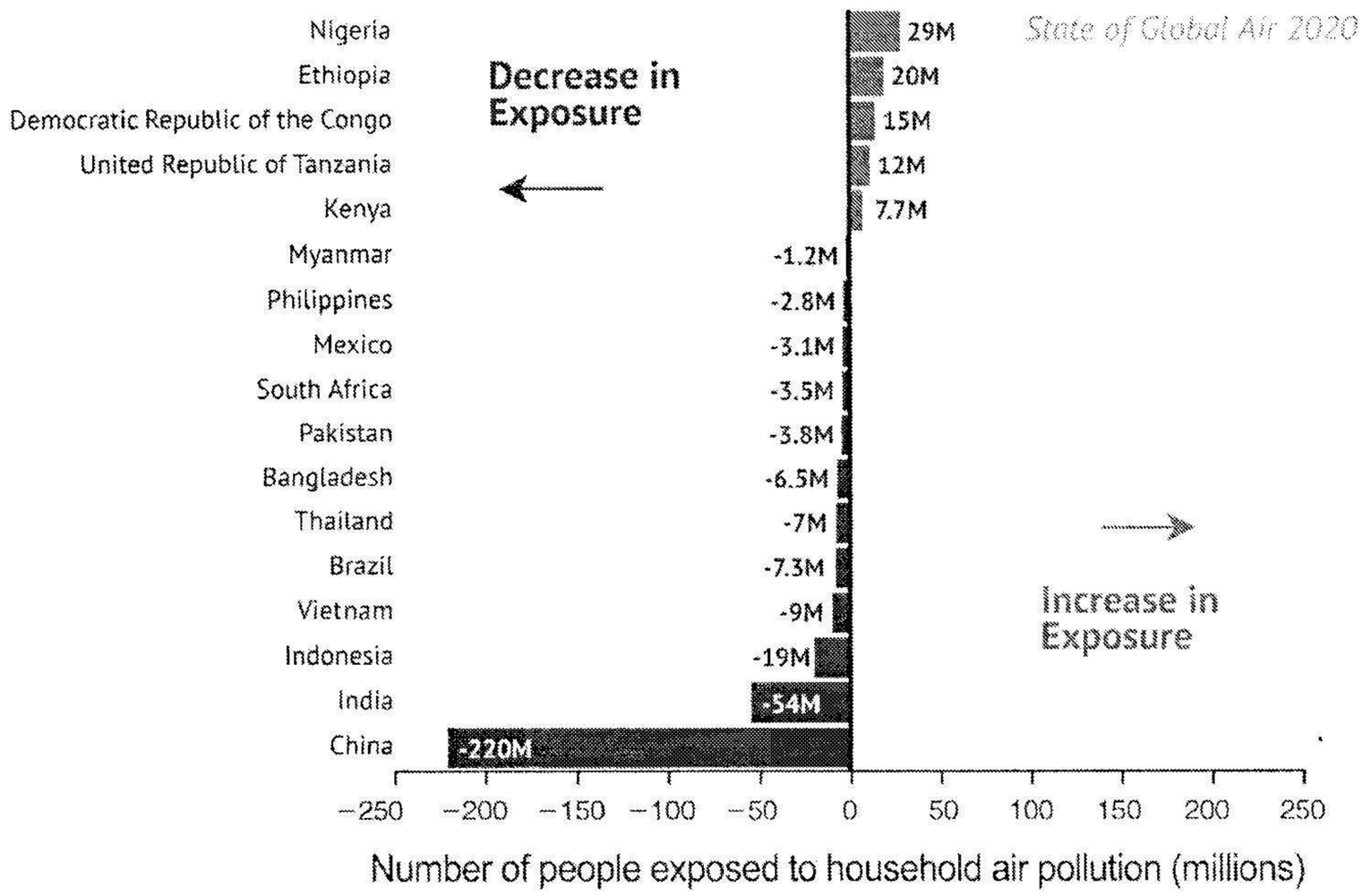


The reduction in exposures to household air pollution is a growing success story, but half of the world's population remains exposed.

The global average reductions in the percentage of populations exposed to household air pollution from 2010 to 2019 mask important differences among individual countries. The impact on the numbers of people affected is clearly dominated by countries in South and East Asia, most notably in India and China, where there have been aggressive campaigns encouraging a switch to cleaner fuels (Figure 10). China reduced the percentage of its population exposed to household air pollution from 54% to 36%, while India reduced its percentage from 73% to 61% over the decade.

Several countries in Africa with fast-growing populations actually experienced net increases in the numbers of people exposed to household air pollution, despite reductions in the percentages of their populations using solid fuels for cooking. Nigeria, for example, reduced the percentage of its population using solid fuels from 82% to 77%, but population growth meant that 29 million people remained exposed. Increases in the numbers of people exposed occurred in countries such as Ethiopia and the Democratic Republic of the Congo where 96% and 93% of the populations, respectively, continue to rely on solid fuels for cooking.

FIGURE 10 Change in the number of people exposed to household air pollution in the 17 countries with over 50 million people and at least 10% of their population cooking with solid fuels, 2010–2019.



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AIR POLLUTION AND DEVELOPMENT

Disparities in socioeconomic development contribute to disparities in exposure and health. To capture different facets of development that are relevant to health outcomes, the GBD project uses a metric called the *sociodemographic index* (SDI). A country's SDI is calculated based on average income per person, educational attainment, and total fertility rate (number of children per woman). It varies from zero to one, with zero indicating the lowest income and educational attainment but the highest fertility rate – indicative of low sociodemographic development – and one indicating the opposite. An analysis of SDI and air pollution exposures reveals patterns for household air pollution and ambient $PM_{2.5}$, with no strong pattern evident for ozone (Figure 11).

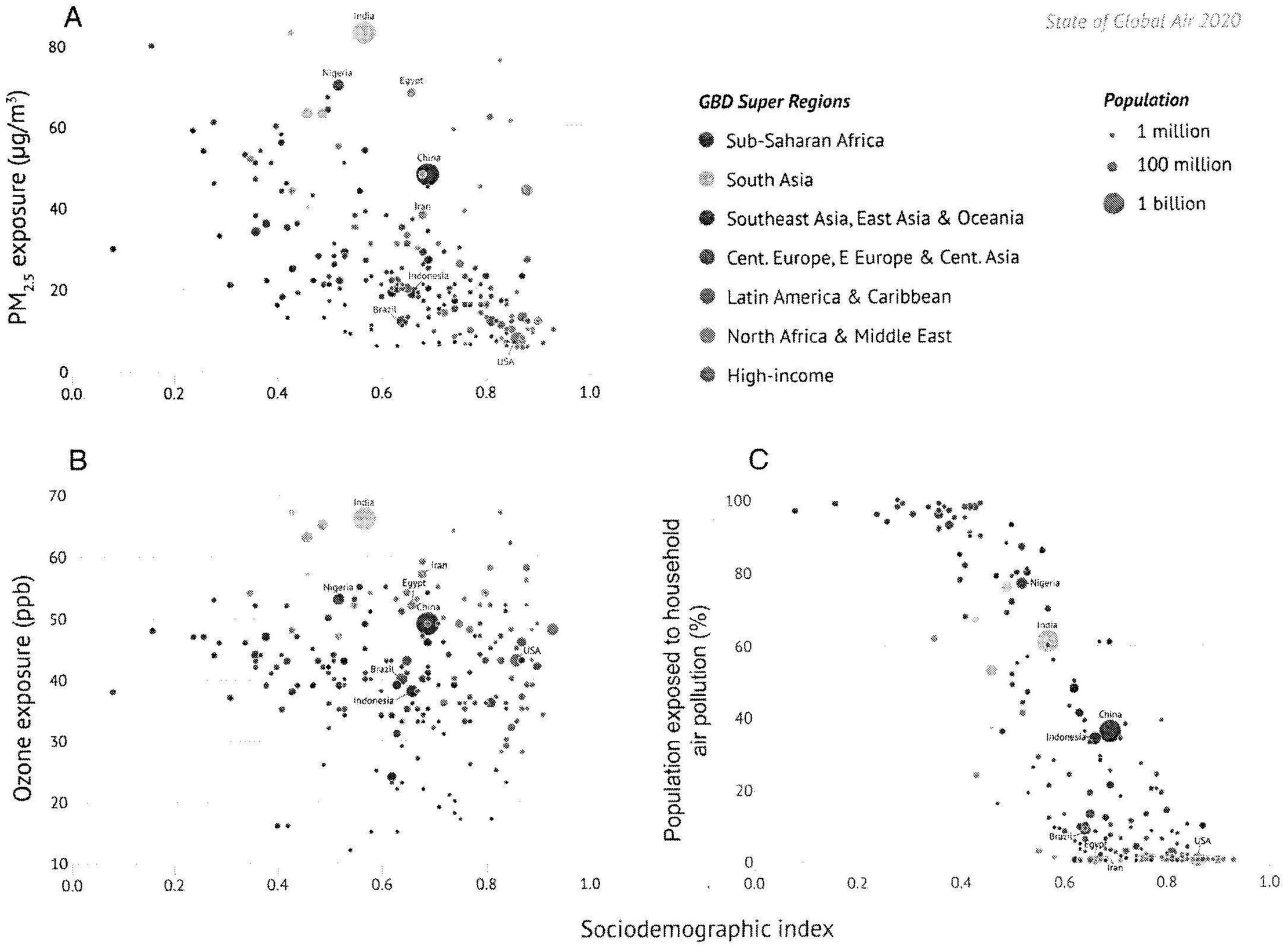
The least-developed countries suffer the worst air quality

Exposure patterns for ambient $PM_{2.5}$ suggest that lower sociodemographic development tends to be associated with higher exposures to $PM_{2.5}$. Countries in sub-Saharan Africa generally have the lowest SDI and the highest $PM_{2.5}$ levels, while high-income countries experience the lowest $PM_{2.5}$ exposure. However, the correlation between SDI and $PM_{2.5}$ is only moderate. Some variation is likely because $PM_{2.5}$ is a regional pollutant that can be carried long distances, affecting neighboring countries regardless of their levels of development. Higher $PM_{2.5}$ exposures in some more-developed countries in North Africa and the Middle East may also reflect impacts from local dust sources as well as wind-blown dust from the Sahara, which would not be expected to be associated with SDI.

Exposure patterns for ozone reveal no consistent relationship between SDI and exposures. However, limited regional patterns suggest some of the highest ozone levels occur in the higher SDI countries of North Africa and the Middle East (see orange dots in Figure 11), particularly in Kuwait, Saudi Arabia, Bahrain, and Iraq. These higher levels may reflect regional sources of ozone precursors due to oil production and related industries, as well as local meteorology.

Exposure patterns for household air pollution reveal a clear relationship between SDI and the proportion of households using solid fuels Countries with lower SDI have higher rates of reliance on solid fuels that may be either subsidized or easily gathered locally; often, these countries also lack the infrastructure to provide clean energy. Household air pollution exposure declines sharply in countries with higher levels of SDI.

FIGURE 11 Exposures in countries with different levels of sociodemographic development: **(A)** $PM_{2.5}$, **(B)** ozone, and **(C)** household air pollution. Dots represent individual countries, color-coded according to GBD Super Region. Dot size reflects population size. Higher SDI indicates a greater level of sociodemographic development.



How Household Air Pollution Is Estimated

In the GBD project, exposure to $PM_{2.5}$ related to household air pollution is estimated using a multi-step 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, updated each year from 1980 to 2019. 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 other key studies (for a total of 75 studies in 43 countries). This translation process relies on a mathematical model that takes into account the type of fuel (solid or non-solid), type of air pollution measurement (e.g., kitchen versus personal), duration of the measurement, whose exposure was measured (men, women, or children), and the sociodemographic index for the location and year.

To make sure that the estimated exposure to $PM_{2.5}$ for each location and year represents household exposures only, GBD scientists subtract the ambient $PM_{2.5}$ concentration for each study location at the time of measurement. In this way, the analysis provides independent estimates of exposures to household pollution and to ambient $PM_{2.5}$.

BURDEN OF DISEASE FROM AIR POLLUTION

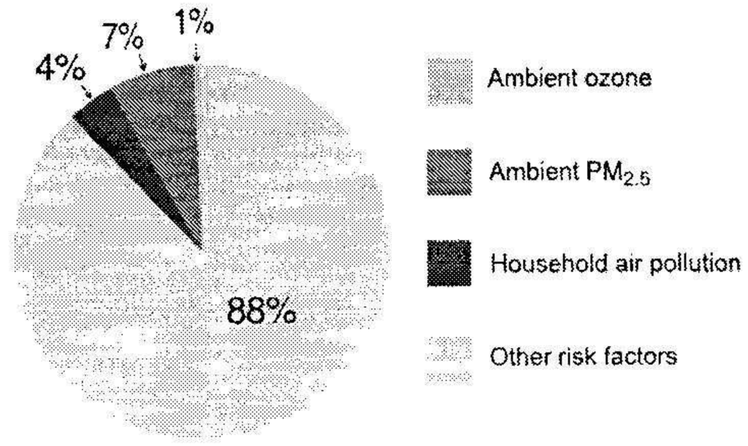
Exposure to air pollution has serious health consequences. Understanding these consequences — the risks faced by particular groups, the impacts of different pollutants, and the changes over time — is key to informing air quality interventions and saving lives.

Understanding the burden of disease that air pollution places on society begins with the scientific evidence for its effects on health. An extensive body of scientific evidence has been amassed over several decades, including studies from many countries of the world. Short-term exposures to air pollution can harm health; for example, high-pollution days can trigger asthma symptoms and cause a local spike in hospitalizations or even deaths related to respiratory and cardiovascular diseases. There is broad scientific consensus that long-term exposures to air pollution contribute to increased risk of illness and death from ischemic heart disease, lung cancer, chronic obstructive pulmonary disease (COPD), lower-respiratory infections (e.g., pneumonia), stroke, type 2 diabetes, and, more recently, adverse birth outcomes, and that the public health burden from these exposures is much larger than that from short-term exposures. The GBD project relies on epidemiological studies and other evidence to estimate the burden of disease from air pollution in terms of the deaths and years of healthy life lost borne by populations as a whole in every country of the globe. (See "How Burden of Disease Is Estimated" on page 22.) Ongoing studies continue to explore air pollution's role in the development of asthma, cognitive disorders, and other effects (e.g., chronic kidney disorders) which, as evidence accumulates, will be considered for inclusion in the GBD project in future years.

In 2019, air pollution is estimated to have contributed to 6.67 million deaths (95% UI: 5.90 to 7.49 million) worldwide, nearly 12% of the global total (Figure 12). Air pollution is the leading environmental risk factor for early death, with its total impact exceeded only by high blood pressure (10.8 million, 95% UI: 9.51 to 12.1 million), tobacco use (8.71 million, 95% UI: 8.1 to 9.3 million), and dietary risks (7.94 million, 95% UI: 6.5 to 9.8 million) (Figure 1). Every year, far more people worldwide die as a result of air pollution exposure than die from traffic collisions, a number estimated at 1.28 million in 2019.

In 2019, air pollution contributed to 6.67 million deaths worldwide.

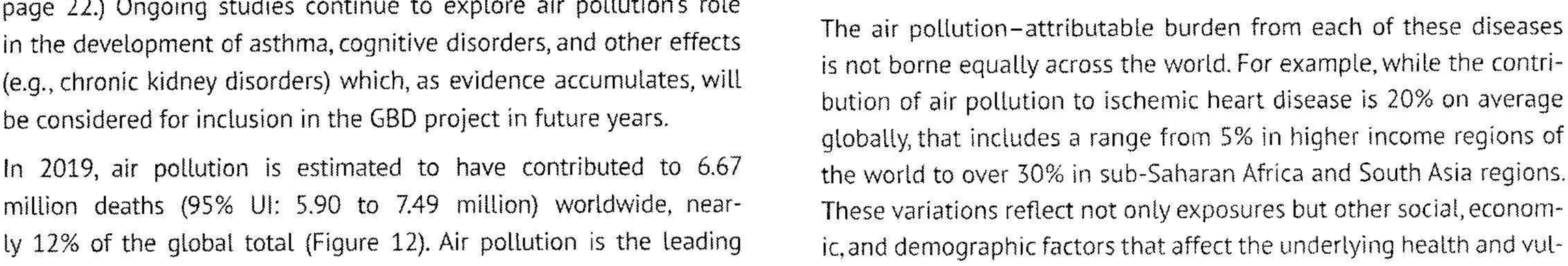
FIGURE 12 Percentage of global deaths attributable to individual pollutants.



This large burden of disease reflects the substantial contribution that long-term exposures to air pollution make to chronic noncommunicable disease and, more specifically, to some of the world's leading causes of death in 2019 (Figure 13). About 80% of air pollution's burden is attributed to noncommunicable diseases. For example, $PM_{2.5}$, household air pollution, and ozone together contribute as much as 40% of deaths from COPD, a highly debilitating lung disease. Air pollution also contributes to as much as 30% of lower-respiratory infection as well as 20% of infant mortality in the first month of life.

The air pollution–attributable burden from each of these diseases is not borne equally across the world. For example, while the contribution of air pollution to ischemic heart disease is 20% on average globally, that includes a range from 5% in higher income regions of the world to over 30% in sub-Saharan Africa and South Asia regions. These variations reflect not only exposures but other social, economic, and demographic factors that affect the underlying health and vulnerability of populations to air pollution in those regions. To reduce the burden of disease attributable to each of these diseases and for each air pollutant, each country will need to explore and understand its own data. Some of these data (e.g., exposures and mortality/DALY rates) are available on the State of Global Air website, while additional data may be found on the Global Burden of Disease website.

FIGURE 13 Percentage of global deaths from specific causes attributable to total air pollution.



Visit stateofglobalair.org to explore data for your country.

A BURDEN BORNE BY THE YOUNG AND OLD

The burden of disease attributable to air pollution does not fall evenly across age groups. Throughout the world, children and the elderly are most acutely affected.

Figure 14 shows a peak in pollution-related deaths among babies in the early (0 to 6 days) and the late (7 to 27 days) neonatal groups, reflecting the influence of particulate matter on adverse birth outcomes and lower-respiratory infections, while the second, larger peak in the older age groups reflects air pollution's contributions to lower-respiratory infections and major noncommunicable diseases that develop over time — ischemic heart disease, stroke, COPD, lung cancer, and type 2 diabetes. DALYs follow a similar pattern as total deaths, though the first peak is much higher for the younger age groups, reflecting the lifetime of years lost for the youngest babies.

FIGURE 14 Distribution of global deaths in 2019 attributable to $PM_{2.5}$, ozone, and household air pollution by age (years, except early neonatal [0 to 6 days] and late neonatal [7 to 27 days]).

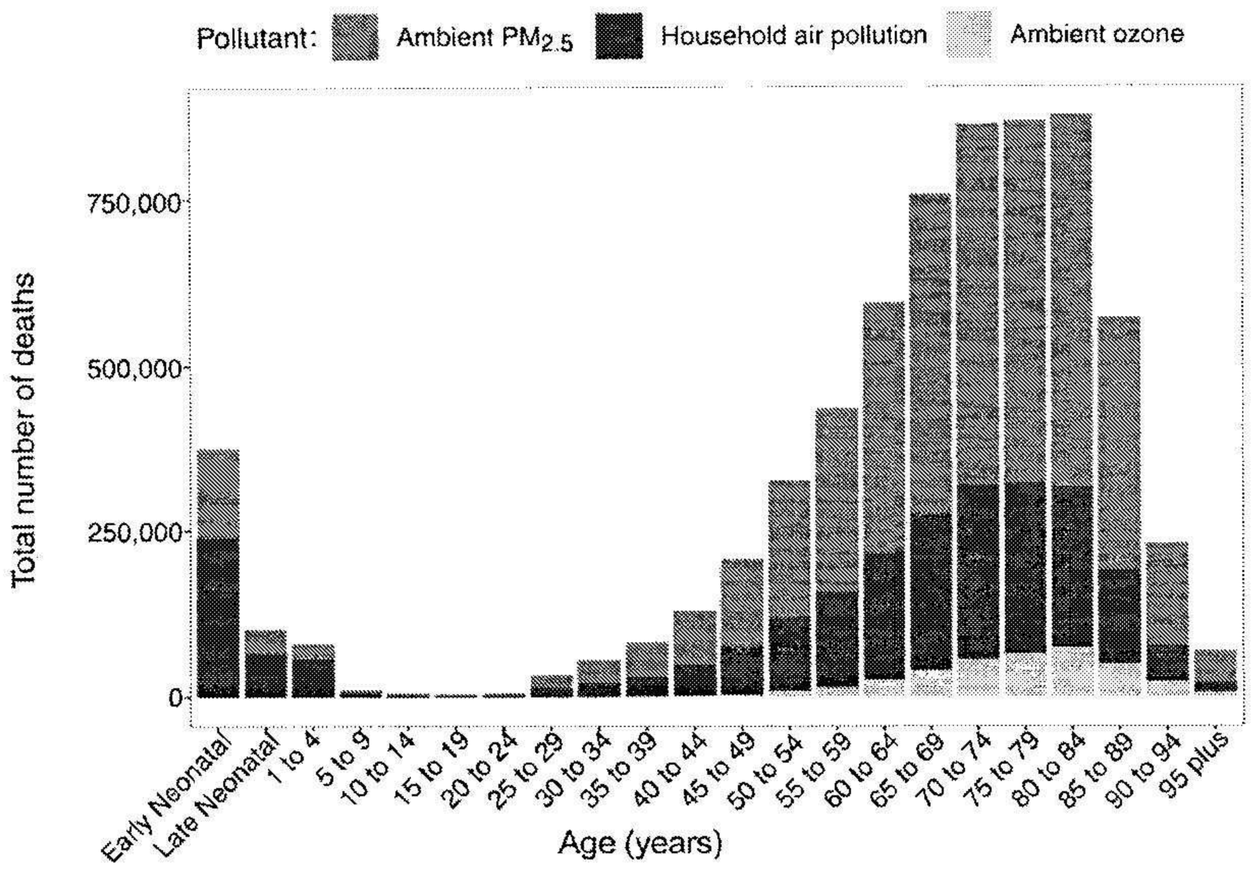


Figure 14 also provides insights into how the three types of air pollution affect different age groups. Ambient $PM_{2.5}$ and household air pollution are the largest contributors to mortality and years of healthy life lost across age groups. Because COPD takes years to develop and is the only health outcome included in the analysis for ozone, the effects of ozone are seen only in adults.

Does Air Quality Affect COVID-19 Susceptibility?

Extensive evidence links exposure to air pollution with higher rates of respiratory and cardiovascular diseases, including lower-respiratory infections. Could air pollution also increase a person's risk of developing a COVID-19 respiratory infection or suffering its most severe complications?

There is reason to believe it could. SARS-CoV-2, the coronavirus that causes COVID-19, is a respiratory virus that can affect the lungs, blood vessels, and many other parts of the body. Exposure to air pollution has been shown to affect the body's immune defense, making an individual more susceptible to respiratory and other infections. In addition, many of the health conditions that have been associated with increased vulnerability to COVID-19 — such as diabetes, cardiovascular disease, and chronic obstructive lung diseases — are also caused by long-term exposure to air pollution.

What we learned from the SARS-CoV-1 outbreak in 2002–2004 offers some insight into the interaction between air pollution and the effects of COVID-19. Several studies reported an association between higher air pollution concentrations and higher than expected death rates from SARS-CoV-1. A handful of early studies of COVID-19 appear to suggest that areas with higher air pollution concentrations — $PM_{2.5}$ or NO_2 in particular — might similarly experience either higher infection rates or higher case fatality rates. Investigators around the world are hard at work trying to understand fully the linkages between COVID-19 and air pollution, and how exposure to air pollution might affect rates of COVID-19 infection, the severity of disease, or the likelihood of dying.

IStock/life in shots

Delhi, India.

BURDEN OF DISEASE FROM AMBIENT FINE PARTICLE AIR POLLUTION

In 2019, long-term exposures to ambient particulate matter ($PM_{2.5}$) pollution contributed to 4.14 million deaths [95% UI: 3.45 to 4.80] and 118 million lost DALYs [95% UI: 95.9 to 138], accounting for 62% of all air pollution–attributable deaths and 55% of DALYs, respectively. Among 69 risk factors included in the GBD analysis that are considered to be potentially modifiable, ambient $PM_{2.5}$ ranks 6th behind high blood pressure, smoking, and high blood sugar, among others. It is the leading risk factor among all environmental and occupational risks.

Global Patterns in $PM_{2.5}$ Burden of Disease

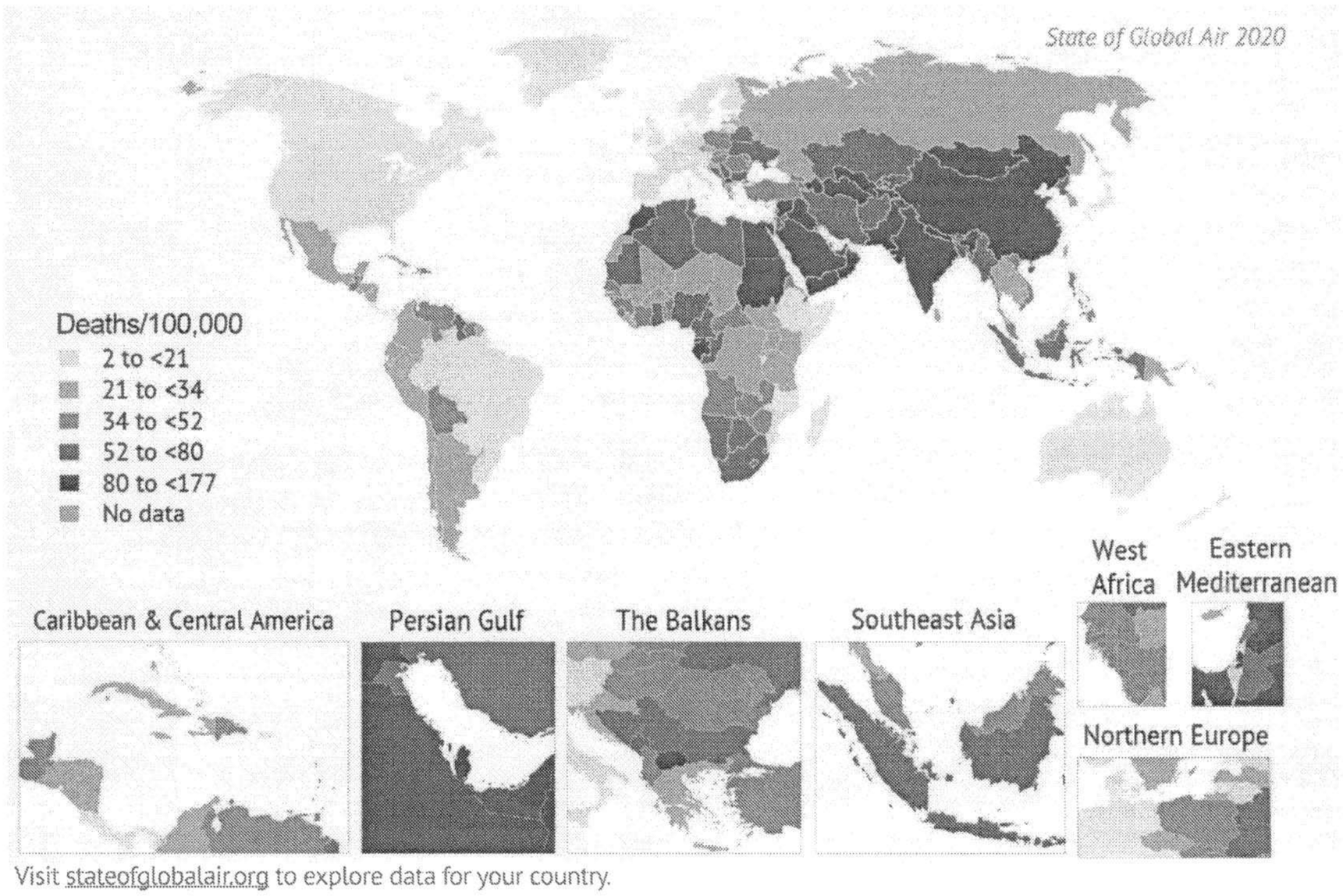
The burden attributable to $PM_{2.5}$ varies widely around the globe, reflecting variation in exposures and underlying prevalence of disease and other population susceptibilities (Figure 15). Globally, countries in Asia and Africa experience the highest age-standardized rates of death and DALYs attributable to $PM_{2.5}$: for example, India (96 deaths/100,000 population, 95% UI: 75 to 116); China (81 deaths/100,000, 95% UI: 67 to 96); Egypt (157/100,000, 95% UI: 117 to 200); Iran (63/100,000, 95% UI: 55 to 71); and Nigeria (59/100,000, 95% UI: 37 to 85). Countries in the GBD High-Income Region have rates that are far lower: Germany (13/100,000, 95% UI: 9.7 to 16); United Kingdom (11/100,000, 95% UI: 7.3 to 14); the United States (8.5/100,000, 95% UI: 4.7 to 13); Canada (5.4/100,000, 95% UI: 2.6 to 8.5); and Norway (3.8/100,000, 95% UI: 1.5 to 6.5).

Ambient $PM_{2.5}$ is the largest driver of air pollution's burden of disease worldwide.

Although age-standardized rates of death are important for comparing the health burden among countries, total numbers of deaths are useful for identifying where the most people are affected. Globally, the $PM_{2.5}$-attributable mortality burden continues to be dominated by the most populous countries in the world – China, which saw 1.42 million $PM_{2.5}$-attributable deaths (95% UI: 1.17 to 1.69 million) and India, which saw 980,000 $PM_{2.5}$-attributable deaths (95% UI: 0.77 to 1.19 million). Together, these two countries account for 58% of worldwide deaths attributed to $PM_{2.5}$ in 2019.

Total mortality is also high in many of the same countries where age-standardized death rates are high. In North Africa and the Middle East, the 10 countries with the highest numbers of $PM_{2.5}$-attributable deaths are Egypt, which had 91,000 such deaths (95% UI: 67,000 to 117,000), followed closely by Iran, Turkey, Morocco, Iraq, Algeria, Saudi Arabia, Yemen, Syria, and Tunisia. In sub-Saharan Africa, the top 10 countries with the highest burden are led by Nigeria (68,500 deaths, 95% UI: 41,000 to 102,000) followed more distantly by South Africa, Ghana, the Democratic Republic of the Congo, Cameroon, Ethiopia, Côte d'Ivoire, Tanzania, Angola, and Kenya. In South Asia, three countries account for most of the $PM_{2.5}$-attributable deaths: India (980,000, 955 UI: 770,000 to 1,192,000), Pakistan (114,000, 95% UI: 78,500 to 151,000), and Bangladesh (74,000, 95% UI: 48,000 to 102,000).

FIGURE 15 Global map of age-standardized rates of death attributable to $PM_{2.5}$ in 2019.



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Trends in $PM_{2.5}$ Burden of Disease

Over the past decade, the number of deaths attributable to ambient $PM_{2.5}$ globally increased by 23.3% (95% UI: 13.9 to 34.4) even as attributable death rates declined by about 4% (–3.9%, 95% UI: –10.8 to 4.9). Similarly, the numbers of ambient $PM_{2.5}$-attributable DALYs have increased by 17.1% despite declines in DALY rates. The difference in these trends hints at the competing factors that influence overall burden of disease from $PM_{2.5}$. Declining age-standardized rates attributable to air pollution reflect improvements in treatment of, and survival from, underlying diseases to which air pollution contributes. Given the relatively stable global $PM_{2.5}$ exposures, increase in deaths or DALYS despite the declining rates points to the substantial impact of the growth and aging of the global population.

These trends are strikingly different across GBD Super Regions (Figure 16). South Asia and Southeast Asia, East Asia, and Oceania saw steep increases in total deaths attributable to $PM_{2.5}$, while more modest increases were seen in sub-Saharan Africa and in North Africa and the Middle East. Together, the increases in these regions vastly outweigh the modest decreases in the High-Income and the Central Europe, Eastern Europe, and Central Asia Regions.

A closer look at the 20 most populous countries provides some insights into where some of the major changes in $PM_{2.5}$-attributable mortality burden have taken place (Figure 17). Over the past decade, 16 of these countries experienced increases in $PM_{2.5}$-attributable deaths, ranging from 2,350 deaths (a 6% increase) in Turkey to 373,000 in India, an increase of 61%. China experienced a 20% increase, about 238,000 deaths. Although they did not have the largest burden overall, Bangladesh and the Democratic Republic of the Congo experienced the highest percentage increases in burden over this time period. Decreases in deaths attributable to $PM_{2.5}$ ranged from a reduction of over 900 deaths (a 2% decrease) in Brazil to over 48,000 in the Russian Federation (a decrease of 39.6%).

What's driving these changes? Several factors can contribute, sometimes with opposite effects. Air pollution exposures may rise or fall. Reductions in mortality rates for the diseases associated with air pollution — for example, through the availability of better treatments — can also reduce pollution-attributable death rates. Because socioeconomic development can be tied to both air pollution exposures and the availability of health care, changes in a country's level of development can also influence the burden of disease over time.

Even as exposures to $PM_{2.5}$ level off, the attributable burden of disease continues to rise as populations grow and age.

Overall, changes in population size and age structure sometimes have the largest impacts on these trends. Even if exposures to air pollution are decreasing, the overall attributable burden of disease can increase if a population is growing faster than exposures are falling. By the same token, a population that is aging will likely face a higher burden of disease because older people develop, and are more susceptible to, diseases linked with air pollution. Together, population growth and aging of the global population are estimated to account for more than half of the increased deaths attributed to $PM_{2.5}$ exposure over the past decade.

FIGURE 16 Trends in total deaths attributable to $PM_{2.5}$ in the GBD Super Regions.

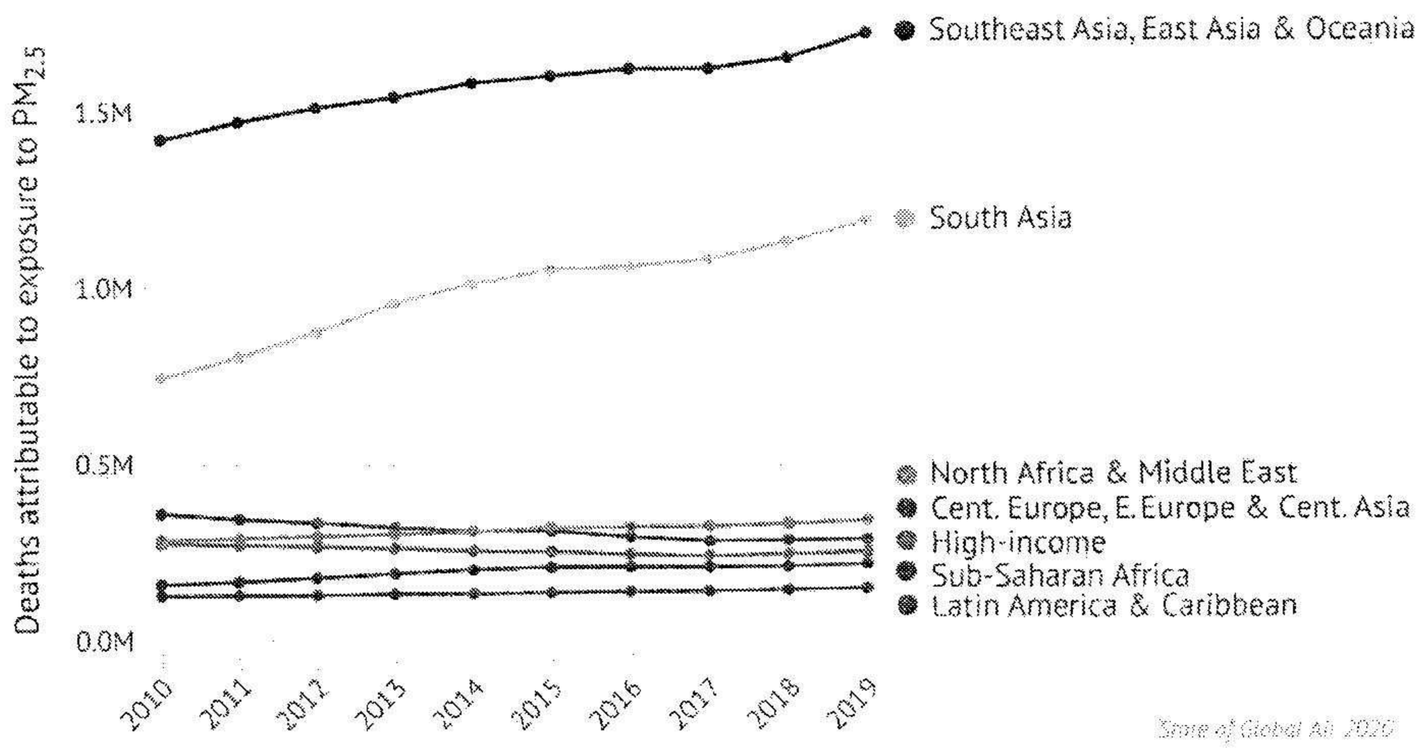
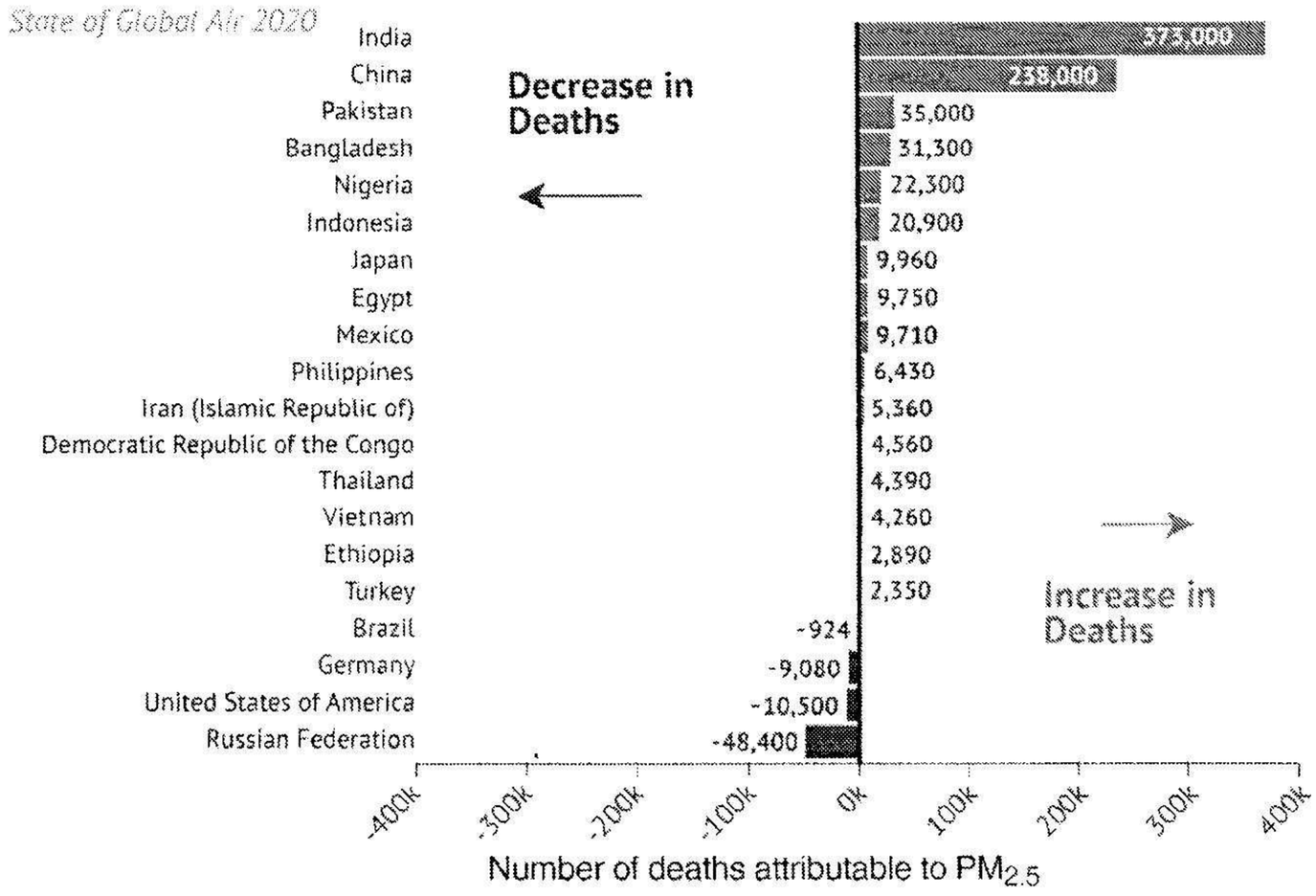
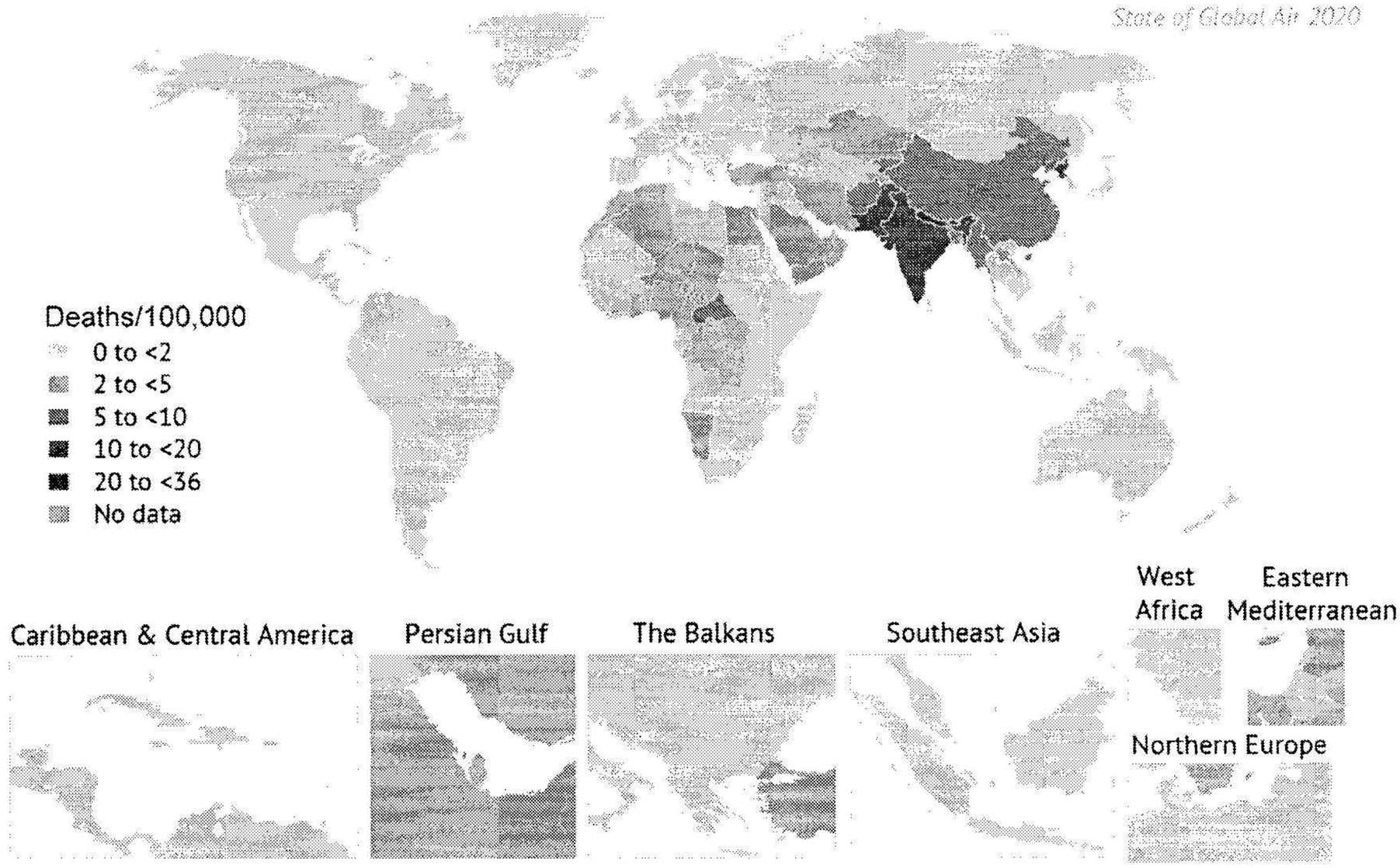


FIGURE 17 Change in total deaths attributable to $PM_{2.5}$ in the 20 most populous countries, 2010–2019.



Visit stateofglobalair.org to explore data for your country.

FIGURE 18 Global map of age-standardized rates of death attributable to ozone in 2019.



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BURDEN OF DISEASE FROM AMBIENT OZONE AIR POLLUTION

In 2019, long-term exposures to ozone contributed to an estimated 365,000 deaths (95% UI: 175,000 to 564,000) from COPD worldwide, accounting for 11.1% (95% UI: 5.32 to 17) of all COPD deaths globally. This premature loss of life equates to 6.21 million (95% UI: 2.99 to 9.63 million) DALYs from COPD across the world.

Ozone exposure accounts for 1 out of every 9 deaths from COPD globally.

Global Patterns in Ozone

The highest age-standardized rates of death attributable to ozone occurred in countries in Asia — in particular, India (18/100,000, 95% UI: 8.9 to 28), Pakistan (14/100,000, 95% UI: 6.7 to 21), and Bangladesh (8.8/100,000, 95% UI: 4.1 to 16) compared with 4.7/100,000 globally (Figure 18). China's rate was lower at 5.9/100,000 (95% UI: 2.7 to 9.6). India and China, which have quite different rates of ozone-attributable deaths but large populations, had the highest overall numbers of ozone-attributable deaths worldwide, with 168,000 (95% UI: 82,000 to 262,000) deaths occurring in India and 93,300 (95% UI: 42,700 to 151,000) occurring in China. The United States has a lower overall rate of ozone-attributable deaths (2.1/100,000, 95% UI: 0.93 to 3.6) compared with these countries, but one that is higher than most other countries in the High-Income Super Region. Given its sizeable population, the United States saw 13,000 (95% UI: 5,600 to 21,000) ozone-attributable deaths, again more than any other country in the High-Income Super Region.

Trends in Ozone's Burden of Disease

Although global mortality rates from COPD attributable to ozone have declined by nearly 13% (95% UI: −20.3 to −4.9) over the past decade, the overall number of associated deaths increased by 16.1% (95% UI: 5.8 to 26.7). Trends in DALYs show the same pattern.

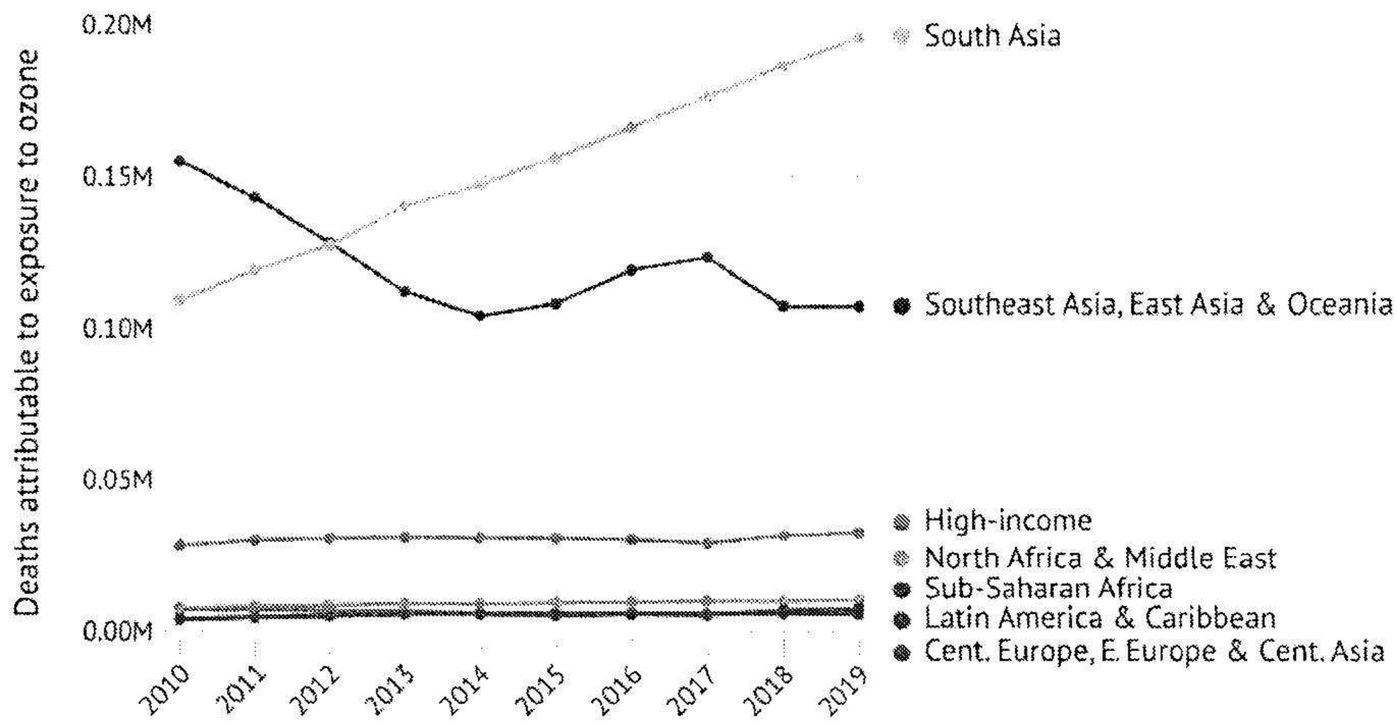
As with $PM_{2.5}$, the regional trends in total mortality burden attributable to ozone vary widely (Figure 19) given regional differences in ozone exposures, as well as underlying health and population characteristics. In general, exposures to ozone have risen at a lower rate than their associated health burdens over the same time period, despite declines in mortality rates from COPD in major regions like Southeast Asia, East Asia, and Oceania. Mortality rates from COPD in South Asia have remained relatively constant. Thus, the increase in burden in these and similar locations is driven largely by growth and aging of their populations. The overall global increase in the number of ozone-attributable deaths from COPD is strongly influenced by the trends in the large populations in the South Asia and the Southeast Asia, East Asia, and Oceania regions. Mortality burden in the High-Income Region is also trending slightly upward. Because COPD typically takes many years to develop as a result of long-term exposure to ozone and other irritants, it takes its toll

primarily in older adults and is therefore most prevalent in countries with aging populations.

Changes in ozone-attributable deaths among the world's 20 most populous countries (Figure 20) show that 15 of these countries experienced increases in burden ranging from about 140 deaths in Mexico (a 6.5% increase) to over 76,000 in India (an 84% increase). Decreases in ozone-attributable mortality ranged from a reduction of about 70 deaths (a 5% decrease) in Vietnam to a reduction of about 52,000 in China, a decrease of 36%. The largest proportional increases were seen in Brazil (which saw a 191% increase in ozone-attributable deaths), Ethiopia (171%), the Democratic Republic of the Congo (97%), and Indonesia (89%). Given that these countries experienced only small increases in ozone exposure during the same time period, and COPD mortality rates have been largely stagnant over this time period, the increases largely reflect the growing numbers of older adults in the population.

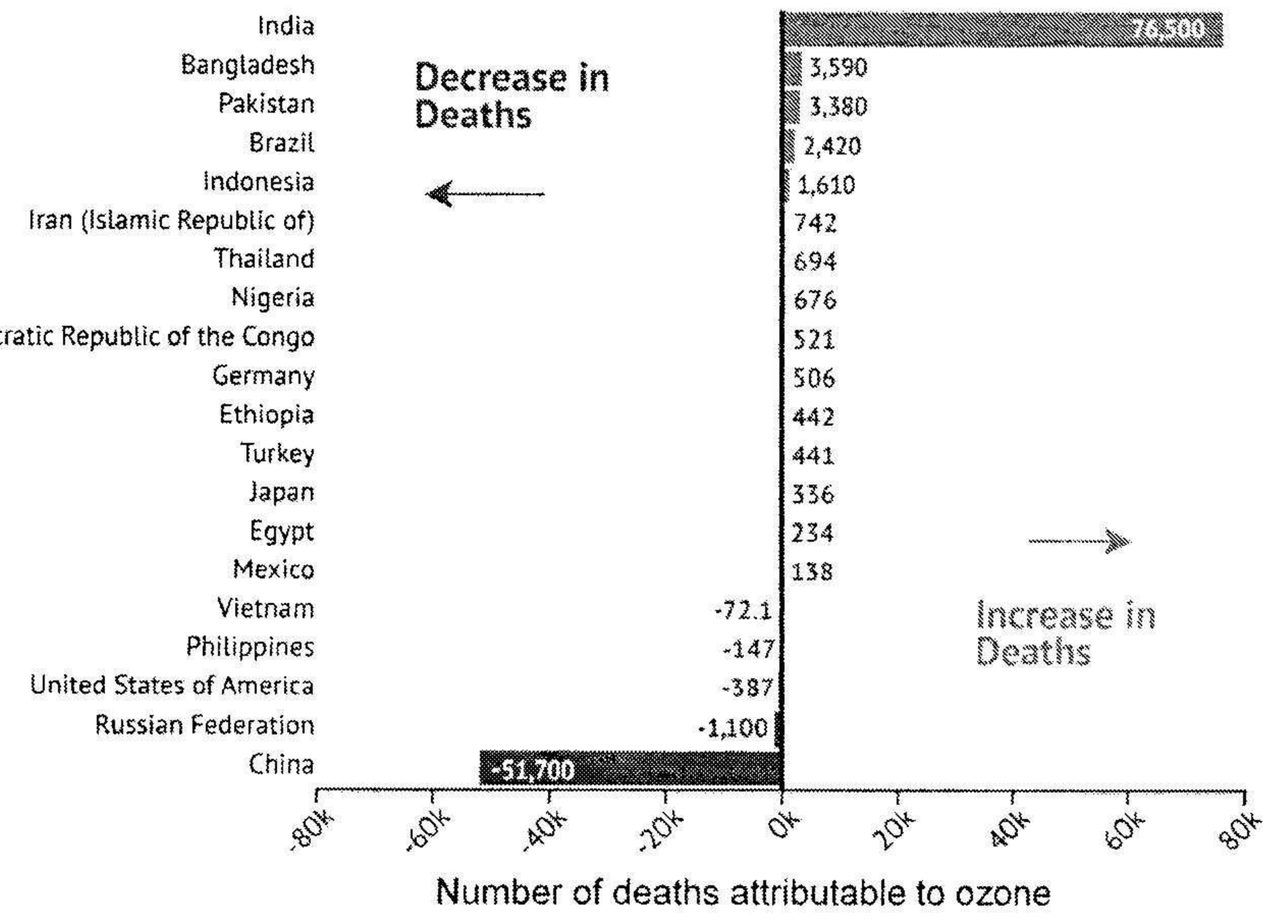
The largest declines in the burden of disease from air pollution stem from reductions in exposure to household air pollution.

FIGURE 19 Trends in total deaths attributable to ozone in the GBD Super Regions.



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FIGURE 20 Change in total deaths attributable to ozone in the 20 most populous countries, 2010–2019.



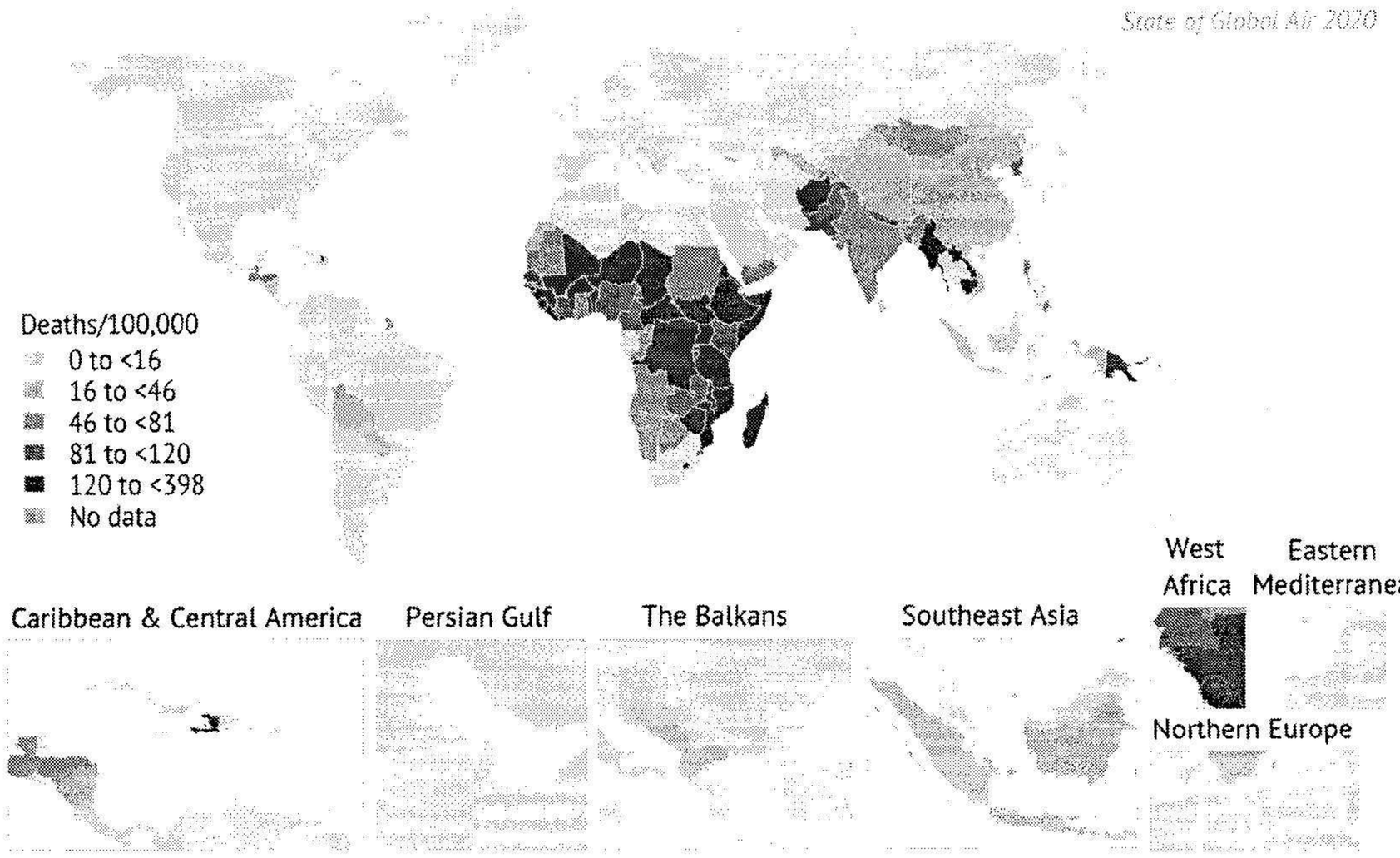
BURDEN OF DISEASE FROM HOUSEHOLD AIR POLLUTION

In 2019, long-term exposure to household air pollution from the burning of solid fuels for cooking contributed to 2.31 million (95% UI: 1.63 to 3.12) deaths and 91.5 million (95% UI: 67.0 to 119) DALYs. More than 90% of the DALYs were accounted for by years of life lost with the remainder due to years lived with disability. Household air pollution accounts for 4.1% of all global deaths and 3.6% of DALYs. Among 69 risk factors included in the GBD that are considered to be potentially modifiable, household air pollution ranks 9th in the number of attributable global deaths. Although this is a decrease from its ranking of 7th in 2010 and reflects important progress in reducing this risk, this position underscores the continuing importance of household air pollution not only among environmental risk factors, but also compared with diet, lifestyle, and other factors.

Global Patterns in Household Air Pollution's Burden of Disease

The age-standardized rates of deaths attributable to household air pollution follow similar regional patterns as exposure to household air pollution (Figure 21). The highest age-standardized rates of death attributable to household air pollution are clearly visible in sub-Saharan Africa where household air pollution-related death rates are close to 200/100,000 in several countries (e.g., Niger, Chad, Mali, and Burkina Faso). The mortality rate of Nigeria, one of the most populous countries in the region, is 83/100,000 (95% UI: 57 to 111), lower but still more than twice the global average of 30/100,000. In South Asia, India has among the lowest rates

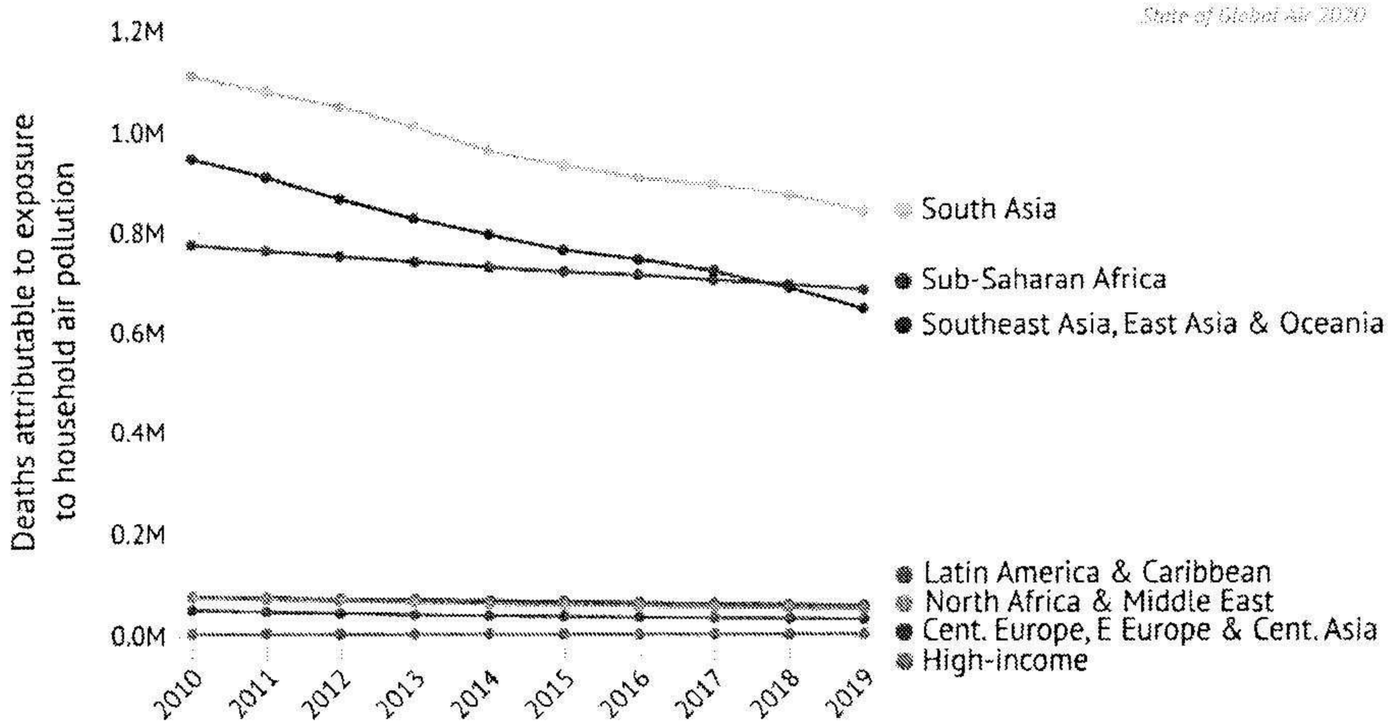
FIGURE 21 Global map of age-standardized rates of death attributable to household air pollution in 2019.



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

(60/100,000, 95% UI: 38 to 84) compared with Nepal (113/100,000, 95% UI: 69 to 166), Pakistan (93/100,000, 95% UI: 59 to 130), and Bangladesh (79/100,000, 95% UI: 51 to 113). In East Asia, the highest rates were reported for the Democratic Republic of Korea (107/100,000, 95% UI: 70 to 146), with the lowest for China (21/100,000, 95% UI: 10 to 35) and Taiwan (1.2/100,000, 95% UI: 0.28 to 3.4). For comparison, most countries in the High-Income Region, have household air pollution–attributable death rates well less than 1/100,000.

FIGURE 22 Trends in total deaths attributable to household air pollution in the GBD Super Regions.



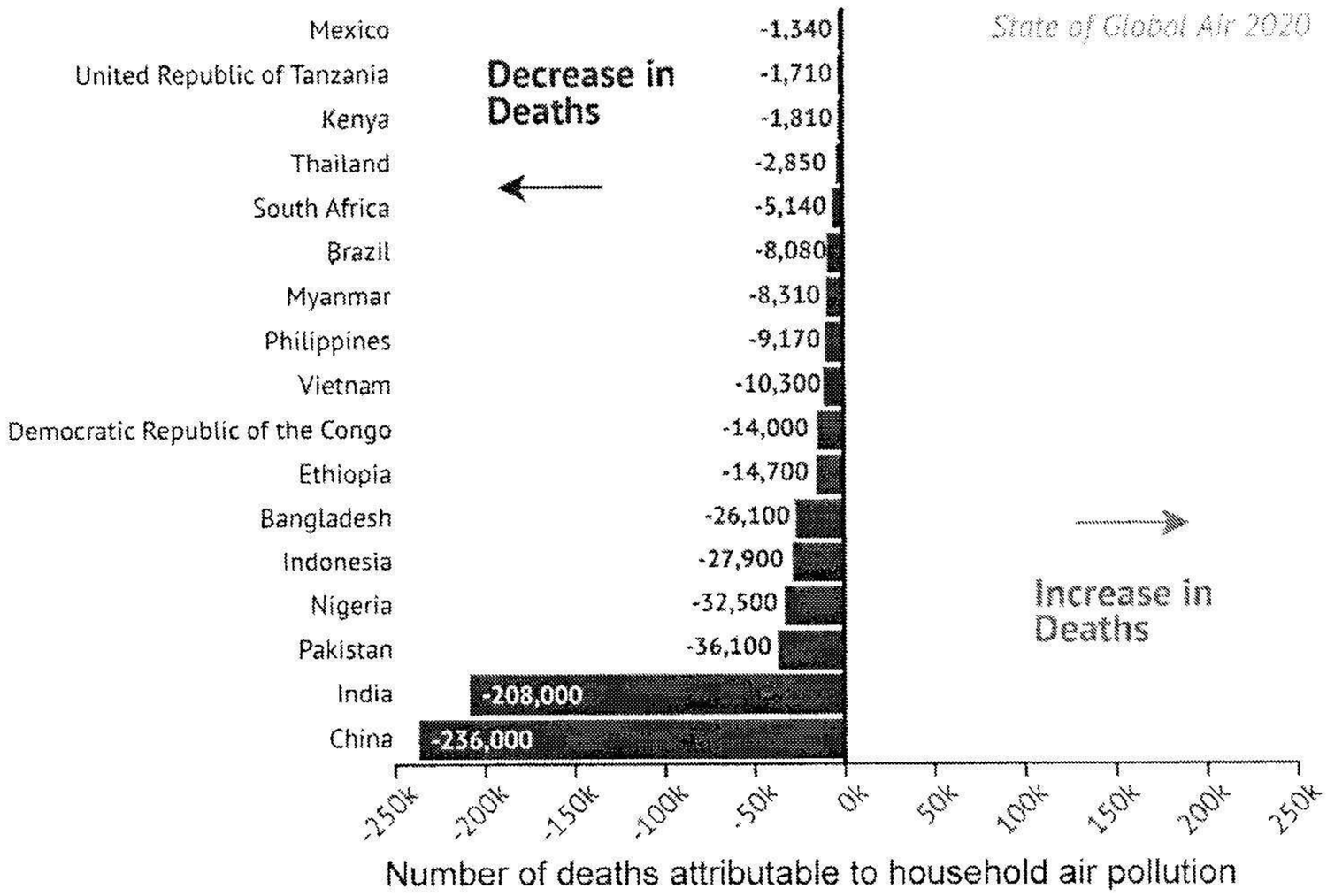
Trends in Household Air Pollution's Burden of Disease

The global burden of disease from household air pollution has decreased steadily over the past decade. Total deaths attributable to household air pollution fell by 23.8% (95% UI: −32.3 to −15.5), while the age-standardized mortality rates dropped by 37.5% (95% UI: −44.0 to −31.1). Total DALYs as well as age-standardized DALY rates attributable to household air pollution have dropped by similar percentages. Most of these declines have occurred in GBD Super Regions where the proportion of the populations using solid fuels and the related mortality rates are highest (Figure 22) — sub-Saharan Africa, South Asia, and Southeast Asia, East Asia, and Oceania.

Among the 17 countries with over 50 million people and where at least 10% of the population relied on solid fuels in 2010, all have seen substantial reductions in the burden of disease attributable to household air pollution in the past decade (Figure 23). By far the greatest gains have been made in China, where large-scale efforts have focused on replacement of coal cookstoves and led to dramatic reductions in exposure to household air pollution, and in India, where access to clean fuels (i.e., liquefied petroleum gas [LPG]) has been dramatically expanded across the country.

As for the other pollutants, these trends reflect not only reductions in exposures, but also declining mortality rates from improved treatment of and survival from air pollution–attributable diseases. In the case of household air pollution, those two factors have, on average, more than offset increases in population size and the aging of populations, even in countries like Nigeria and Ethiopia where the actual numbers of people exposed to household air pollution increased (Figure 10).

FIGURE 23 Change in the number of deaths attributable to household air pollution in the 17 countries with over 50 million people and at least 10% of their population cooking with solid fuels, 2010–2019.



How Burden of Disease Is Estimated

The GBD project's estimation of the burden of disease begins with a systematic evaluation of the scientific evidence and whether it is strong enough to attribute a given health outcome or cause of death to a particular pollutant. Every risk–outcome pair included in the GBD has undergone this rigorous evaluation.

For those outcomes linked through this process to individual pollutants, the GBD project then calculates air pollution's burden of disease in each country using:

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

The results of these calculations are expressed for the population in every country in a number of ways. In the *State of Global Air*, we focus on four:

- **Total number of deaths:** The number of deaths in a given year attributable to air pollution that likely occurred earlier than would be expected in the absence of air pollution.
- **Disability-adjusted life-years (DALYs):** The sum of the years of life lost from those early deaths plus the years lived with a disability, such as paralysis from a stroke related to air pollution exposure. Because DALYs reflect both the overall number of people affected and the age at which death or disability occurs, they better represent the total burden on society by capturing the years in which individuals are prevented from participating fully in life and the economy. Given the set of diseases currently attributed to air pollution in GBD, most of the DALY burden stems from early deaths rather than years of life with disability; for this reason, the *State of Global Air* focuses largely on mortality.
- **Age-standardized rates:** The total number of deaths or DALYs per 100,000 people, calculated based on a standard distribution of population across age categories. Age-standardized rates allow direct comparison of the health burden among countries with very 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/or sicker populations.
- **Loss of life expectancy at birth**: The difference in years between a person's expected lifespan and the length of life that would be expected if air pollution were not present.

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

Numbers, Numbers! Estimates of the burden of disease attributed to air pollution have been proliferating at a rapid pace in recent years. In addition to the GBD estimates, among the most influential are those reported by the World Health Organization (WHO), which published its most recent estimates in 2016. Since that time, the WHO and the GBD approaches to estimating air pollution burden of disease have increasingly converged, and the differences between their estimates are diminishing. In 2018, the WHO and IHME signed a memorandum of understanding to collaborate on the development of burden of disease estimates in general, a step that may lead to closer collaboration on air pollution in particular.

AIR POLLUTION'S YOUNGEST VICTIMS

For the first time in 2019, the GBD analysis accounts for the impacts of particulate matter pollution (ambient $PM_{2.5}$ and household air pollution) exposures on infants' health and survival in their first month of life (ages 0 to 27 days). Relying on a growing body of evidence linking mothers' exposures during pregnancy to air pollution with the increased risk of their infants being born too small (low birth weight) or too early (preterm birth), the GBD estimated that 476,000 newborns worldwide died in 2019 as a result of air pollution exposure.

In 2019, air pollution contributed to nearly 500,000 deaths among infants in their first month of life.

A Fragile Stage

Low birth weight is typically defined as weighing less than 2,500 grams (5.5 pounds) at birth, while preterm birth is defined as being born before 37 weeks of gestation, the period that the child is carried in the mother's womb (full term is 38 to 40 weeks). These conditions, which are related because babies born too early are often small, make infants more susceptible to a range of diseases that carry a high rate of death or higher risks of long-term disabilities. For example, they are linked to a higher risk of lower-respiratory infections, diarrheal diseases, and other serious infections as well as brain damage and inflammation, blood disorders, and jaundice.

Air pollution accounts for 20% of newborn deaths worldwide, most related to complications of low birth weight and preterm birth.

The smaller the baby or the earlier she is born, the higher the risk of complications. If these babies survive infancy, they remain at a higher risk for not only lower-respiratory infections and other infectious diseases throughout early childhood but also for major chronic diseases throughout life.

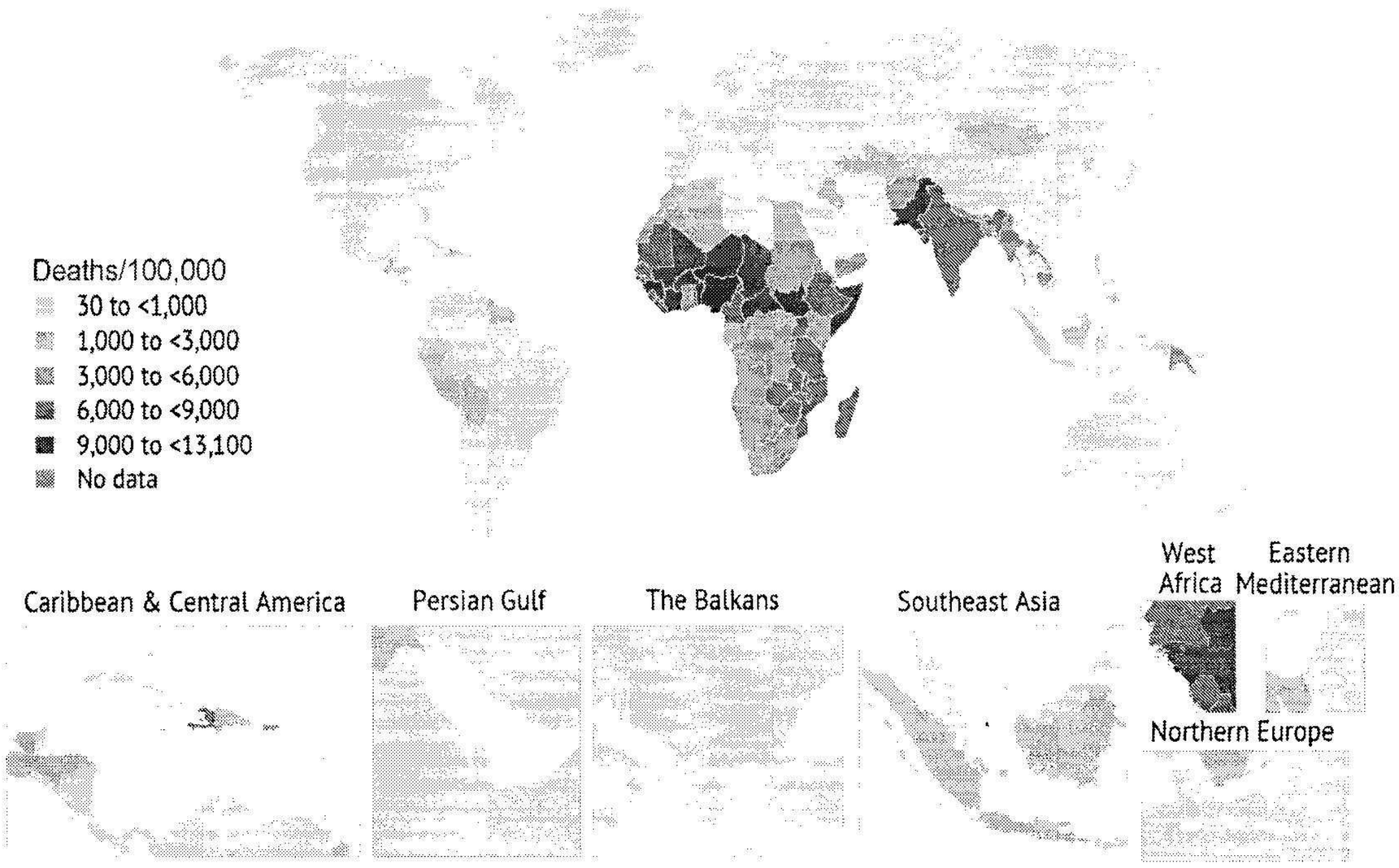
In 2019, about 2.42 million newborns died in the first 0 to 27 days of life from all causes. Of these, low birth weight and preterm births, combined with the health conditions that can often follow them, accounted for about 1.78 million deaths. A number of factors can contribute to low birth weight and preterm birth, including being pregnant with more than one baby (e.g., twins or triplets), and various aspects of a mother's health, including chronic health conditions, malnutrition, and tobacco use. Many of these risk factors are influenced by some of the same sociodemographic factors that increase a woman's risk of being exposed to high levels of air pollution. As a result, women in countries with low levels of sociodemographic development are especially at risk for adverse birth outcomes, with the related consequences for their children.

Impacts of Air Pollution

A growing body of both epidemiological and toxicological research links air pollution with increased risks of low birth weight and preterm birth. Although the biological reasons for this linkage are

FIGURE 24 Global map of neonatal death rates attributable to air pollution in 2019.

State of Global Air 2020



Of neonatal deaths attributable to air pollution, nearly two-thirds are related to household air pollution. Babies born in sub-Saharan Africa and South Asia face the highest risk.

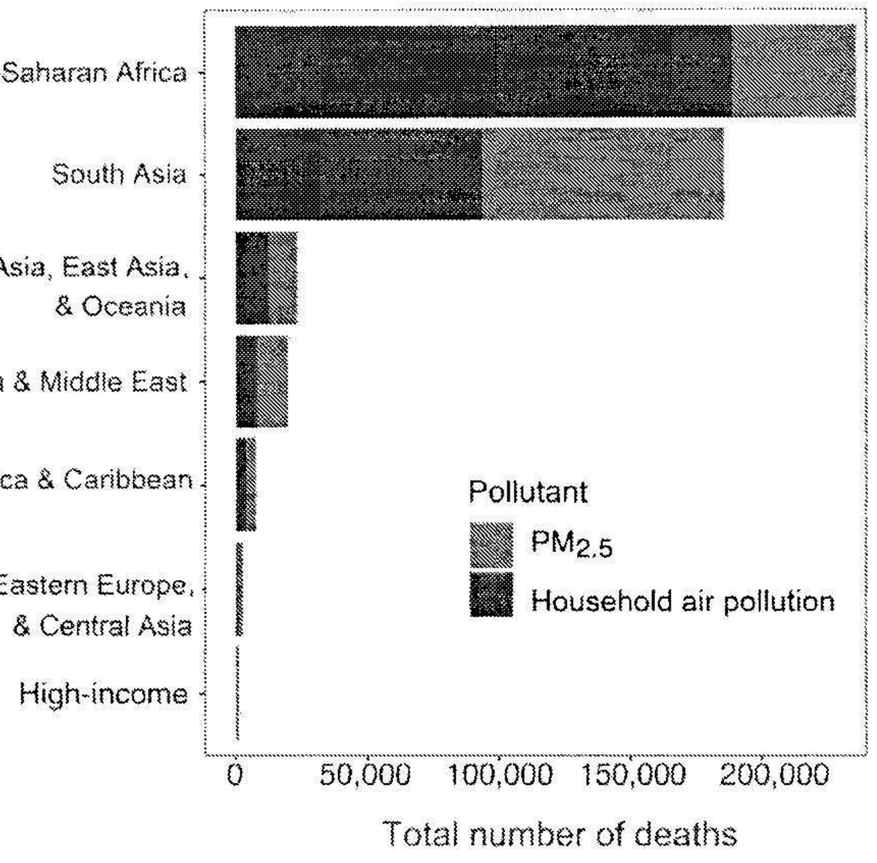
not fully known, it is thought that air pollution may affect a pregnant woman, her developing fetus, or both through pathways similar to those of tobacco smoking, which is a well-known risk factor for low birth weight and preterm birth. One plausible mechanism is that pollution particles or their components may move across the membranes of the lungs and be carried to other parts of the body, affecting placental function and the fetus. Another is that pollutants may initiate systemic inflammation or oxidative stress that affects the health of both the pregnant woman and her baby. Further research is likely to shed more light on possible biological mechanisms.

In previous years, GBD scientists have assessed air pollution's burden of disease for only one health outcome affecting babies: lower-respiratory infections. The inclusion of a broader suite of health effects — those mediated by low birth weight and preterm birth — represents a significant expansion in our understanding of how air pollution affects its youngest victims.

Global Patterns in Infant Deaths

Infants born in sub-Saharan Africa and South Asia have the highest rates of neonatal death attributable to air pollution, from 9,000 to 13,100 per 100,000 live births (Figure 24). High rates of pollution-attributable infant death are also seen in other parts of Asia, North Africa, and the Middle East, where $PM_{2.5}$ exposures are relatively high.

FIGURE 25 Deaths attributable to particulate matter in 2019 among babies in their first month of life in the GBD Super Regions.



Both indoor and outdoor pollution can be harmful to mothers and babies, but on a global scale, exposures to household air pollution are particularly dominant. Of all neonatal deaths attributable to air pollution, household air pollution (from burning solid fuels for cooking) accounts for about 64%, while the rest are attributable to ambient $PM_{2.5}$ (Figure 25). The highest percentage of deaths attributable to household air pollution (80%) was in the sub-Saharan region, while the lowest was in High-Income Region (< 2%).

How Burden of Disease Is Estimated for Adverse Birth Outcomes

To assess air pollution's impact on infant health, GBD scientists conducted a systematic review of the scientific evidence. This review included over 70 epidemiological studies that examine the relationships between $PM_{2.5}$ or household air pollution and two fundamental indicators of risk in newborns:

- **Birth weight**, assessed based on continuous data (e.g., a baby's weight at birth) or threshold-based data (e.g., categorizing a newborn as either low birth weight or not, based on a cutoff weight of 2,500 grams); and
- **Gestational age**, assessed based on continuous data (total weeks of gestation up to 37 weeks) or threshold-based data (categorizing babies born before 37 weeks of gestation as "preterm" and those born before 32 weeks of gestation as "very preterm").

In assessing these studies, scientists took steps to distinguish between the effects of air pollution and those of other maternal risk factors that could affect birth outcomes, such as having twins or smoking during pregnancy. Based on the available evidence, scientists developed mathematical functions for estimating the proportion of neonatal deaths in a population accounted for by air pollution in two ways:

- **Direct effects** of air pollution as seen in lower-respiratory infections in babies 0 to 27 days old, and
- **Indirect effects** of air pollution as seen in low birth weight or preterm birth and the range of diseases linked with these outcomes. The functions for these indirect effects use continuous distributions between exposure and outcome to account for the increasing risk to babies the lower their birth weight or the earlier they are born (e.g., a month early versus a week early) relative to the ideal.

Because lower-respiratory infections can result from air pollution directly as well as indirectly as an effect of low birth weight or preterm birth, the calculations of total burden of disease from lower-respiratory infections include steps to avoid double counting.

CONCLUSIONS

The GBD project offers the most comprehensive and comparative analysis of the major risk factors that contribute to disease and early death worldwide – a crucial foundation for setting priorities to improve public health. Each year, the *State of Global Air* reports on air pollution's position within this comparative framework and on pollution levels and trends around the world. Knowledge of these trends is essential to understanding patterns in the burden of disease across countries and regions and vital to informing actions to reduce pollution in ways that have the greatest potential to benefit health.

Air pollution – comprising ambient $PM_{2.5}$, ozone, and household air pollution – is an increasingly important risk factor contributing to death and disability worldwide. In 2019, air pollution ranked 4th among major mortality risk factors globally, accounting for nearly 6.75 million early deaths and 213 million years of healthy life lost. Ambient $PM_{2.5}$ accounted for 4.14 million deaths (118 million years of healthy life lost); household air pollution accounted for 2.31 million deaths (91.5 million years of healthy life lost), and ozone accounted for about 365,000 early deaths (6.21 million years of healthy life lost). Taken together, these forms of air pollution accounted for more than 1 in 9 deaths worldwide in 2019.

As science advances, GBD scientists adjust their methods to account for the latest understanding of the ways in which air pollution affects human health. This year, the inclusion of adverse birth outcomes in the analysis brings a more complete picture of air pollution's burden of disease for infants in their first month of life. In 2019, particulate matter air pollution – ambient $PM_{2.5}$ and household air pollution – contributed to the deaths of nearly 500,000 infants in this age group.

The reality is that despite the explosion in data in recent years that have brought intense focus on air pollution, little or no progress has been made toward reducing air pollution and its associated health burden in many regions of the world. Over the last decade, levels of $PM_{2.5}$ exposure have remained high or increasing particularly in parts of Asia, Africa, and the Middle East. East Asia has seen marked regional reductions in pollution levels, driven primarily by major declines in $PM_{2.5}$ in China.

Ozone levels continue to creep upward, reflecting growing emissions of its precursor chemicals and a warming climate that helps accelerate ozone's formation. Countries in South Asia, which already have some of the highest ozone exposures in the world, have experienced the largest increases in exposure and burden over the past decade, while some countries in the High-Income, Central Europe, Eastern Europe, Central Asia and East Asia Regions saw modest declines in exposure, but not necessarily in burden.

Some of the largest improvements in air quality in the past decade stem from a shift away from the use of solid fuels for cooking. Of the three pollutants the GBD project studies, household air pollution is most closely linked to socioeconomic and demographic development. Improvements in sociodemographic indicators, coupled with major investments in clean energy for cooking by countries like China and India, have driven significant declines in exposure to global household air pollution and its associated burden of disease. However, much work remains to be done; roughly half the world's population continues to rely on solid fuels for cooking. The rate of solid fuel use remains highest in sub-Saharan Africa and several countries in Asia, home to the majority of the world's global poor.

Marked disparities in air quality among regions have barely changed over the last decade.

The marked disparities in air quality among regions have barely changed over the last decade; with few exceptions, the low- and middle-income regions remain the dirtiest, and high-income regions remain clean or are getting cleaner. The result is that millions of people every year have borne an avoidable burden from air pollution–related disease and premature mortality.

Reducing the burden of disease from air pollution poses an increasing challenge even where levels of exposure are leveling off or declining. Populations that are growing, and especially populations with an increasing number of older individuals, can see a rising number of people affected by air pollution even with the same exposure levels, since many of the chronic conditions associated with air pollution take years to develop and thus have a greater impact on health as populations age.

Communication of these patterns and trends forces recognition of the magnitude of the problem and whether or not we're making progress toward cleaner air and healthier communities. However, progress requires actions – actions that must be grounded in an understanding of the sources and drivers of air pollution and other risk factors at regional, national, and local levels; that take advantage of known solutions to sources of air pollution; and that address the economic, educational, and social disparities in resources necessary to make and sustain progress on air pollution and health.

This year, the emergence of a global pandemic and the subsequent closure of economies around the world have given us a stark reminder of the value of clean air. The air cleared in many places, opening vistas not seen in decades. At the same time, this global health emergency has laid bare vulnerabilities and disparities in our states of health, our health care systems, and our communities – conditions that may indeed have been worsened by disparities in both current exposures and years of prior exposure to air pollution. Understanding the interplay between air pollution and the COVID-19 pandemic will require much more careful research. The pandemic has nonetheless strengthened the case for accelerating efforts to achieve the lasting reductions in air pollution needed to remove it as one of the major risk factors for early death and disability around the world.

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KEY RESOURCES

GLOBAL BURDEN OF DISEASE 2019 METHODS

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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 site.

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.

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Explore information on monitoring and management of air pollution on the C40 Knowledge Hub.

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 Katy Walker, principal scientist; Pallavi Pant, staff scientist; Joanna Keel and Lee Ann Adelsheim, research assistants; Hilary Selby Polk, managing editor; Sofia Chang-DePuy, digital communications manager; Hope Green, editorial project manager; Aaron Cohen, consulting scientist at HEI and affiliate professor of Global Health at IHME; Bob 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 Dean Owen, senior manager for marketing and communications.

University of British Columbia

Professor Michael Brauer of the School of Population and Public Health at UBC serves as an expert adviser on this project. Dr. Brauer is a long-time principal collaborator on the air pollution assessment for the Global Burden of Disease (GBD) project and led the effort to define the project's global air pollution exposure assessment methodology.

Other Contributors

ZevRoss Spatial Analytics provided data visualization support and developed the interactive features of the site. Metropolis Creative designed the website; Charles River Web developed the website; Creative Science Writing provided writing support for the report and website; StoryMine produced the video.; and Cameographics composed the report.

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University of California, Berkeley.

(1947–2020)

The Legacy of Kirk Smith

Kirk R. Smith, MPH, PhD, was both a consummate scientist and a passionate advocate advancing the cause of reducing exposure – especially of mothers and children – to harmful household burning of solid fuels. Among his many other contributions, including to the development of WHO Air Quality Guidelines and UN Sustainable Development Goals, Kirk was a Global Burden of Disease pioneer. He led the first assessments for household air pollution and made seminal contributions to the development of methods for air pollution burden estimation. His knowledge and vision will be sorely missed, but his legacy is likely to live on in the many scientists and others he trained and inspired – and in the slow but steady decline in these exposures that has been happening worldwide, in no small part due to Kirk's work.

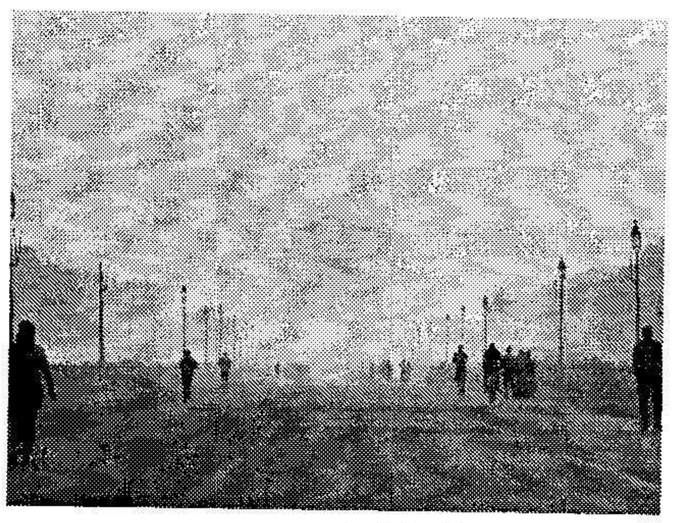
STATE OF
GLOBAL AIR /2020

Air Pollution and COVID-19

How Has COVID-19 Affected Air Quality? The response to COVID-19 has made humanity's influence on air quality more visible. While dramatic reductions in travel and industrial activity brought significant societal and personal costs, many places around the world saw blue skies and starry nights, often for the first time in many years.

During shutdowns, air quality monitoring data from around the world have shown:

- Substantial reductions in nitrogen dioxide (NO_2)
- Modest reductions in fine-particle air pollution ($PM_{2.5}$)
- Higher levels of ozone (O_3) (likely due in part to the reductions in NO_2 and changes in meteorological factors including temperature)



Amit kg/shutterstock.com



Clean Air Collective, India.

In many instances, these changes have been only temporary. As restrictions have lifted, emissions have risen — quickly erasing any gains in air quality. Nonetheless, the blue skies have offered a reminder of what pollution takes away, inspiring renewed demands for cleaner air in the longer term.

Does Air Quality Affect COVID-19 Susceptibility? The health effects of long-term exposure to air pollution have likely made some people more vulnerable to COVID-19. Here's what we know about the possible connections so far:

- Long-term exposure to air pollution can cause many of the health conditions associated with increased vulnerability to COVID-19, such as diabetes, cardiovascular disease, and chronic obstructive lung disease.
- Exposure to air pollution has been shown to affect the body's immune defense, increasing susceptibility to respiratory and other infections.
- Studies of the SARS-CoV-1 outbreak in 2002–2004 reported an association between higher air pollution levels and higher than expected death rates for that disease.
- A few early studies of COVID-19 similarly appear to suggest that areas with higher air pollution levels experience higher rates of infection or of case fatalities.

Looking Forward With time and a continued focus on tracking outcomes and possible contributing factors such as air pollution, the world will learn more about COVID-19 and how to reduce its toll. Just as the COVID-19 crisis has demonstrated the need for multiple strategies to manage the pandemic, solutions to air pollution will require multifaceted ongoing efforts to bring attention to its health threats, to identify the policy changes necessary to control it, and to monitor progress over time. The State of Global Air supports these efforts by providing a global report card on the current status of air pollution and health worldwide.

HEI IHME UBC

The State of Global Air website is a collaboration between the Health Effects Institute and the Institute for Health Metrics and Evaluation, with expert input from the University of British Columbia.

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AIR POLLUTION

India recorded highest infant deaths due to air pollution in 2019, shows study

Scroll.in 21 October 2020

As many as 16.67 lakh people, including 1.16 lakh infants died due to air pollution in India in 2019, according to the survey.

More than 1,16,000 infants in India did not survive their first month due to air pollution in 2019, according to the State of Global Air 2020 report published on Wednesday. This was the highest among the 116 countries that were surveyed.

The report released by the Health Effects Institute said long-term exposure to outdoor and household air pollution – which led to strokes, heart attacks, diabetes, lung cancers, chronic lung diseases and neonatal diseases – contributed to a total of 16,67,000 deaths in India in 2019.

In a first, the report analysed the impact of air pollution on infants' health and survival in their first month, and found that there was growing evidence to link mothers' exposure to air pollution during pregnancy with an increased risk of their infants being born underweight or pre-mature, which lead to neonatal deaths.

The report estimated that a total of 4,76,000 infants died due to air pollution in 2019, out of which 1,16,000 deaths were recorded in India.



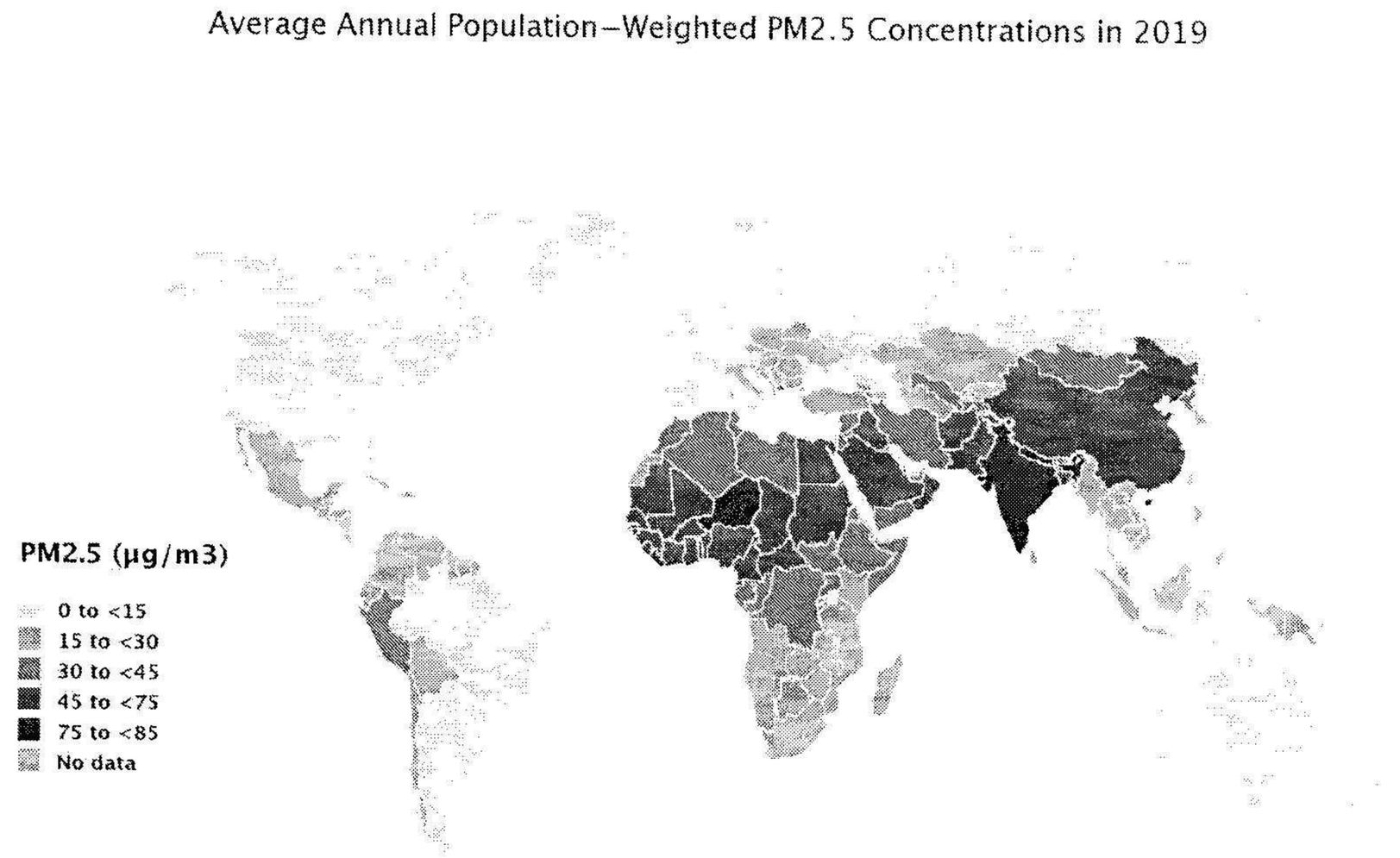
Total deaths among newborns attributable to air pollution in 2019

Corroborating the study's observations, Kalpana Balakrishnan, Director of Indian Council of Medical Research told *Hindustan Times* that over 70 studies show that exposure to household and ambient air pollution is associated with adverse pregnancy outcomes. She said air pollution must be included alongside these risk factors to address the burden of low-birth weight and preterm births.

"We don't totally understand what the mechanisms are at this stage, but there is something going on that is causing reductions in baby growth and ultimately birth weight," Katherine Walker, Principal Scientist at the Health Effects Institute, told *The Guardian*. "There is an epidemiological link, shown across multiple countries in multiple studies."

PM 2.5 exposure

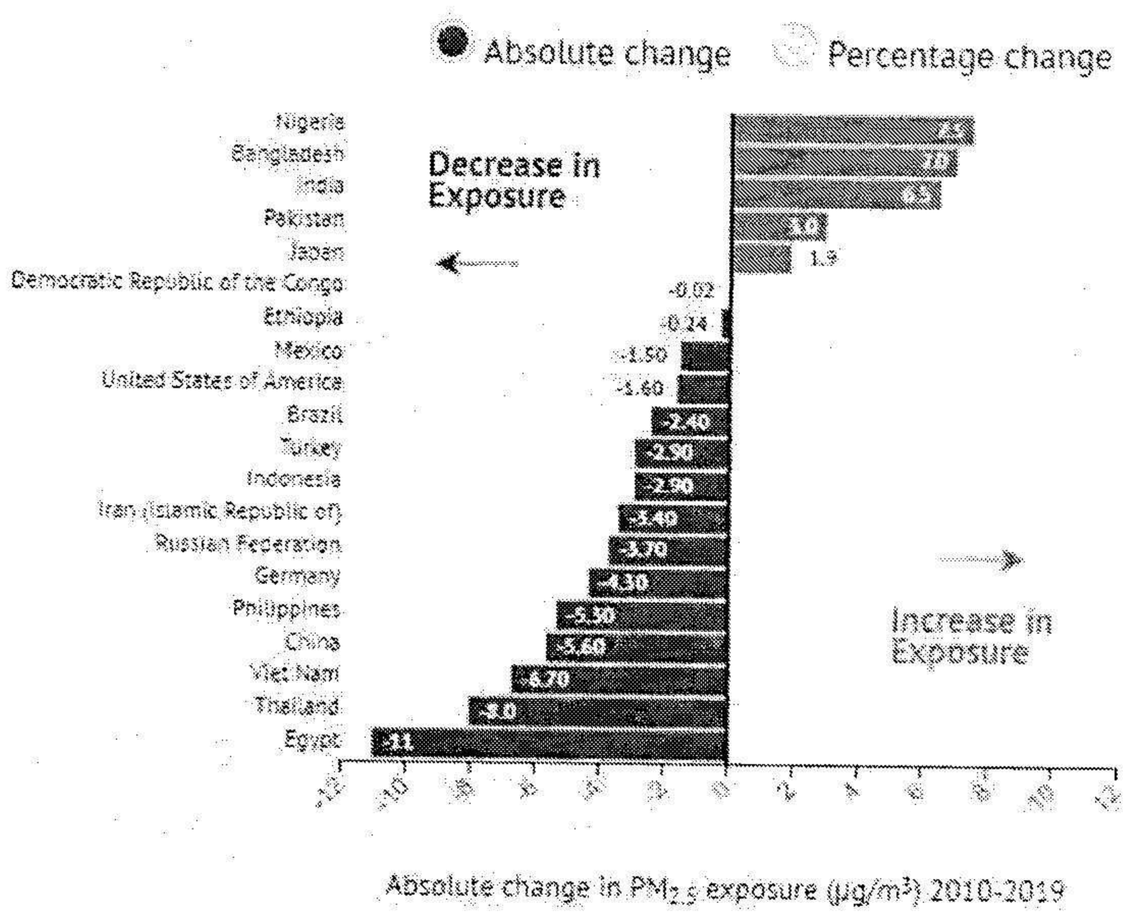
The report said that in 2019, more than 4.1 million people died due to long-term PM 2.5 exposure. India recorded 9,80,000 deaths, second only to China, due to the micro particles. The report also noted that in 2019, on an annual average basis, people in India experienced the highest exposure to PM 2.5 – particles with a diameter of less than 2.5 micrometres.



Population-weighted annual average PM 2.5 concentrations in 2019

The report also showed that over the past decade, India was among five of the 20 most populous countries that witnessed a deterioration in terms of PM 2.5 exposure.

Nigeria and Bangladesh were the only countries that were worse than India. The top five also included Pakistan and Japan.



Change in population-weighted annual average PM 2.5 exposure in the 20 most populous countries, 2010–2019

In terms of ozone exposure too, India recorded the highest number of deaths in 2019, according to the report. As many as 1,68,000 people died due to ozone exposure.

However, India and China vastly improved their household air pollution levels – a trend that the report attributed to the shift towards cleaner fuel. In the last decade, India witnessed 2,08,000 fewer deaths due to household air pollution, the report said.

Number of Deaths Attributable to Ozone in 2019



State of Global Air

Numbers of deaths attributable to ozone in 2019

The report concentrates on data from 2019, so does not include the impacts of the lockdown policies around the world this year. The authors said the Covid-19 pandemic would have had an impact on air quality and deaths from air pollution, but these effects were not yet clear.

Source: https://scroll.in/latest/976376/india-recorded-highest-infant-deaths-due-to-air-pollution-in-2019-shows-study; accessed on 4 November 2020

ANNEXURE H (colly)
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Coronavirus: Delhi health minister blames pollution, winters, festive season for rise in cases

Delhi reported 5,891 fresh infections on Friday, marking the highest single-day spike for the Capital.

Delhi Health Minister Satyendar Jain on Saturday said that the festive season, decrease in temperature and increase in pollution levels were reasons behind the fresh spurt of coronavirus cases in the capital, reported ANI. Jain also said that people have started being ignorant about wearing masks.

The health minister's comment came a day after Delhi reported 5,891 fresh cases of Covid-19 on Friday, marking the highest single-day spike for the Capital. The number of daily cases has gone past the 5,000-mark on four days this week. The coronavirus toll in Delhi went up by 47 to 6,470 on Friday.

"It is a combined effect of the festive season, decrease in temperature and increased pollution," Jain told reporters, according to ANI. "The experts had also suggested that at this time Covid-19 cases could rise. People are also giving less importance to wearing face masks."

Earlier this week, Delhi's air quality index deteriorated to the "severe" category for the first time this year. Officials in the meteorological department, however, predicted improvement in air quality over the weekend. According to a study published in *Cardiovascular Research*, scientists estimated that about 15% of deaths worldwide from Covid-19 could be attributed to long-term exposure to air pollution.

On Thursday, Jain had said that the government was now going for a strategy of "aggressive tracing and testing". Entire family and close contacts of even asymptomatic positive cases were being tested, Jain had said.

Meanwhile, the Union home ministry has called for a special review meeting with Delhi government officials in view of the spike in cases, *Hindustan Times* reported on Saturday. The meeting will be chaired by Union Home Secretary Ajay Bhalla, while Union health secretary and other senior central officials will also be present.

Source: https://scroll.in/latest/977303/coronavirus-delhi-health-minister-blames-pollution-winters-festive-season-for-rise-in-cases; accessed on 4 November 2020

Covid virus found on pollution particles, masks & social distancing a must, say govt experts

Citing a Harvard study, govt health experts say there could be a correlation between high pollution levels and Covid deaths, and reiterated the need to stay vigilant.

ABANTIKA GHOSH 27 October, 2020 9:06 pm IST

New Delhi: Fragments of the SARS-CoV-2 virus have been found in suspended particulate matter (pm) that are the major contributors to air pollution, Dr Balram Bhargava, Secretary, Department of Health Research, said Tuesday.

Noting that it is well-known that pollution is one of four contributors to deaths in society apart from malnutrition, tobacco and high blood pressure, Dr Bhargava said, "Some studies in the US and from Europe have looked at polluted areas and compared mortalities during and after lockdown. They found a correlation between pollution and COVID deaths … a study in Boston by the Harvard (T.H.) Chan Institute found particles of the virus on PM2.5 particles. Whether they are active or not … virus particles have been demonstrated on suspended particulate matter."

The scientist was responding to a question on the link between Covid-19 mortality and pollution.

The correlation is significant given that the National Capital Region is recording severe levels of air pollution, as it usually does this time of year, while the Covid pandemic continues.

Dr Bhargava advocated strict adherence to wearing masks, which give dual protection against Covid and pollution, and cited the example of cities like Tokyo where people have made it a constant habit. He reiterated that masks and social distancing remained the most cost-effective preventive measures.

Must keep up surveillance

While India's Covid-19 numbers have shown a significant dip over the last few weeks, both Health Secretary Rajesh Bhushan and Niti Aayog member (health) Dr V.K. Paul emphasised the need to keep up vigilance in terms of compliance to Covid-appropriate behaviour and also for governments to keep up contact-tracing.

The top five states with the highest Covid burden have remained more or less static, but Karnataka, Chhattisgarh, Delhi, West Bengal and Maharashtra accounted for 58 per cent of deaths in the last 24 hours. Of the new cases reported in the last 24 hours, 49.4 per cent were from Delhi, Karnataka, Maharashtra, West Bengal and Delhi.

Dr Paul flagged the issue of Delhi testing less than it did a few weeks ago, but Bhushan noted that the national capital had recorded 4,000 cases for three consecutive days, indicating that testing does not seem to be coming down.

"This is a crucial time because we are seeing the disease coming back with more force in many European countries. Track, test, trace and treat

is our strategy and there is no room for any laxity. For each positive case, ideally 15-20 people should be quarantined to prevent the spread of the disease. People paid heed to the PM's appeal and were very cautious during the festivals. We have to continue this," Dr Paul said.

Source: https://theprint.in/health/covid-virus-found-on-pollution-particles-masks-social-distancing-a-must-say-govt-experts/531981/; accessed on 4 November 2020

From Record 5.9k Last Fri, City Cases Soar To 6,725

The Times of India Delhi, November 04, 2020, Durgesh Nandan Jha

Hospitals Fast Running Out Of ICU Beds

New Delhi: Delhi recorded 6,725 new cases of Covid-19 — its highest single-day tally — on Tuesday, taking the total number of cases to over 400,000 even as hospitals struggled to accommodate the critically ill patients due to paucity of ICU beds.

The 6,725 fresh cases came out of 59,540 tests conducted in the past 24 hours, the government said.

This is the first time when the number of daily cases has crossed the 6,000mark in Delhi.

Earlier, on October 30, the city had reported a high of 5,891 cases. Forty-eight new fatalities were recorded on Tuesday, pushing the toll in the capital to 6,652.

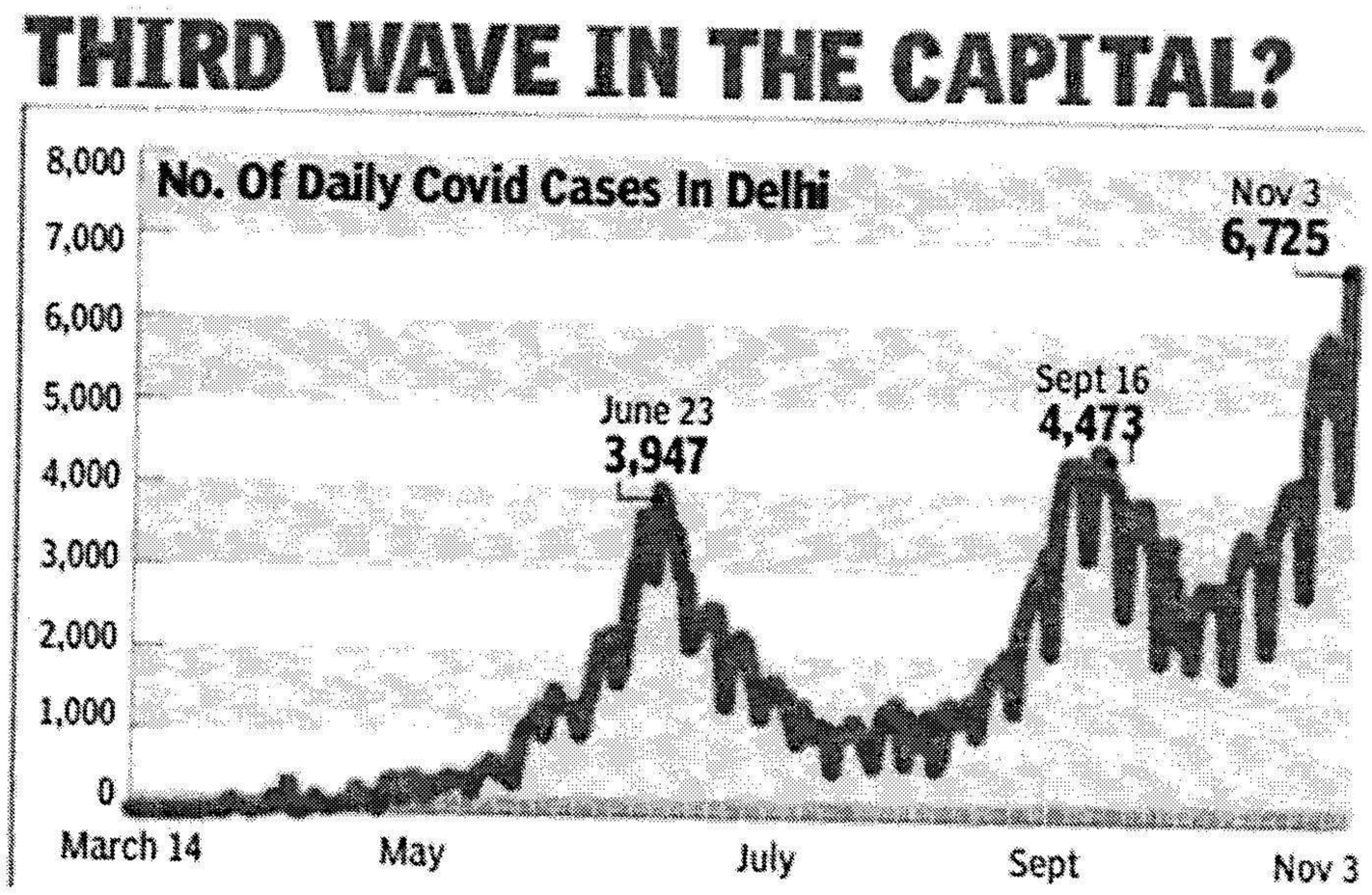
The medical director of Lok Nayak Hospital, Dr Suresh Kumar, said the spike in daily cases has led to a rise in demand for hospital beds. "We are getting 90 to 100 new Covid-19 patients daily over the past 2-3 days. In August, we were getting less than 30 patients daily," he added.

City's positivity rate of 11.3% four times India avg

Lok Nayak Hospital, which is run by the Delhi government, has 2,000 beds for Covid-19 patients, of which 200 have ventilators attached. Only 11 ventilators were available on Tuesday.

Overall, data shared by the hospitals showed that 68% of ventilator beds and 70% of ICU beds without ventilators were occupied. "The situation is grave. New cases are increasing and many people are still not following any preventive measures. This can lead to a spiralling effect in the next four to six weeks as the infection spreads further in

communities, said Dr S K Sarin, director of the Institute of Liver and Biliary Sciences.



The positivity rate — number of positive cases among those tested — in Delhi is 11.3% at present, nearly four times the rate in the country. The case fatality rate is 1.7% which is also higher than the national average of 1.5%.

Critical care specialist Dr Shrikanth Srinivasan of Manipal Hospital said Delhi is facing the double impact of a Covid-19 outbreak and increased air pollution, both leading to an increase in severe symptoms among those infected. "Social-distancing norms, hand hygiene and wearing of masks should be strictly adhered to. Early testing and seeking appropriate healthcare are paramount and could make the difference between life and death," he said.

According to Dr Priyadarshini Pal Singh, who heads emergency and critical care at Apollo Hospital, delay in admission is one of the reasons behind the rise in critical illness due to Covid. If someone has Covid-19 symptoms, for example fever, cough or difficulty in breathing, s/he should get tested immediately. Even those under home isolation should be under medical supervision, she said.

Dr Singh said deterioration of symptoms could be very sudden in the novel coronavirus. "Covid-19 is known to cause happy hypoxia, an unusual complication portrayed by low oxygen level in blood without obvious breathing difficulty."

On Monday, the Union home ministry held a review meeting to assess the deteriorating situation in the national capital and decided on a series of measures, including targeted RT-PCR testing in critical zones like marketplaces, restaurants, salons and barber shops to control the spread of the disease. It was also felt that Delhi Metro travel needs to be regulated strictly in line with the laid-down standard operating procedure.

Source: https://www.magzter.com/article/Newspaper/The-Times-of-India-Delhi/From-Record-59k-Last-Fri-City-Cases-Soar-To-6725; accessed on 4 November 2020

ANNEXURE I

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ITEM NO.4 COURT NO.1 SECTION PIL-W

S U P R E M E C O U R T O F I N D I A
RECORD OF PROCEEDINGS

Writ Petition(s)(Civil) No(s). 728/2015

ARJUN GOPAL & ORS. Petitioner(s)

VERSUS

UNION OF INDIA & ORS. Respondent(s)

(WITH IA No. 72421/2019 - APPROPRIATE ORDERS/DIRECTIONS and IA No. 24794/2020 - APPROPRIATE ORDERS/DIRECTIONS and IA No. 178878/2018 - APPROPRIATE ORDERS/DIRECTIONS and IA No. 76593/2019 - APPROPRIATE ORDERS/DIRECTIONS and IA No. 119396/2017 - CLARIFICATION/DIRECTION and IA No. 13877/2019 - EXEMPTION FROM FILING O.T. and IA No. 178876/2018 - INTERVENTION/IMPLEADMENT and IA No. 10915/2019 - INTERVENTION/IMPLEADMENT and IA No. 4/2019 - INTERVENTION/IMPLEADMENT and IA No. 179554/2018 - INTERVENTION/IMPLEADMENT and IA No. 179145/2018 - INTERVENTION/IMPLEADMENT and IA No. 179036/2018 - INTERVENTION/IMPLEADMENT)

WITH W.P.(C) No. 891/2016 (PIL-W)
W.P.(C) No. 895/2016 (PIL-W)
W.P.(C) No. 899/2016 (PIL-W)
W.P.(C) No. 213/2017 (PIL-W)

Date : 03-03-2020 These matters were called on for hearing today.
CORAM :
HON'BLE THE CHIEF JUSTICE
HON'BLE MR. JUSTICE B.R. GAVAI
HON'BLE MR. JUSTICE SURYA KANT

Counsel for the parties

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Mrs. Gayatri Gulati Sreyas, Adv.

UPON hearing the counsel the Court made the following

O R D E R

I.A. No.24794/2020 in Writ Petition (C) No.728/2015

Mr. Gopal Sankaranarayanan, learned senior counsel appearing for the petitioners/applicants, has brought to our notice violations of our earlier order(s) banning the use of certain chemicals in the fireworks by the manufacturers.

According to Mr. Sankaranarayanan, learned senior counsel, many of the respondents-manufacturers are using the same chemicals which have been banned by this Court under various orders. He also pointed out that many respondents-manufacturers are also not labeling their products as required by this Court's order dated 10.02.2017.

If the aforesaid allegations are true then there is no doubt that the respondents-manufacturers would be guilty of contempt of this Court.

We therefore issue notice to the respondents-manufacturers mentioned at page 10 of the instant application for directions viz., M/s Standard Fireworks, M/s Hindustan Fireworks, M/s Vinayaga Fireworks Industries, M/s Shree Mariamman Fireworks, M/s Shree Suryakalaa Fireworks and M/s Selva Vinayagar Fireworks, except respondent no.5, to show cause why they should not be punished for contempt of this Court for the alleged violation of this Court's earlier orders.

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The Joint Director, Central Bureau of Investigation (CBI) at Chennai, is directed to make a detailed investigation regarding the alleged violation of this Court's earlier orders by the aforesaid respondents-manufacturers by using the ingredients which have been banned and by mislabeling their products contrary to the directions of this Court as stated in the instant application.

Order accordingly.

The Registry of this Court is directed to serve a copy of the instant application for directions upon the Joint Director, CBI at Chennai forthwith.

The Joint Director, CBI at Chennai, shall submit his/her report to this Court within a period of six weeks from the date of receipt of copy of this order.

List the matter after eight weeks.

(SANJAY KUMAR-II)
ASTT. REGISTRAR-cum-PS

(INDU KUMARI POKHRIYAL)
ASSISTANT REGISTRAR