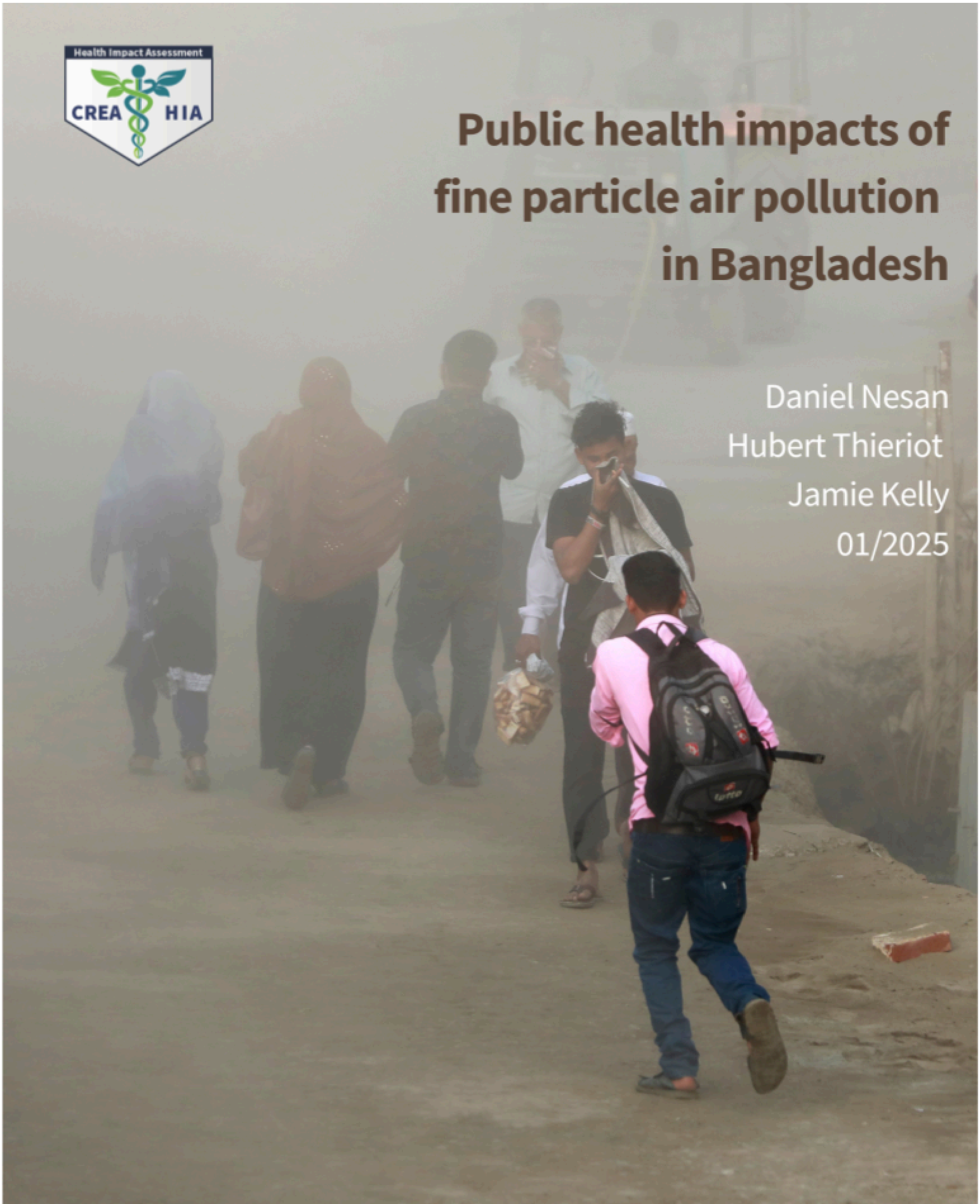
Health Impact Assessment

CREA HIA

Public health impacts of fine particle air pollution in Bangladesh

Daniel Nesan
Hubert Thieriot
Jamie Kelly

01/2025



CREA is an independent research organisation focused on revealing the trends, causes, and health impacts, as well as the solutions to air pollution.

Public health impacts of fine particle air pollution in Bangladesh

18th January 2025

Authors

Daniel Nesan

Hubert Thieriot

Jamie Kelly

Editor

Jonathan Seidman

Designer

Wendi Wu

Acknowledgements

CREA gratefully acknowledges the support, feedback, and insight received from the Global Strategic Communications Council (GSCC)

The views expressed in this report are those of the authors and should not be attributed to any of the aforementioned.

About CREA

The Centre for Research on Energy and Clean Air (CREA) is an independent research organisation focused on revealing the trends, causes, and health impacts, as well as the solutions to air pollution. CREA uses scientific data, research, and evidence to support the efforts of governments, companies, and campaigning organisations worldwide in their efforts to move towards clean energy and clean air, believing that effective research and communication are the keys to successful policies, investment decisions, and advocacy efforts. CREA was founded in Helsinki and has staff in several Asian and European countries.

Disclaimer

CREA is politically independent. The designations employed and the presentation of the material on maps contained in this report do not imply the expression of any opinion whatsoever concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Public health impacts of fine particle air pollution in Bangladesh

Key findings

- Reducing exposure to $PM_{2.5}$ pollution in Bangladesh could prevent approximately 102,456 deaths annually. This includes deaths due to ischemic heart disease (29,920), stroke (23,075), chronic obstructive pulmonary disease (20,976), lower respiratory infections (9,720), and lung cancer (3,063).
- Children under five are especially vulnerable, with 5,258 deaths annually attributed to lower respiratory infections caused by $PM_{2.5}$ exposure.
- $PM_{2.5}$ exposure also contributes to significant morbidity: 668,482 annual emergency room visits due to asthma, 263 million lost workdays annually, 900,485 preterm births, and 696,389 low birth weight births annually.
- Meeting Bangladesh's national air quality standard (35 µg/m^3) could reduce deaths by 19%, bringing the total to approximately 83,236 annually. Adherence to this standard would also reduce Years of Life Lost (YLL) by 21%.
- Achieving stricter international air quality guidelines could save more lives: Meeting the WHO 2021 guideline (5 µg/m^3) would reduce deaths by 79% – saving 81,282 lives each year – eliminate almost all asthma-related emergency visits and preterm births, and avoid 262 million annual sick leave days.
- Urban areas bear the brunt of pollution impacts, with Dhaka and Chattogram alone accounting for 48% of total national deaths. However, rural and coastal regions, though less polluted, also exceed safe air quality levels and would benefit from improved standards.
- The health impact estimates presented in this report are conservative, given our reliance on the Global Burden of Disease framework and the integration of official $PM_{2.5}$ measurements from ground monitoring stations for calibration.
- Ground-based $PM_{2.5}$ measurements reveal levels approximately 20 µg/m^3 higher than previous estimates from global datasets.

Contents

Introduction

Bangladesh, one of the fastest-growing economies in the world, is facing a severe air pollution crisis. In 2023, it was ranked the most polluted country globally, with an annual average $PM_{2.5}$ concentration of 79.9 µg/m^3—more than double the national standard of 35 µg/m^3 and 15 times the World Health Organization's (WHO) guideline of 5 µg/m^3 (IQ Air, 2023). The consequences of this extreme pollution are staggering: air pollution has become the leading risk factor for premature death in the country, cutting the average life expectancy by nearly five years (AQLI, 2024).

The health impacts are severe and far-reaching. Studies estimate that air pollution contributes to over 200,000 deaths annually in Bangladesh (World Bank, 2023a). Fine particulate matter ($PM_{2.5}$) is a known trigger for respiratory and cardiovascular diseases, strokes, and lung cancer. Among children, it exacerbates asthma, stunting, and cognitive impairment, while in newborns, it is linked to low birth weight and premature birth. These health burdens also come with economic costs, including higher healthcare expenses and reduced productivity, which in 2019 amounted to 11 billion USD, or 4.4–4.8% of the country's GDP (World Bank, 2023a).

Efforts by the Department of Environment, Bangladesh, to regulate $PM_{2.5}$ levels have faced significant challenges. Although the country attempted to align with the U.S. Environmental Protection Agency (USEPA) standards by adopting a 15 µg/m^3 limit in 2005, it has struggled to make substantial progress. The recent decision to set the standard at 35 µg/m^3 in 2022 has raised concerns about the rationale behind such measures and their effectiveness in addressing air pollution. A lack of a comprehensive strategy tailored to Bangladesh's specific conditions has further hindered progress in improving air quality and safeguarding public health.

The primary contributors to Bangladesh's ambient air pollution include industrial emissions, power plants, vehicular exhaust, construction activities, biomass burning, and open waste burning. Seasonal dust storms and transboundary pollution from west of Bangladesh further exacerbate the problem, with an estimated 30% of the air pollution in major Bangladeshi cities originating from across the border (World Bank, 2023b). The geography of South Asia, particularly the Indo-Gangetic Plain which includes Bangladesh, parts of eastern Pakistan, most of northern and eastern India, and southern Nepal, traps pollutants due to winds from the coast and the natural barrier formed by the Himalayas to the north (Hasnat, Kabir and Hossain, 2018).

Despite growing concern over air quality, research on the health effects of ambient air pollution in Bangladesh remains limited (Raza et al., 2022; Islam et al., 2023b). Most studies have focused on environmental degradation or emissions sources, with few directly examining the impact on public health. International research has consistently linked high $PM_{2.5}$ levels to chronic diseases and mortality, and there is an urgent need for localised studies to guide evidence-based policy interventions.

This report seeks to bridge the gap by evaluating the health impacts of current pollution levels and assessing the potential improvements under different air quality standards. It aims to provide policymakers and health officials with actionable insights to developing effective air quality management strategies, raising public awareness, and implementing targeted health interventions to reduce the burden of pollution-related diseases in Bangladesh.

Results

The objective of this report is to calculate the health impacts of current $PM_{2.5}$ levels in Bangladesh at the national, division, and district levels, and to reveal how these impacts will be reduced by meeting the national limit of 35 µg/m^3, the WHO guideline from 2005, 10 µg/m^3, and the WHO guideline from 2021, 5 µg/m^3. To achieve this, we perform a Health Impact Assessment (HIA) of ambient $PM_{2.5}$. First, we estimate human exposure to $PM_{2.5}$ by combining satellite-derived estimates of $PM_{2.5}$ for the year 2022, updated to Jan 2024-Dec 2024 by using machine learning. Next, we calculate the health impacts by combining pollutant exposure level with peer-reviewed data on the relationship between air pollution and health outcomes (Myllyvirta, 2020). This general methodology, as well as the specific tools, are all widely used by scientists and governments worldwide (Eionet Portal, 2021; EPA, 2011; Zhang et al., 2019), and are based on scientific information that has been established through the use of scientific research. For a detailed description of this methodology, the reader is referred to the Methodology section.

Current $PM_{2.5}$ concentrations in Bangladesh

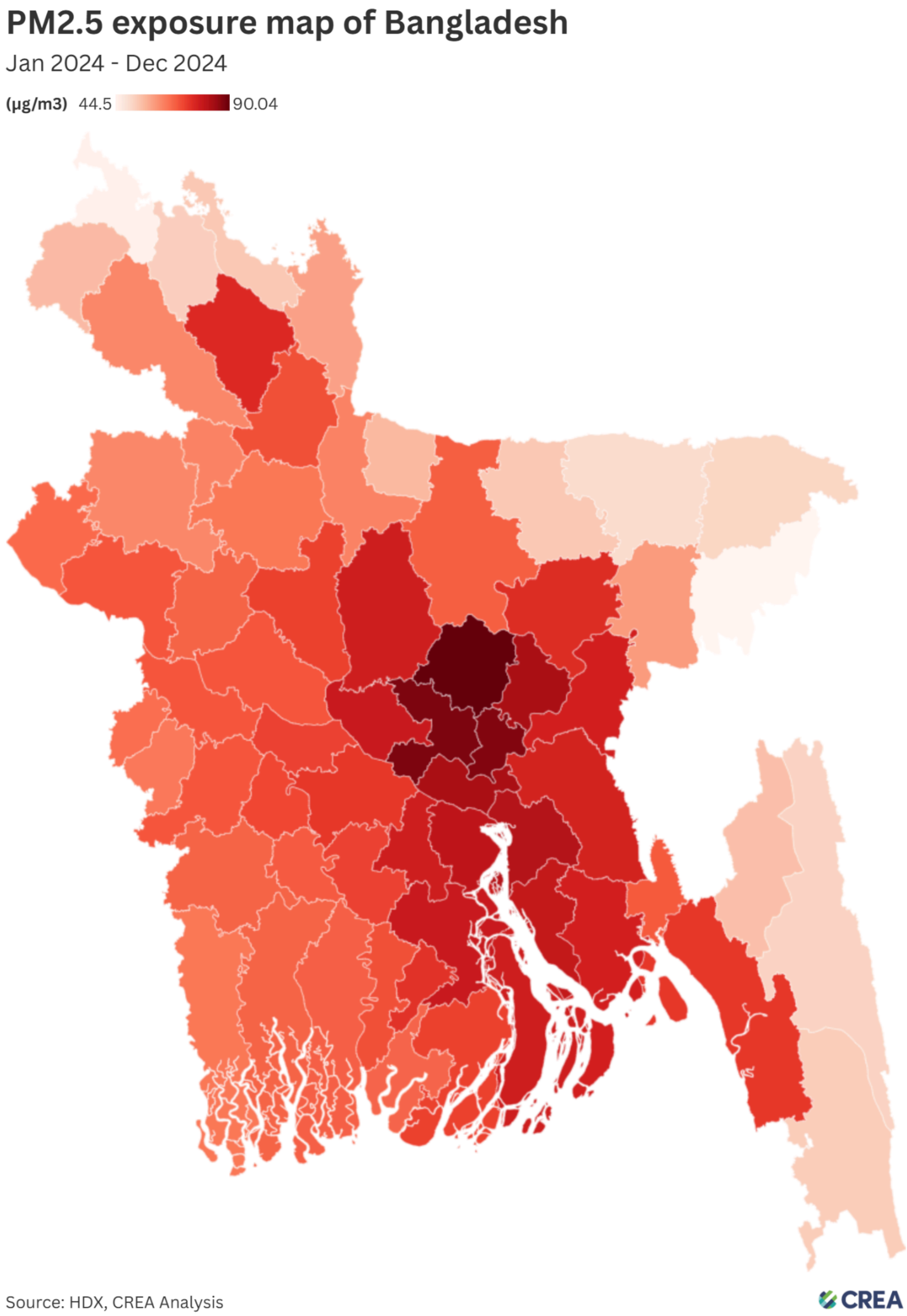


Fig 1 –Population weighted $PM_{2.5}$ exposure across Bangladesh (Jan 2024 - Dec 2024)

Figure 1 presents our calculated fine particulate matter concentrations ($PM_{2.5}$) across Bangladesh. The data indicates that $PM_{2.5}$ levels are highest in the central and northern regions of Bangladesh, particularly around the capital, Dhaka, where concentrations exceed 100 µg/m^3. This region, marked by a combination of dense urban population and industrial activities, faces critical levels of air pollution, contributing to significant public health risks, including respiratory and cardiovascular diseases. In comparison, the southern coastal regions, closer to the Bay of Bengal, exhibit comparatively lower concentrations of $PM_{2.5}$, generally ranging between 25 and 50 µg/m^3. While these areas experience less severe pollution than the northern and central parts of the country, $PM_{2.5}$ levels across all divisions remain substantially higher than the WHO's 2021 guideline for annual average $PM_{2.5}$ exposure of 5 µg/m^3, as well as Bangladesh's own national limit of 35 µg/m^3 as shown in Figure 2.

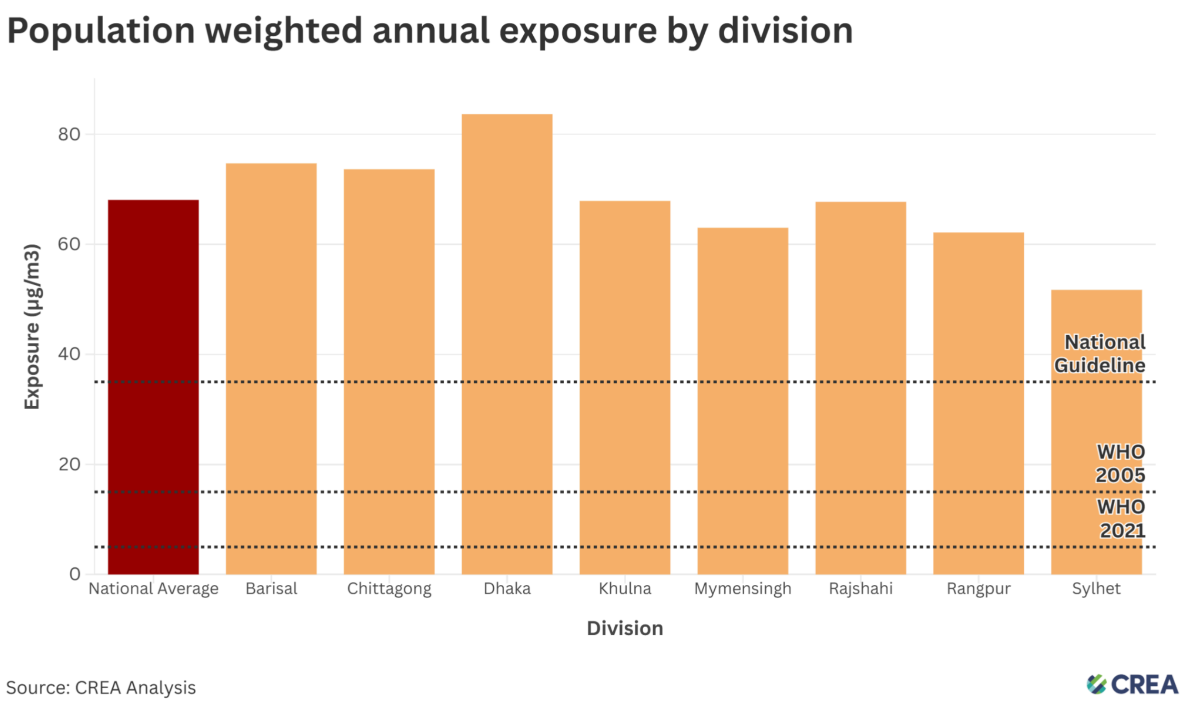


Fig 2 –$PM_{2.5}$ Concentration Levels Across Bangladesh Divisions

These findings suggest that despite some minor regional differences, the entirety of Bangladesh remains exposed to harmful levels of particulate matter. The high pollution levels across the entire country, regardless of regional population density, underlines the urgency for effective air quality management strategies to mitigate the health impacts of $PM_{2.5}$ exposure.

The ambient $PM_{2.5}$ levels measured by the Department of Environment, Bangladesh, reveal concentrations significantly higher than previously estimated using globally available datasets. On average, and over the eight cities for which our data is complete enough, these ground-based measurements exceeded estimates derived from the Van Donkelaar $PM_{2.5}$ basemap by approximately 20 µg/m^3. In contrast, estimates were much more closely aligned in neighbouring countries as shown in the figure below.

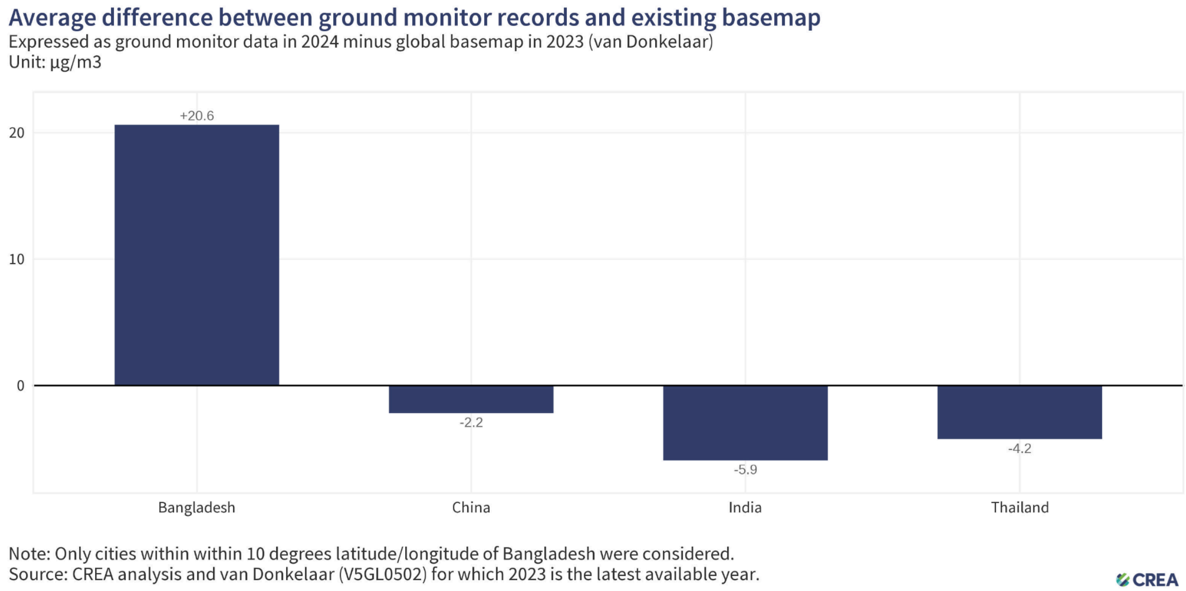


Fig 3: Average difference between $PM_{2.5}$ data recorded at ground monitoring station and the global $PM_{2.5}$ basemap

National health impacts

Table 1 shows our calculated health impacts of $PM_{2.5}$. We find that exposure to $PM_{2.5}$ has a huge impact on public health. $PM_{2.5}$ air pollution is a leading cause of mortality in Bangladesh. We find that $PM_{2.5}$ pollution is responsible for approximately 102,456 deaths annually. This reflects the considerable public health burden associated with ambient air pollution in the country.

Table 1 –Estimate of health impacts in Bangladesh as a result of exposure to $PM_{2.5}$ pollution under four different scenarios

Division	Current Levels	National Guideline	2005 WHO Guideline	2021 WHO Guideline
Chronic Obstructive Pulmonary Disease	21,012 (9,228-32,795)	16,531 (6,523-26,535)	9,114 (2,379-15,849)	3,570 (0-8,519)
Diabetes	10,408 (7,178-13,640)	10,072 (6,796-13,351)	7,585 (3,594-11,575)	2,808 (0-7,561)
Ischaemic Heart Disease	29,920 (18,296-41,542)	24,831 (13,840-35,825)	16,104 (6,763-25,444)	7,540 (0-16,973)
Lower Respiratory Infections	9,720 (6,855-12,587)	6,872 (4,679-9,066)	2,504 (635-4,371)	633 (0-2,051)
Lower Respiratory Infections In Children	5,258 (3,205-7,313)	3,718 (2,195-5,239)	1,355 (287-2,425)	342 (0-1,114)
Lung Cancer	3,063 (1,498-4,627)	2,085 (934-3,235)	807 (260-1,356)	221 (0-538)
Stroke	23,075 (9,233-36,917)	19,127 (6,033-32,223)	12,568 (1,593-23,541)	6,060 (0-15,144)
Total Deaths from All Causes	**102,456 (55,493-149,421)**	**83,236 (41,000-125,474)**	**50,037 (15,511-84,561)**	**21,174 (-51,900)**
Years of lives lost				
Stroke	37,693 (14,586-60,799)	31,314 (9,459-53,171)	20,571 (2,195-38,946)	9,873 (0-24,882)
Chronic Obstructive Pulmonary Disease	380,867 (167,127-594,610)	299,621 (118,130-481,117)	165,201 (43,070-287,332)	64,734 (0-154,429)
Ischaemic Heart Disease	769,082 (469,035-1,069,127)	638,545 (354,241-922,847)	412,751 (171,238-654,263)	192,537 (0-434,655)
Lower Respiratory Infections	185,359 (130,156-240,560)	131,042 (88,862-173,226)	47,736 (12,051-83,420)	12,060 (0-39,124)
Lower Respiratory Infections In Children	463,850 (282,331-645,367)	327,928 (193,491-462,365)	119,455 (25,147-213,762)	30,176 (0-98,331)
Lung Cancer	74,379 (35,582-113,175)	50,636 (22,177-79,097)	19,607 (6,140-33,073)	5,377 (0-13,078)

Years lived with disability				
Sick Leave Days	262,679,597 (217,779,893-309,517,394)	117,573,341 (98,822,888-136,640,072)	31,731,064 (26,902,426-36,559,707)	15,687,160 (13,322,560-18,043,860)
Chronic Obstructive Pulmonary Disease	155,319 (102,759-207,881)	122,188 (72,317-172,058)	67,370 (27,729-107,010)	26,399 (0-61,016)
Diabetes	175,010 (99,701-250,319)	169,383 (94,647-244,120)	127,544 (50,435-204,652)	47,233 (0-128,380)
Other outcomes				
Asthma Emergency Room Visits	668,482 (384,302-969,250)	282,478 (165,459-401,728)	37,829 (22,426-53,138)	Below risk threshold
Preterm Births	900,485 (336,368-987,804)	279,548 (122,609-300,467)	10,694 (5,156-11,362)	Below risk threshold
Lower Respiratory Infections In Children	5,258 (3,205-7,313)	3,718 (2,195-5,239)	1,355 (287-2,425)	342 (0-1,114)
Low Birthweight Births	696,389 (169,242-1,601,223)	262,638 (73,321-512,247)	44,975 (13,676-79,789)	7,319 (2,261-12,753)

Table 1 also shows the years of lives lost (YLL), years lived with disability (YLD) and other health outcomes associated with $PM_{2.5}$ pollution nationally in Bangladesh. Chronic diseases such as ischemic heart disease, chronic obstructive pulmonary disease (COPD), and stroke represent the largest contributors to YLL, reflecting the severe morbidity and potential fatal consequences of prolonged exposure to fine particulate pollution. The data also shows the prolonged health burdens individuals face, often leading to decreased quality of life and productivity. In particular, asthma-related emergency room visits and sick leave days represent a direct economic burden, with approximately 668,482 emergency room visits due to asthma and 262 million annual lost workdays attributed to $PM_{2.5}$ exposure. Similarly, maternal and child health outcomes are notably affected, with over 900,000 preterm births and almost 700,000 low birthweight births annually, pointing to the intergenerational impact of air pollution.

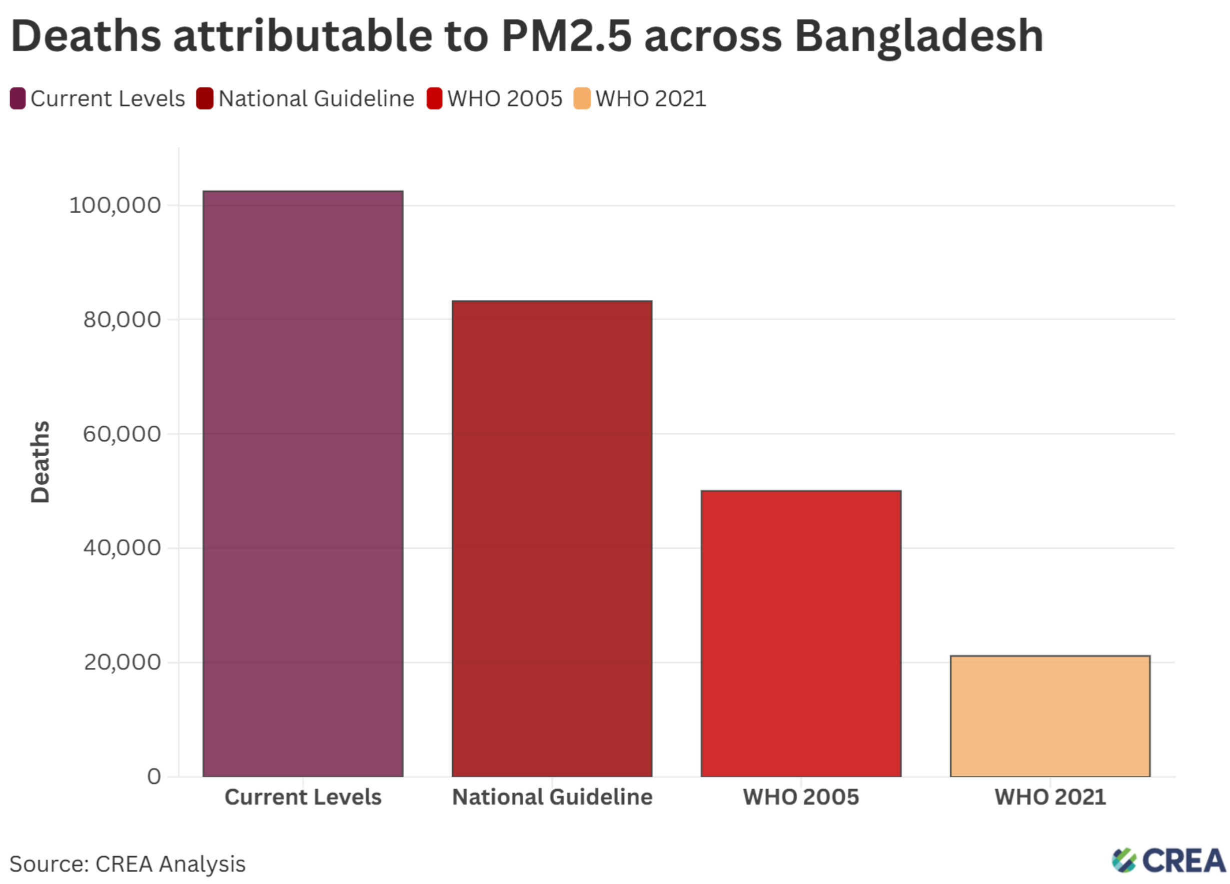


Fig 4 –Estimate of annual deaths in Bangladesh as a result of exposure to $PM_{2.5}$ pollution under four different Air Quality Standards: Current Levels, National Guideline, WHO Guideline 2005, and WHO Guideline 2021.

As shown in Table 1 and Figure 3, achieving Bangladesh's national guideline for $PM_{2.5}$, which is set at 35 µg/m^3, could reduce overall mortality by 19%. This would result in a decrease in deaths to 83,236 annually. The data suggests that adherence to national standards could yield significant health benefits, albeit the potential reductions are still limited given the relatively lenient national standard compared to international guidelines.

More substantial reductions in deaths could be attained by adhering to WHO guidelines. Meeting the 2005 WHO guideline for $PM_{2.5}$, set at 10 µg/m^3, is projected to reduce $PM_{2.5}$ deaths by 51%. This highlights the potential for greater health improvements by aligning national policies with these internationally recognized standards.

The most significant reductions in mortality are associated with achieving the 2021 WHO guidelines, which recommend a $PM_{2.5}$ level of 5 µg/m^3. This would result in a 79% reduction in deaths, as indicated in Table 1. These findings underscore the critical health gains that could be achieved through stricter air quality regulations, with substantial public health benefits observed across different levels of pollution control.

In addition to the reduction in deaths, achieving Bangladesh's national guideline of 35 µg/m^3 for annual $PM_{2.5}$ concentrations would result in substantial overall health benefits across the population – it would reduce the average YLL due to chronic diseases, number of respiratory infections, and other health issues by approximately 21% from current levels, offering immediate improvements in public health outcomes as shown in Table 1. Additionally, YLL due to lower respiratory infections in children would decrease significantly by 29%, reflecting a large improvement in addressing health risks among the most vulnerable groups.

Moving beyond the national guidelines, adherence to the 2005 WHO guideline of 10 µg/m^3 could yield even greater health improvements. Estimates suggest this reduction in $PM_{2.5}$ levels would lead to a 56% decrease in average YLL from chronic obstructive pulmonary disease (COPD), ischemic heart disease, lower respiratory infections, lung cancer, and stroke, while also contributing to a 41% decrease in average YLD. This intermediate target demonstrates the potential health gains achievable by tightening air quality standards beyond the current unmet national guideline in Bangladesh.

Finally, reaching the 2021 WHO guideline of 5 µg/m^3, while ambitious, presents the largest potential impact. Meeting this target would result in a 93% reduction in YLL from lower respiratory infections in children and nearly eliminate the need for asthma emergency visits and preterm births, as well as avoid more than 247 million annual sick leave days. These health benefits underscore the potential of stricter standards to enhance public health and productivity, especially if Bangladesh pursues a target of the most ambitious WHO guidelines. Together, these findings highlight a multitiered approach where incremental improvements yield cumulative benefits, with the highest gains clearly seen under the more stringent air quality targets.

Health Impacts by Division

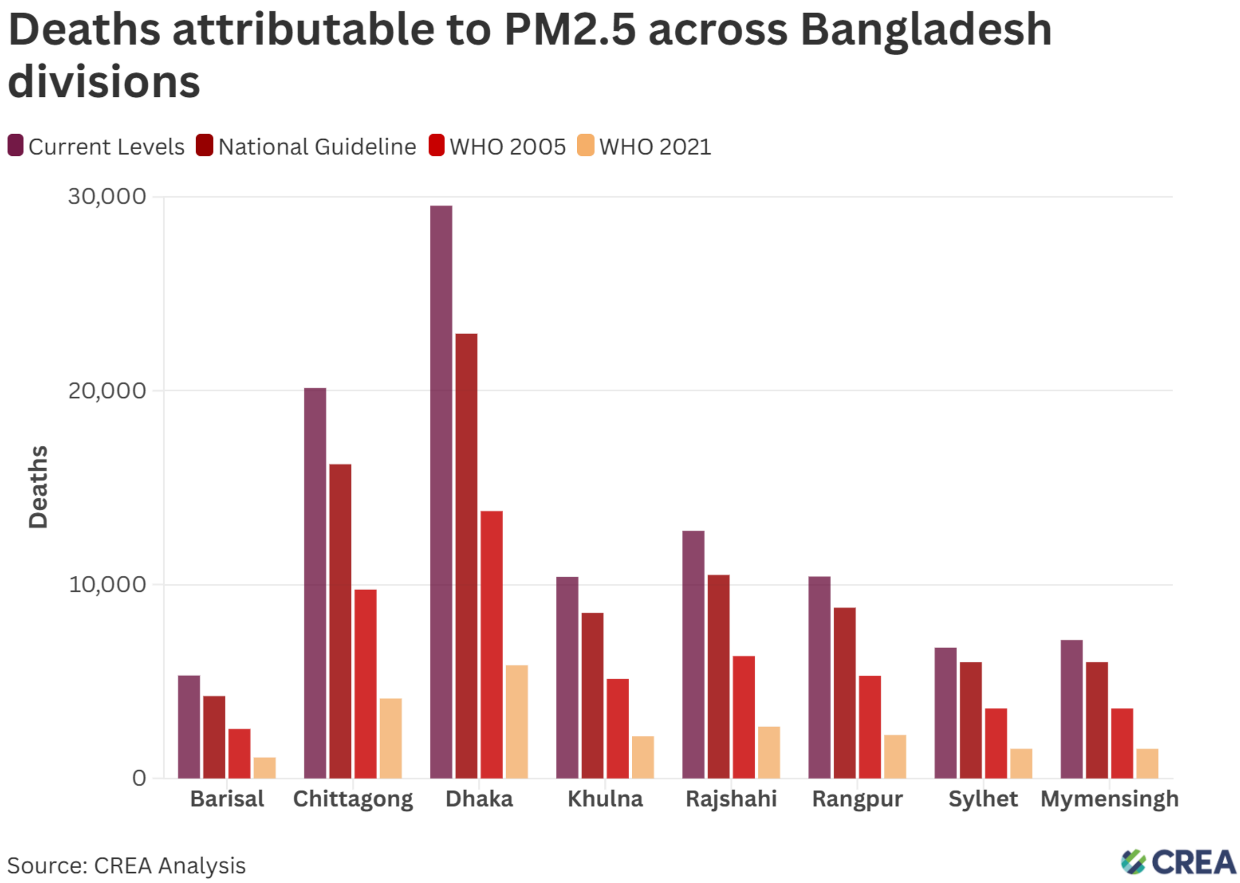


Fig 5 –Estimate of annual deaths in Bangladesh by division as a result of exposure to $PM_{2.5}$ pollution under four different Air Quality Standards: Current Levels, National Guideline, WHO Guideline 2005, and WHO Guideline 2021.

Figure 4 illustrates the significant geographic disparities in deaths due to $PM_{2.5}$ pollution across Bangladesh's eight divisions, with high-burden urban regions like Dhaka and Chittagong (Chattogram) accounting for 48% of total national deaths. These densely populated regions, where industrial activities and vehicle emissions are most concentrated (Bajracharya and Sultana, 2020), exhibit markedly higher rates of pollution-related mortality; 29,543 and 20,143 annual deaths in Dhaka and Chittagong, respectively. Under current $PM_{2.5}$ levels, deaths in these urban centres stand out, highlighting the urgent need for targeted air quality management strategies.

When examining these impacts under different air quality standards, the benefits of even modest improvements become clear. For instance, achieving Bangladesh's national guideline of 35 µg/m³ could lead to a meaningful reduction in deaths, especially in these hardest-hit districts. If $PM_{2.5}$ concentrations were brought down to align with the national guideline, it would likely produce a significant drop in mortality in major urban areas. However, the benefits of stricter targets become increasingly apparent as we consider the 2005 WHO guideline of 10 µg/m³ and the 2021 guideline of 5 µg/m³. Achieving these levels could further reduce deaths, with the 2021 guideline offering the most substantial improvement in public health outcomes. While rural and coastal districts show relatively lower mortality rates due to fewer pollution sources and lower population densities, even these regions remain significantly above safe $PM_{2.5}$ thresholds. Thus, meeting national and international air quality standards would still benefit these regions, though the most immediate impacts would be felt in high-burden urban centres.

Table 2 –Total years of lives lost due to $PM_{2.5}$ pollution by division in Bangladesh under four different Air Quality Standards

Division	Current Levels	National Guideline	2005 WHO Guideline	2021 WHO Guideline
Barisal	125,306 (67,847-182,765)	96,758 (46,760-146,758)	54,054 (14,903-93,203)	22,788 (0-55,901)
Chittagong	475,154 (256,731-693,574)	369,153 (178,395-559,911)	206,228 (56,861-355,595)	86,943 (0-213,275)
Dhaka	700,215 (383,872-1,016,558)	522,547 (252,525-792,569)	291,918 (80,488-503,346)	123,069 (0-301,894)
Khulna	244,563 (130,943-358,183)	194,466 (93,979-294,956)	108,638 (29,954-187,321)	45,800 (0-112,350)
Rajshahi	300,315 (160,736-439,893)	239,070 (115,533-362,608)	133,554 (36,824-230,285)	56,306 (0-138,118)
Rangpur	243,870 (128,920-358,820)	200,566 (96,925-304,208)	112,045 (30,894-193,196)	47,237 (0-115,874)
Sylhet	156,678 (80,812-232,544)	136,599 (65,985-207,215)	76,371 (21,057-131,683)	32,198 (0-78,980)
Mymensingh	167,317 (88,680-245,955)	136,657 (66,041-207,276)	76,343 (21,051-131,637)	32,186 (0-78,953)
Total	**2,413,418 (1,298,541-3,528,292)**	**1,895,816 (916,143-2,875,501)**	**1,059,151 (292,032-1,826,266)**	**446,527 (0-1,095,345)**

Table 3: Total years lived with disability due to $PM_{2.5}$ pollution by division in Bangladesh under four different Air Quality Standards

Division	Current Levels	National Guideline	2005 WHO Guideline	2021 WHO Guideline
Barisal	18,964 (11,245-26,682)	16,479 (9,004-23,954)	10,997 (4,101-17,893)	4,261 (0-10,936)
Chittagong	72,103 (42,665-101,540)	62,870 (34,353-91,389)	41,957 (15,647-68,267)	16,259 (0-41,722)
Dhaka	104,382 (62,580-146,184)	88,995 (48,627-129,363)	59,391 (22,149-96,633)	23,015 (0-59,058)
Khulna	37,503 (22,037-52,971)	33,120 (18,096-48,143)	22,102 (8,242-35,962)	8,566 (0-21,978)
Rajshahi	46,076 (27,059-65,094)	40,716 (22,248-59,185)	27,172 (10,134-44,211)	10,530 (0-27,020)
Rangpur	37,964 (22,059-53,868)	34,159 (18,665-49,652)	22,796 (8,500-37,090)	8,834 (0-22,668)
Sylhet	25,061 (14,281-35,842)	23,272 (12,713-33,831)	15,538 (5,794-25,281)	6,021 (0-15,451)
Mymensingh	25,969 (15,120-36,818)	23,274 (12,717-33,832)	15,532 (5,792-25,271)	6,019 (0-15,445)
Total	**368,022 (217,046-518,999)**	**322,885 (176,423-469,349)**	**215,485 (80,359-350,608)**	**83,505 (0-214,278)**

Tables 2 and 3 show the years of life lost and years lived with disability across Bangladesh's divisions, and how they will reduce if different air quality standards are met. Meeting the national guideline would reduce YLL significantly across divisions, with the greatest reductions seen in densely populated areas such as Dhaka and Chittagong. As with deaths, these divisions currently experience the highest $PM_{2.5}$ exposure, resulting in disproportionately high YLL figures. By achieving its own national guideline, Bangladesh could alleviate a significant portion of the disease burden associated with air pollution. Moving to the WHO-2005 guideline of 10 $\mu g/m^3$ would further lower YLL across all divisions, providing additional benefits in both high-burden and moderately impacted regions such as Rajshahi and Khulna. Finally, the strictest target, the 2021 WHO guideline of 5 µg/m^3, would yield the largest reductions in YLL across the board. Urban divisions would experience the most dramatic improvements, while rural and coastal areas would also see meaningful reductions, underscoring the widespread health advantages of achieving optimal air quality.

Similarly, meeting the local national guideline would lead to a notable decrease in YLD, particularly in urban areas like Dhaka and Chittagong, where pollution-driven disability burdens are currently highest. Further reductions under the WHO-2005 and WHO-2021 standards would extend these benefits, significantly lowering disability rates across all divisions. Achieving the 2021 guideline of 5 µg/m^3 would offer the most pronounced reduction in YLD, especially for regions with high levels of current disability burdens. This target demonstrates the potential for cleaner air to reduce not only mortality but also the prolonged disability that affects individuals' quality of life and economic productivity.

Overall, while $PM_{2.5}$ pollution affects the entire country, the heaviest burden of mortality falls on Bangladesh's urban areas. By pursuing incremental air quality improvements through the national guideline and gradually aligning with WHO guidelines, Bangladesh has an opportunity to alleviate the health impacts of air pollution where they are most acute. Targeted interventions in pollution hotspots, combined with broader efforts to meet national and international standards, would provide widespread health benefits and reduce the country's overall burden of disease.

Uncertainties and comparisons with other studies

This study uses a methodology to calculate the health impacts of $PM_{2.5}$ which potentially underestimates the impacts on premature deaths. The results of this study are subject to uncertainties stemming from variations in data sources, methodologies, and assumptions. This study employs the GBD model to estimate health impacts from $PM_{2.5}$ exposure given its alignment with conservative estimates and in alignment with local official data sources (Islam *et al.*, 2023), ensuring a robust foundation for determining health impacts. While the GEMM model is often considered more precise due to its broader dataset—comprising observational cohort studies and non-linear exposure-response relationships that better capture the complexities of how $PM_{2.5}$ affects health across diverse populations and exposure levels. In contrast, GBD's simpler linear approaches may underestimate risks at high pollution levels (Burnett *et al.*, 2018; Wang *et al.*, 2024).

In Figure 6 below, we present a chart comparing GBD and GEMM results across Bangladesh for mortality factors to illustrate the differences in estimation. On average, GEMM data for deaths attributable to $PM_{2.5}$ is 2.3 times higher than the GBD dataBoth GBD and GEMM data are also available in the companion online dashboard, where users can explore and compare the two models in greater detail.

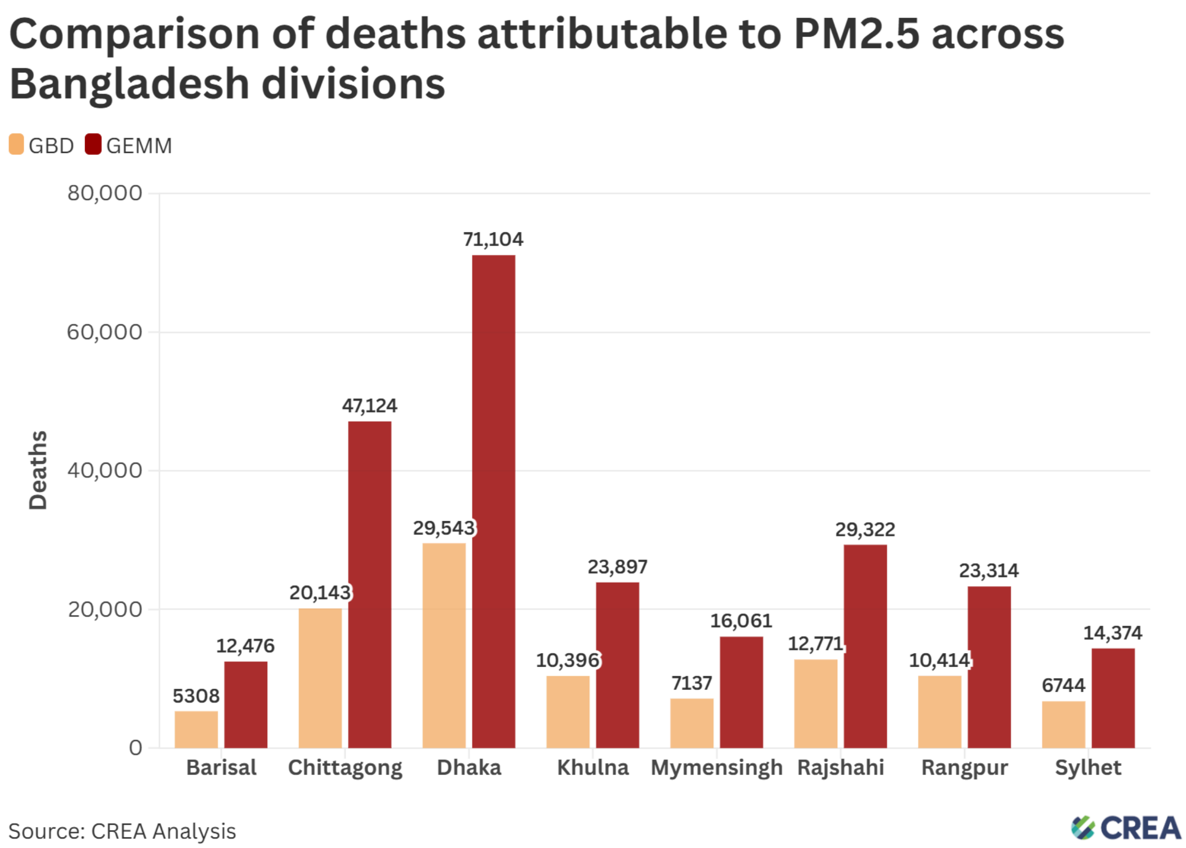


Figure 6: Comparison of premature deaths attributable to PM2.5 in Bangladesh between GBD and GEMM risk function.

However, in this report, only the GBD figures are discussed to maintain a conservative and consistent approach to the analysis. Nonetheless, these conservative estimates highlight the severe health implications of air pollution even under cautious modeling approaches. Employing GEMM or alternative models would likely yield significantly higher impact estimates, further underscoring the urgency for action.

Conclusion and Recommendations

The results in this report underscore the severe public health impacts of $PM_{2.5}$ pollution across Bangladesh and the need to implement and enforce more effective air quality management strategies. Given the variation in health impacts across regions, with the highest burden concentrated in urban centres, targeted interventions could be more beneficial. The analysis of different air quality standards — Bangladesh's national guideline, the 2005 WHO guideline, and the 2021 WHO guideline—demonstrates that aligning $PM_{2.5}$ levels with even modest improvements can yield substantial national health benefits. Additionally, the following recommendations would also yield potential improvements in health outcomes:

Integration of the National Air Quality Management Plan (NAQMP) 2024–2030: The recently launched NAQMP provides a comprehensive policy framework to combat air pollution, emphasizing sectoral emission reductions, capacity-building, and public engagement. It highlights actionable measures such as reducing emissions from industries, transportation, brick kilns, and agriculture, with a focus on achieving WHO Interim Target 1 for PM2.5 in the near term. This plan should be operationalized as a central tool for air quality governance. (Ministry of Environment, Forest and Climate Change, 2024)

Bangladesh should prioritize meeting its current air quality standards through a time-bound action plan: This plan should include clear reduction targets, emergency measures to address pollution spikes on peak days, and long-term strategies informed by source apportionment and carrying capacity studies. Such an approach ensures actionable, evidence-based steps to improve air quality while building a foundation for transitioning towards stricter guidelines like the 2005 WHO target of 10 $\mu g/m^3$ and the 2021 WHO target of 5 $\mu g/m^3$ in the future. (Khatun, Saadat and Ashraf, 2023).

Promote Cleaner Energy Sources: Reducing reliance on coal and diesel as primary energy sources will be essential in curbing $PM_{2.5}$ in the long term (Clean Air Asia, 2020). Policies incentivizing the adoption of renewable energy, as well as support for cleaner transportation and industry, could substantially reduce $PM_{2.5}$ (World Future Council, 2019). Collaboration with international organisations on transitioning to cleaner energy could provide Bangladesh with both technical assistance and funding opportunities.

Implement Emissions Control in High-Burden Areas: Immediate focus should be placed on emissions control in high-burden urban centres, especially Dhaka and Chattogram. This could involve stricter industrial emissions regulations, enhanced vehicular emissions standards, and improved monitoring and enforcement mechanisms. To ensure measurable results, a phased approach targeting the emissions from most polluting industries, such as brick kilns and power plants (Khatun, Saadat and Ashraf, 2023), is recommended.

Expand Air Quality Monitoring Infrastructure: Currently, air quality data in Bangladesh is limited, especially in rural and coastal areas; expanding monitoring networks would allow for better tracking of $PM_{2.5}$ trends and more accurate health impact assessments (Ram, 2024). Establishing a national monitoring framework that integrates ground-based and satellite data would provide a comprehensive view of air quality across the country.

Methodology

$PM_{2.5}$ Exposure Map Construction

The $PM_{2.5}$ exposure map used in this report was created by combining satellite-derived and model-based estimates from the Van Donkelaar V5.GL.04 $PM_{2.5}$ basemap with ground-based measurements, offering a detailed representation of air pollution levels across Bangladesh and nearby provinces. To expand the dataset, we included ground-based measurements from neighbouring regions within 10 degrees of latitude and longitude.

Since the Van Donkelaar basemap only extends to 2022, we applied a machine learning approach to update it, reflecting $PM_{2.5}$ levels for the period from 1 January 2024 to 31 December 2024.

Data Sources

Ground-based $PM_{2.5}$ measurements were obtained from monitoring agencies across Bangladesh, India, China, and Thailand for the period of interest. The data sources include:

- Bangladesh: Department of Environment, Government of Bangladesh
- India: Central Pollution Control Board (CPCB)
- China: Ministry of Ecology and Environment
- Thailand: Air4Thai, a division of the Pollution Control Department

Ground-based measurements from the Government of Bangladesh were critical in calibrating satellite-derived PM2.5 estimates. Using local, official data enhances the accuracy and relevance of the findings to national health policy frameworks

Data Integration

To integrate satellite-derived and ground-based data, we employed a Random Forest algorithm. This model was trained to predict ground-level $PM_{2.5}$ concentrations using the following predictor variables:

- $PM_{2.5}$ prior: Estimates from the Van Donkelaar dataset for 2022.

- MERRA-2 $PM_{2.5}$ difference: The difference in $PM_{2.5}$ concentrations between the current period and the 2022 Van Donkelaar dataset.
- Distance to the coast.
- Elevation and topography sourced from SRTM.
- Population density and growth sourced from the Gridded Population of the World (GPW) dataset.

Since most monitoring stations are concentrated in urban areas, the update was limited to urban zones, as defined by the GRUMP dataset. Rural areas were left unchanged, retaining their original $PM_{2.5}$ values from the Van Donkelaar dataset.

Health Impacts Assessment

Based on the spatial distributions of the $PM_{2.5}$ simulated exposure map, we then calculated the corresponding public health impacts between 1 January 2024 to 31 December 2024. CREA has developed a detailed, globally implementable health impact assessment (HIA) framework based on the latest science (Myllyvirta, 2020). This framework includes as complete a set of health outcomes as possible without obvious overlaps.

The emphasis is on outcomes for which incidence data is available at the national level from global datasets and outcomes that have high relevance for healthcare costs and labour productivity. These health endpoints were selected and quantified in a way that enables economic valuation, adjusted by levels of economic output and income in different jurisdictions.

For each evaluated health outcome, we have selected a concentration-response relationship that has been used to quantify the health burden of air pollution at the global level in peer-reviewed literature. This indicates that the evidence is mature enough to be applied across varying geographies and exposure levels. The calculation of health impacts follows a standard epidemiological calculation:

$$\Delta cases = Pop \times \sum_{age} \left[Frac_{age} \times Incidence_{age} \times \frac{RR_{c,age} - 1}{RR_{c,age}} \right],$$

Where:

Pop is the total population in the grid location;

age is the analysed age group; in the case of age-dependent concentration-response functions, a 5-year age segment; in other cases, the total age range to which the function is applicable;

$Frac_{age}$ is the fraction of the population belonging to the analysed age group;

Incidence is the baseline incidence of the analysed health condition;

c is the pollutant concentration with c_{base} referring to the baseline concentration or current ambient concentration; and,

$RR_{conc,\ age}$ is the function giving the risk ratio of the analysed health outcome at the given concentration for the given age group compared with clean air. In the case of a log-linear, non-age specific concentration-response function, the RR function becomes:

$$RR(c) = RR_0 c - c_0 \Delta c_0 \ when\ c > c_0, \text{ 1 otherwise}$$

Where:

RR_0 is the risk ratio found in epidemiological research;

Δc_0 is the concentration change that RR_0 refers to; and,

c_0 is the assumed no-harm concentration - in general, the lowest concentration found in study data.

Data on the total population and population age structure was taken from the Global Burden of Disease results for 2019 (Murray *et al.*, 2020), which was accessed by the Institute for Health Metrics and Evaluation (IHME, 2020). The spatial distribution of the population within each city and country, as projected for 2020, was based on the Gridded Population of the World v4 from the Center for International Earth Science Information Network (CIESIN, 2018).

Adult deaths were estimated using the risk functions developed by Burnett *et al.* (2018), as applied by Lelieveld *et al.* (2019). Deaths of small children under five years old from lower respiratory infections linked to $PM_{2.5}$ pollution were assessed using the Global Burden of Disease risk function for lower respiratory diseases (IHME, 2020). For all mortality results, cause-specific data was taken from the Global Burden of Disease project results for 2019 (IHME, 2020).

Health impact modelling projects the effects of pollutant exposure during the study year. Some health impacts are immediate, such as exacerbation of asthma symptoms and lost working days, whereas other chronic impacts may have a latency of several years. Concentration-response relationships for emergency room visits for asthma and work absences were based on studies that evaluated daily variations in pollutant concentrations and health outcomes; these relationships were applied to changes in annual average concentrations. An overview of the input data to estimate public health impacts of air pollution is shown in Table 4.

Table 4 - Input parameters and data used in estimating physical health impacts

Age group	Effect	Pollutant	Concentration-response function	Concentration change	No-risk threshold	Reference	Incidence data
0-17	Asthma emergency room visits	$PM_{2.5}$	1.025 (1.013 – 1.037)	10 µg/m³	6 µg/m³	Zheng et al. (2015)	Anenberg et al. (2018)
18-99	Asthma emergency room visits	$PM_{2.5}$	1.023 (1.015 – 1.031)	10 µg/m³	6 µg/m³	Zheng et al. (2015)	Anenberg et al. (2018)
Newborn	Preterm birth	$PM_{2.5}$	1.15 (1.07 – 1.16)	10 µg/m³	8.8 µg/m³	Sapkota et al. (2012)	Chawanpaiboon et al. (2018)
20-65	Work absence	$PM_{2.5}$	1.046 (1.039 – 1.053)	10 µg/m³	N/A	WHO (2013)	EEA (2014)
0-4	Deaths from lower respiratory infections	$PM_{2.5}$	IHME (2020)		5.8 µg/m³	IHME (2020)	IHME (2020)
25-99	Deaths from non-communicable diseases,	$PM_{2.5}$	Burnett et al. (2018)		2.4 µg/m³	Burnett et al. (2018)	IHME (2020)

	disaggregated by cause, and from lower respiratory infections						
25-99	Disability caused by diabetes, stroke and chronic respiratory disease	$PM_{2.5}$	IHME (2020)		2.4 µg/m^3	Burnett et al. (2018)	IHME (2020)

Note: Numeric values in the column, 'Concentration-response function', refer to odds ratio (OR) corresponding to the increase in concentrations given in the column 'concentration change'. Literature references indicate the use of a non-linear concentration-response function. No-harm threshold refers to a concentration below which the health impact is not quantified, generally because the studies on which the function is based did not include people with lower exposure levels. Data on concentration-response relationships do not exist for all geographies, so a global risk model is applied to all cities. Incidence data are generally unavailable at the city level so national averages have to be applied.

References

Bajracharya, P. and Sultana, S. (2020) 'Rank-size Distribution of Cities and Municipalities in Bangladesh', *Sustainability*, 12, p. 4643. Available at: https://doi.org/10.3390/su12114643.

Burnett, R., Chen, H., Szyszkowicz, M., Fann, N., Hubbell, B., et al. (2018). Global Estimates of Mortality Associated with Long-Term Exposure to Outdoor Fine Particulate Matter. Proceeding of the National Academies of Science, 115 (38): 9592-9597. https://doi.org/10.1073/pnas.1803222115

Clean Air Asia (2020) *South and Southeast Asian Countries Coal-Fired Power Plant Emission Standards*. Clearn Air Asia. Available at: https://cleanairasia.org/sites/default/files/2021-05/-%201.3%20South%20and%20Southeast%20Asian%20Countries%20Coal-Fired%20Power%20Plant%20Emission%20Standards%20Policy%20Analysis%202020.pdf

Hasnat, G.N.T., Kabir, Md.A. and Hossain, Md.A. (2018) 'Major Environmental Issues and Problems of South Asia, Particularly Bangladesh', in C.M. Hussain (ed.) *Handbook of*

Environmental Materials Management. Cham: Springer International Publishing, pp. 1–40. Available at: https://doi.org/10.1007/978-3-319-58538-3_7-1.

Health Effects Institute. 2024. State of Global Air 2024. Special Report. Boston, MA:Health Effects Institute. ISSN 2578-6873

Institute for Health Metrics and Evaluation (IHME) (2020). GBD Results. http://ghdx.healthdata.org/gbd-results-tool

Islam, M. S., Roy, S., Tusher, T. R., Rahman, M., & Harris, R. C. 2023a. Assessment of Spatio-Temporal Variations in PM2. 5 and Associated Long-Range Air Mass Transport and Mortality in South Asia. *Remote Sensing*, *15*(20), 4975.

Islam, S. M. S., Uddin, R., Das, S., Ahmed, S. I., Zaman, S. B., Alif, S. M., ... & Naghavi, M. 2023b. The burden of diseases and risk factors in Bangladesh, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *The Lancet Global Health*, *11*(12), e1931-e1942.

Khatun, F., Saadat, S.Y. and Ashraf, K. (2023) *BREATHING UNEASY: An Assessment of Air Pollution in Bangladesh*. Center for Policy Dialogue. Available at: https://www.theigc.org/sites/default/files/2023-11/BREATHING-UNEASY-An-Assessment-of-Air-Pollution-in-Bangladesh.pdf.

Lelieveld et al., (2023). Air pollution deaths attributable to fossil fuels: observational and modelling study. BJM. www.bmj.com/content/383/bmj-2023-077784

Myllyvirta, L. (2020). Quantifying the Economic Costs of Air Pollution from Fossil Fuels. Centre for Research on Energy and Clean Air (CREA). https://energyandcleanair.org/publication/quantifying-the-economic-costs-of-air-pollution-from-fossil-fuels/

Ram, A. (2024) ‘Low-cost sensors can point to solutions for world’s most polluted cities’, *CBC News*, 28 March. Available at: https://www.cbc.ca/news/climate/air-quality-international-bangladesh-dhaka-1.7156475

World Bank. 2023a. “Building Back a Greener Bangladesh: Country Environmental Analysis.” Washington DC, The World Bank Group.

World Bank. 2023b. Striving for Clean Air: Air Pollution and Public Health in South Asia. South Asia Development Matters. Washington, DC: World Bank. doi:10.1596/978-1-4648 1831-8. License: Creative Commons Attribution CC BY 3.0 IGO.

World Future Council (2019) ‘100% Renewable Energy in Bangladesh: RE for All’, *World Future Council*, 28 August. Available at: https://www.worldfuturecouncil.org/100-renewable-energy-bangladesh/