Impact of Air Pollution on Chronic Respiratoy Diseases: An Exploratory Data Analysis of GBD Data

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Contents

1 Abstract

This study investigates the global impact of air pollution on chronic respiratory diseases (CRDs) using data from the Global Burden of Disease (GBD) 2021. Through exploratory data analysis, we examine the contribution of different types of air pollutants—ambient particulate matter, household air pollution, ozone, and nitrogen dioxide—to CRD-related mortality and disability. In 2021, CRDs accounted for 22.1% of all deaths and 29.4% of all years lived with disability (YLDs) attributable to air pollution. The burden is disproportionately higher in countries with low and low-middle Socio-demographic Index (SDI), and in regions with limited or minimal health system capacity. While mortality rates have declined over time, the chronic health impact remains significant, with a shift toward long-term disability. The findings highlight the urgent need for targeted interventions and policy measures to mitigate air pollution and reduce its health burden, especially in vulnerable populations.

2 Introduction

Air pollution is one of the leading environmental risk factors for public health worldwide. It can be broadly categorized into ambient (outdoor) air pollution, which originates from sources such as traffic emissions, industrial activities, forest fires, and energy production, and household (indoor) air pollution, which is prevalent in rural areas of low-income countries due to the burning of solid fuels like wood, dung, and crop residues for cooking and heating (Dhimal et al., 2021). Both forms of air pollution are strongly associated with chronic respiratory diseases (CRDs), including chronic obstructive pulmonary disease (COPD) and asthma, as well as other serious health conditions such as lower respiratory infections, cardiovascular diseases, diabetes, and adverse birth outcomes. It is estimated that around 3.6 billion people are exposed to household air pollution, highlighting the global scale of the issue (Dhimal et al., 2021). This study aims to analyze the impact of air pollution on CRDs using data from the Global Burden of Disease (GBD) project. Through exploratory data analysis (EDA), we identify patterns, trends, and disparities across countries, age groups, and genders. The goal is to deepen our understanding of how air pollution affects respiratory health and to support the development of more effective public health interventions.

3 Methodology

This study employs an exploratory data analysis (EDA) approach to investigate the global burden of chronic respiratory diseases (CRDs) attributable to air pollution. Data were sourced from the Global Burden of Disease (GBD) 2021 dataset, accessed via the GBD Results Tool. The dataset includes metrics such as deaths, DALYs (Disability-Adjusted Life Years), YLLs (Years of Life Lost), and YLDs (Years Lived with Disability), stratified by age, sex, location, health system type, and socio-demographic index (SDI). The analysis focuses on key risk factors including ambient particulate matter pollution, household air pollution from solid fuels, ambient ozone pollution, and nitrogen dioxide pollution. Data preparation involved selecting relevant columns, and ensuring consistency across formats. The analysis was conducted using R, allowing for efficient data manipulation and visualization. Temporal trends, geographical distribution, and disparities across SDI classes and health system types were examined to provide a comprehensive view of the impact of air pollution on CRDs.

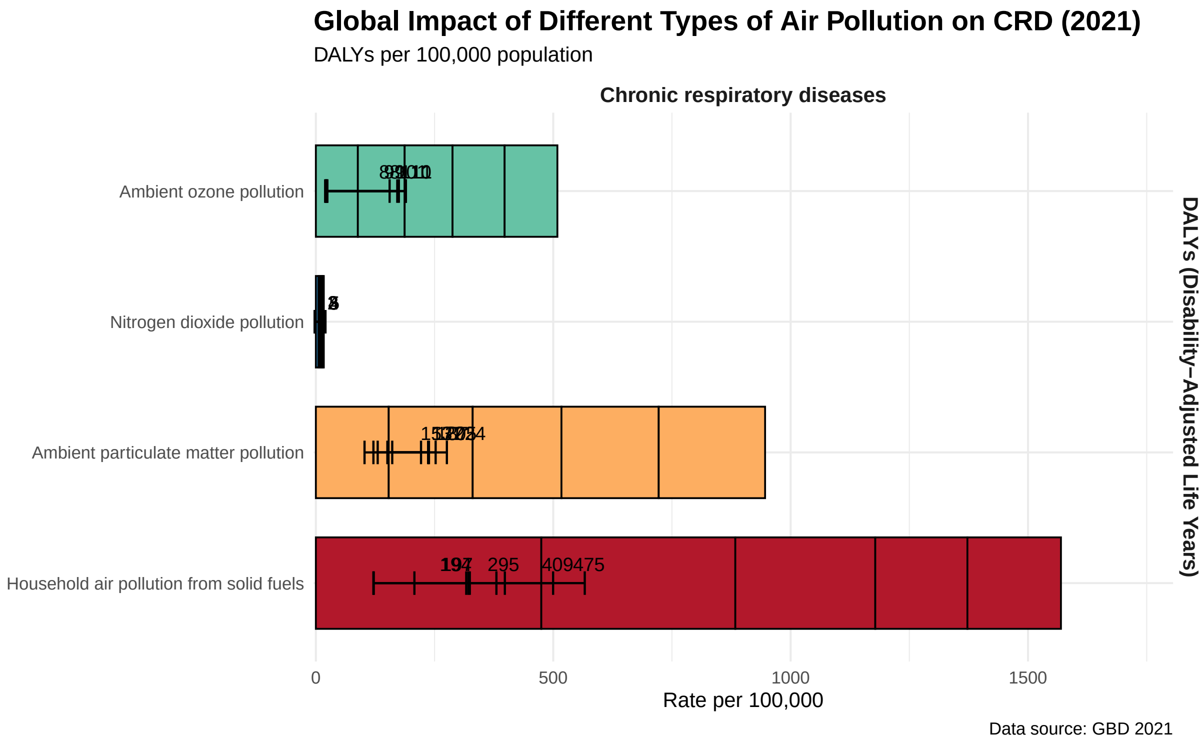
Variable	Values
measure	Deaths, DALYs (Disability-Adjusted Life Years), YLDs (Years Lived with Disability), YLLs (Years of Life

location	Global, High SDI, High-middle SDI, Middle SDI, Low-middle SDI, Low SDI, Advanced Health System, Ba
sex	Male, Female, Both
age	All ages, 15-49 years, Age-standardized, 85-89 years, 90-94 years, 0-14 years, 50-74 years, 95+ years, 75-84
cause	All causes, Chronic respiratory diseases, Chronic obstructive pulmonary disease, Asthma
rei	Air pollution, Household air pollution from solid fuels, Ambient ozone pollution, Ambient particulate matt
metric	Number, Rate
year	1990, 2000, 2010, 2020, 2021

measure: Deaths, DALYs (Disability-Adjusted Life Years), YLDs (Years Lived with Disability), YLLs (Years of Life Lost)
location: Global, High SDI, High-middle SDI, Middle SDI, Low-middle SDI, Low SDI, Advanced Health System, Basic Health System, Limited Health System, Minimal Health System, China, Democratic People's Republic of Korea, Taiwan, Cambodia, Indonesia, Malaysia, Lao People's Democratic Republic, Maldives, Myanmar, Philippines, Sri Lanka, Thailand, Timor-Leste, Viet Nam, Kiribati, Fiji, Micronesia (Federated States of), Marshall Islands, Papua New Guinea, Solomon Islands, Samoa, Tonga, Armenia, Vanuatu, Georgia, Azerbaijan, Kazakhstan, Tajikistan, Mongolia, Kyrgyzstan, Albania, Turkmenistan, Uzbekistan, Czechia, Bosnia and Herzegovina, Hungary, Bulgaria, Croatia, Poland, Romania, Montenegro, North Macedonia, Serbia, Slovakia, Belarus, Slovenia, Estonia, Russian Federation, Latvia, Ukraine, Republic of Moldova, Lithuania, Brunei Darussalam, Singapore, Andorra, Australia, New Zealand, Japan, Republic of Korea, Austria, Belgium, Cyprus, France, Germany, Iceland, Finland, Greece, Ireland, Denmark, Italy, Luxembourg, Malta, Norway, Netherlands, Israel, Spain, Portugal, United Kingdom, Argentina, Switzerland, Uruguay, Canada, Sweden, Chile, United States of America, Bahamas, Barbados, Antigua and Barbuda, Cuba, Belize, Dominica, Dominican Republic, Grenada, Guyana, Haiti, Jamaica, Saint Vincent and the Grenadines, Saint Lucia, Trinidad and Tobago, Suriname, Bolivia (Plurinational State of), Ecuador, Peru, Colombia, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Venezuela (Bolivarian Republic of), Brazil, Paraguay, Algeria, Bahrain, Egypt, Iran (Islamic Republic of), Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Palestine, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, Türkiye, United Arab Emirates, Yemen, Afghanistan, Bangladesh, India, Bhutan, Nepal, Pakistan, Angola, Central African Republic, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Seychelles, Somalia, United Republic of Tanzania, Uganda, Zambia, Botswana, Lesotho, Namibia, South Africa, Eswatini, Zimbabwe, Benin, Burkina Faso, Cabo Verde, Cameroon, Chad, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Sao Tome and Principe, Senegal, Sierra Leone, Togo, American Samoa, Bermuda, Cook Islands, Greenland, Guam, Monaco, Nauru, Niue, Northern Mariana Islands, Palau, Saint Kitts and Nevis, Puerto Rico, Tokelau, San Marino, United States Virgin Islands, Tuvalu, South Sudan, Sudan, Taiwan (Province of China), Turkey, East Asia, Southeast Asia, Oceania, Central Asia, Central Europe, Eastern Europe, High-income Asia Pacific, Australasia, Western Europe, Southern Latin America, High-income North America, Caribbean, Andean Latin America, Central Latin America, Tropical Latin America, North Africa and Middle East, South Asia, Central Sub-Saharan Africa, Eastern Sub-Saharan Africa, Southern Sub-Saharan Africa, Western Sub-Saharan Africa
sex: Male, Female, Both
age: All ages, 15-49 years, Age-standardized, 85-89 years, 90-94 years, 0-14 years, 50-74 years, 95+ years, 75-84 years
cause: All causes, Chronic respiratory diseases, Chronic obstructive pulmonary disease, Asthma
rei: Air pollution, Household air pollution from solid fuels, Ambient ozone pollution, Ambient particulate matter pollution, Particulate matter pollution, All risk factors, Nitrogen dioxide pollution
metric: Number, Rate
year: 1990, 2000, 2010, 2020, 2021

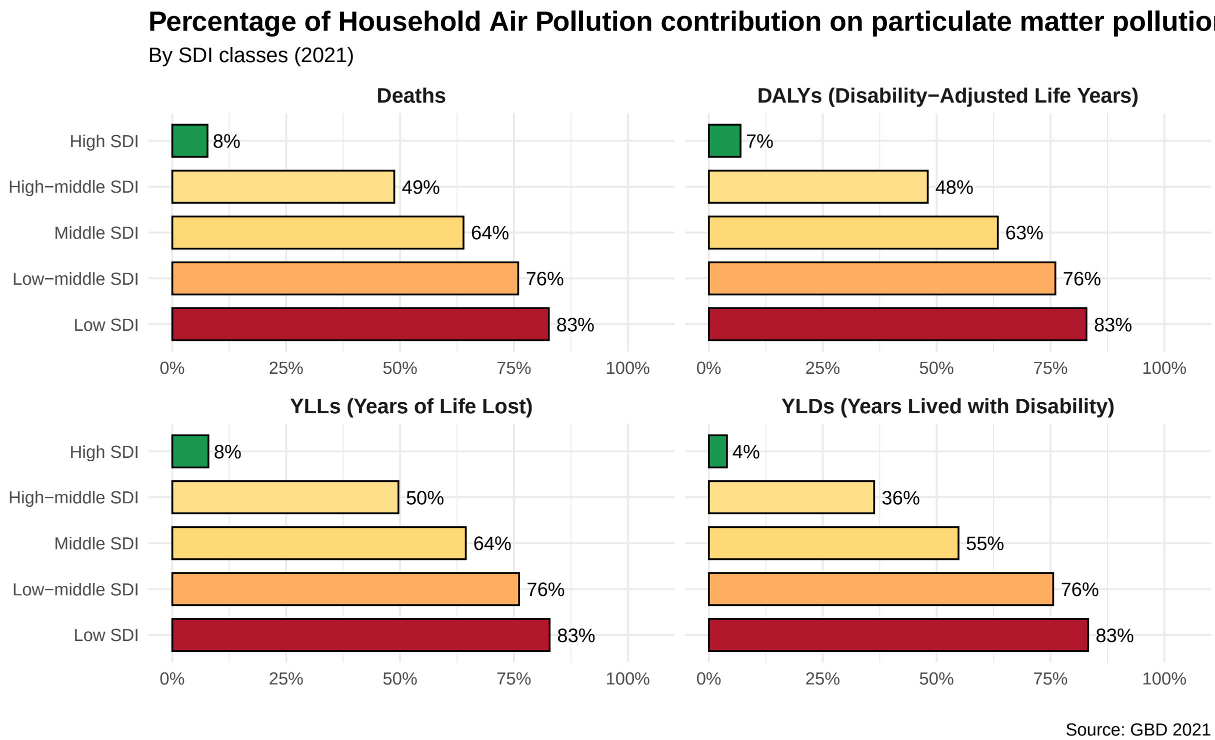
4 Results

4.1 Impact of different types of polluents

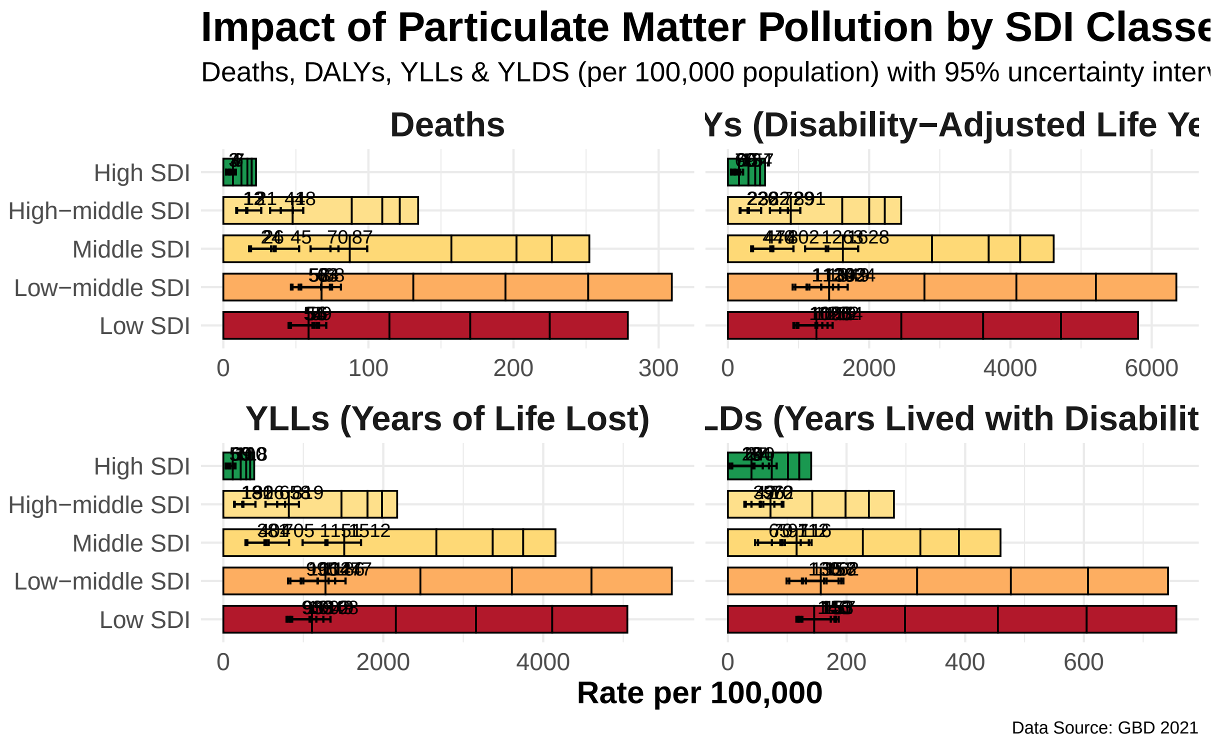


4.2 Impact on different Socio-demographic Index

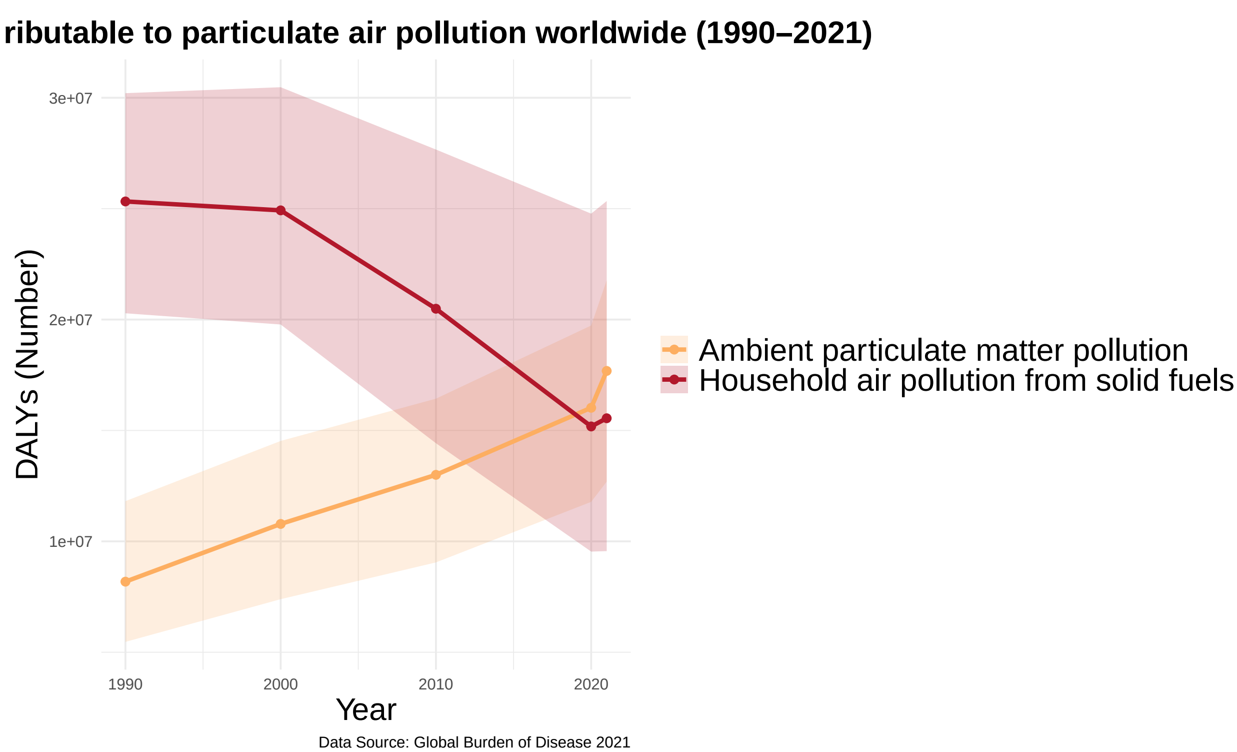
4.2.1 Percentage of Household Air Pollution contribution on particulate matter pollution



4.2.2 Impact of Particulate Matter Pollution by SDI Classes (2021)

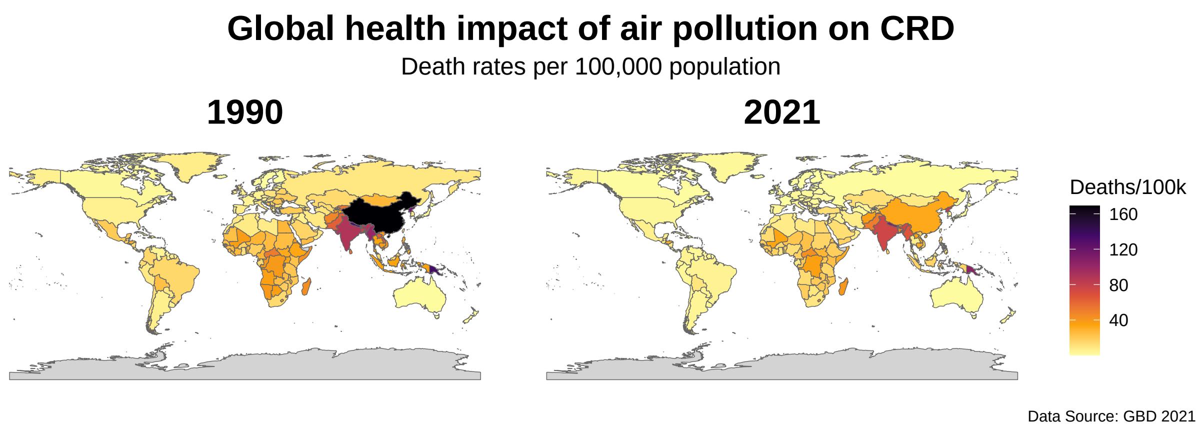


4.3 DALYs attributable to household vs ambient particulate air pollution worldwide (1990–2021)

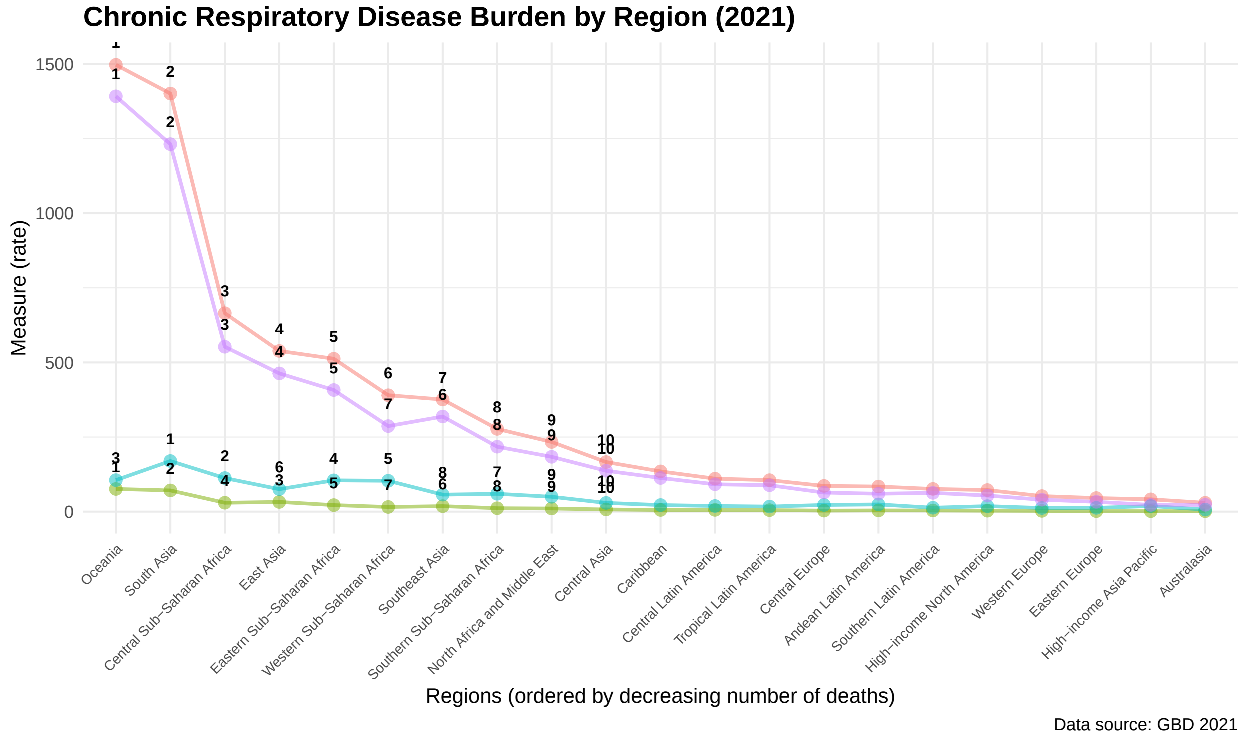


4.4 Geographical Distribution

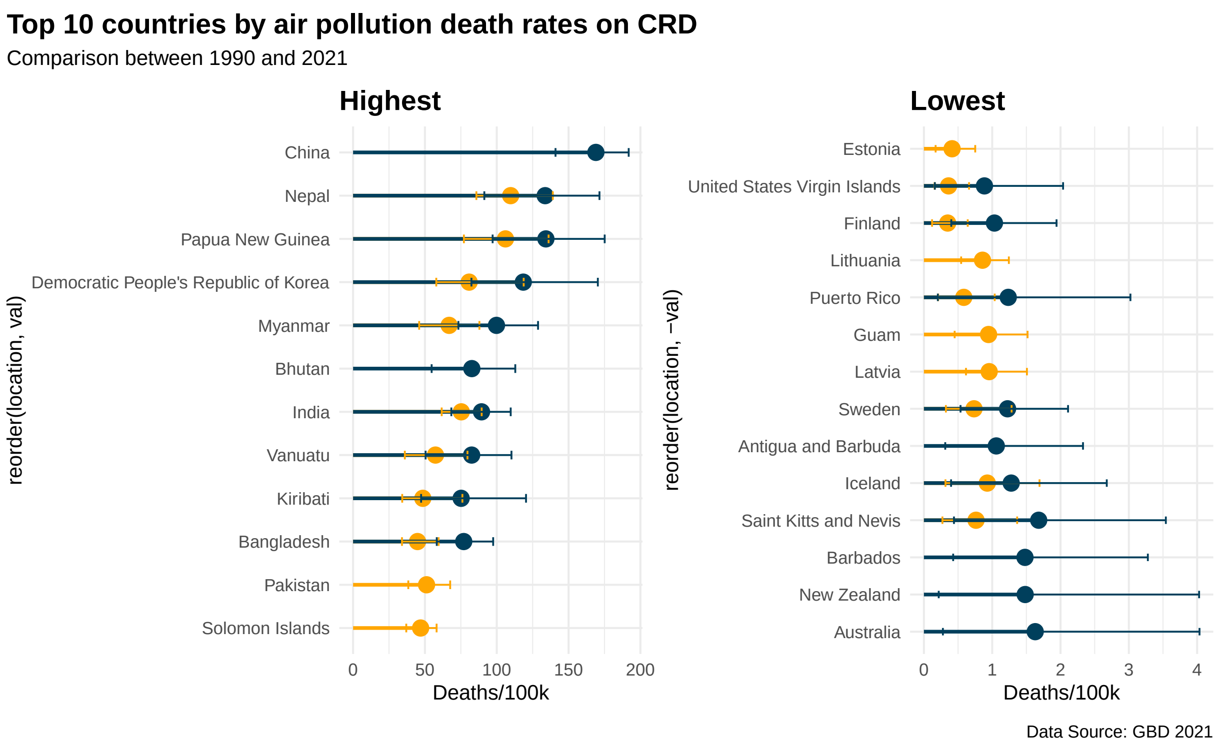
4.4.1 Global health impact of air pollution on CRD in 1990 and 2021



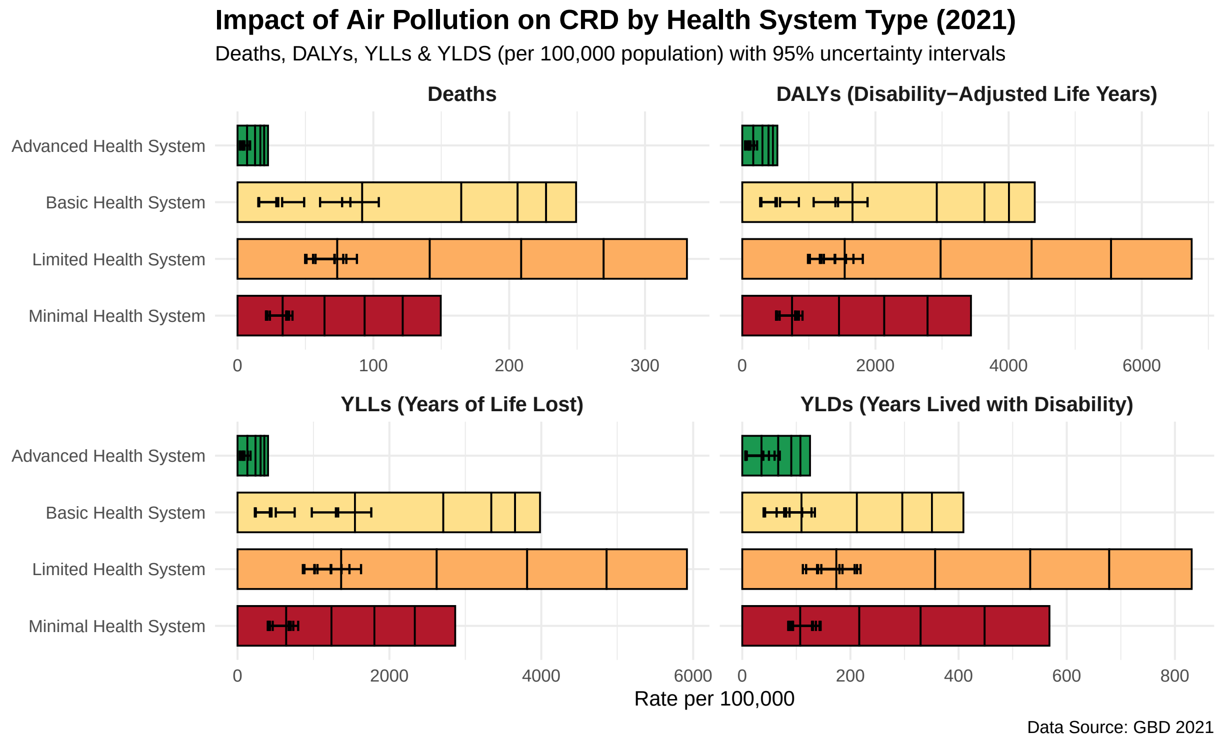
4.4.2 Country ranking by all measures in 2021



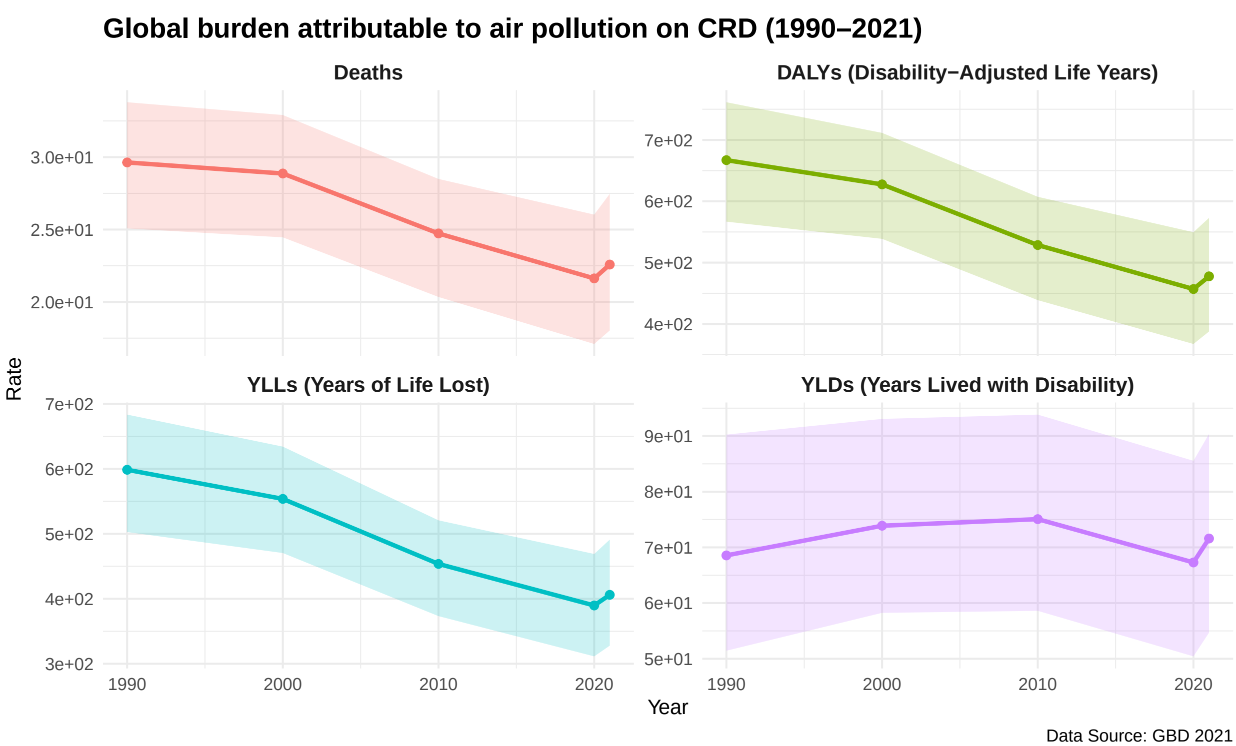
4.4.3 Top 10 countries by air pollution death rates on CRD



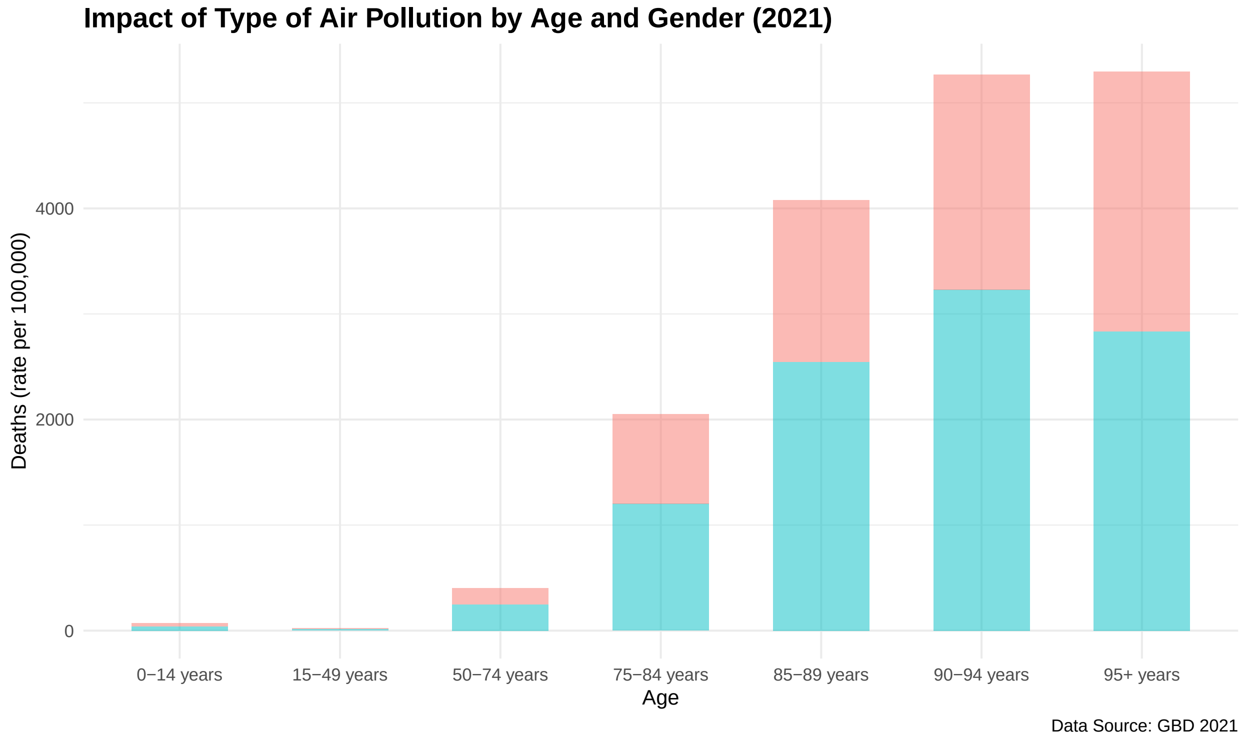
4.5 Impact of Air Pollution on CRD by Health System Type (2021)



4.6 Temporal trends



4.7 Age and Gender



5 Discussion

Our findings align closely with the study by Dhimal et al., which emphasized the extensive impact of both ambient and household air pollution on global health metrics, particularly mortality and disability-adjusted life years (DALYs) from 1990 to 2019. Similar to our analysis, Dhimal et al. reported how ambient and household pollution disproportionately affect vulnerable groups—infants, elderly, women, and those with pre-existing cardiorespiratory conditions—while also highlighting regional disparities by socio-demographic index (SDI) (Dhimal et al., 2021). Our study corroborates these findings, revealing comparable geographical and demographic patterns, and reinforcing the need for targeted environmental health strategies in low-SDI regions. Ostro et al.'s assessment of the GBD methodology for estimating the burden of ambient air pollution in low- and middle-income countries underscores critical methodological complexities (Ostro et al., 2018). They argue that changes in exposure modeling, such as refining $PM_{2.5}$ concentration estimates and adjusting exposure–response curves, significantly alter burden estimates across different geographical contexts. Our research applies similar methodological refinements—employing updated exposure-response functions and stratifying by pollutant type—and arrives at notably consistent estimates of CRD burden, especially in countries with limited monitoring infrastructure. This parallel strengthens confidence in our approach and supports the WHO's revised burden metrics. Finally, the recent Lancet study by Bennitt et al. (2025) provides a comprehensive evaluation of household air pollution (HAP) trends and burdens from 1990 to 2021, reporting that in 2021 approximately 2.67 billion people (33.8% of the global population) were exposed to HAP at mean $PM_{2.5}$ concentrations of 84.2 µg/m³. They also estimate 111 million attributable DALYs, constituting 3.9% of the global DALY total (Bennitt et al., n.d.). Our analysis produces similar exposure prevalence and burden figures, reinforcing the enduring health impact of HAP despite gradual reductions in percentage exposure since 1990. This concordance emphasizes the need for continued interventions aimed at reducing solid fuel usage and improving indoor air quality, particularly in rural, low-income communities.

6 Limitations

While this study provides valuable insights into the global impact of air pollution on chronic respiratory diseases, several limitations must be acknowledged. First, the GBD dataset relies on modeled estimates, which may be affected by data availability and quality across countries, particularly in low-income regions. Second, the attribution of disease burden to specific pollutants is complex and may involve overlapping exposures, making it difficult to isolate the effects of individual pollutants. Additionally, the analysis does not account for potential confounding factors such as smoking, occupational exposures, or socioeconomic determinants that may influence respiratory health. The use of aggregated data also limits the ability to explore individual-level risk factors or causal relationships. Finally, while the study spans multiple years, changes in data collection methods or definitions over time may affect comparability. Future research should aim to integrate more granular data and consider longitudinal designs to better understand the dynamics of air pollution and respiratory disease burden.

7 Conclusions

In 2021, chronic respiratory diseases (CRDs) accounted for approximately 22.1% of all deaths and 29.4% of all years lived with disability (YLDs) attributable to air pollution. Ambient particulate matter emerged as the leading contributor to the global CRD burden, followed by household air pollution, whose impact is inversely related to the Socio-demographic Index (SDI) level. The burden of air pollution on CRDs is most pronounced in low-middle SDI countries, with the exception of YLDs, followed by low SDI regions. While the impact of ambient pollution is increasing over time, the influence of household air pollution is gradually declining. Geographically, the highest death rates due to air pollution were observed in Oceania, South Asia, and Sub-Saharan Africa, whereas the lowest rates occurred in North America, Europe, and Australasia. Health system capacity also plays a critical role: countries with limited or minimal health systems experience a significantly higher burden of CRD due to air pollution. Although progress has been made in reducing mortality, the chronic health impact remains substantial — with a noticeable shift from mortality to long-term disability and illness. Finally, the mortality rate from air pollution-related CRDs is directly proportional to age and consistently higher in men than in women, underscoring the need for targeted interventions and gender-sensitive public health strategies

8 References

Bennitt, F. B., Wozniak, S., Causey, K., Spearman, S., Okereke, C., Garcia, V., Hashmeh, N., Ashbaugh, C., Abdelkader, A., Abdoun, M., Abdurebi, M. J., Abedi, A., Zuñiga, R. A. A., Aboagye, R. G., Abubakar, B., Abu-Zaid, A., Adane, M. M., Adegboye, O. A., Adekanmbi, V., … Burkart, K. (n.d.). *Global, regional, and national burden of household air pollution, 1990–2021: A systematic analysis for the global burden of disease study 2021.* Retrieved October 1, 2025, from https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(24)02840-X/fulltext?uuid/x3duuid%3A40008a0f-2266-4637-8209-d6041e2790e4

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Ostro, B., Spadaro, J. V., Gumy, S., Mudu, P., Awe, Y., Forastiere, F., & Peters, A. (2018). Assessing the recent estimates of the global burden of disease for ambient air pollution: Methodological changes and implications for low- and middle-income countries. *Environmental Research*, *166*, 713–725. https://doi.org/10.1016/j.envres.2018.03.001

9 Annexes

9.1 Search link and generated file

1990 + Global + SDI + Health System
https://vizhub.healthdata.org/gbd-results?params=gbd-api-2021-permalink/4ea5715918446e5a6d9b154d62e0cc4a
IHME-GBD_2021_DATA-4835a3dc-1.csv
2000 + Global + SDI + Health System
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IHME-GBD_2021_DATA-c56a3848-1.csv
2010 + Global + SDI + Health System
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IHME-GBD_2021_DATA-1923af35-1.csv
2020 + Global + SDI + Health System
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IHME-GBD_2021_DATA-d14075a8-1.csv
2021 + Global + SDI + Health System
https://vizhub.healthdata.org/gbd-results?params=gbd-api-2021-permalink/3fad5e919cb9822381a5b56543978c2a
IHME-GBD_2021_DATA-840155c6-1.csv
1990 + All countries + Age (all + standardized) + Sex (Both)
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IHME-GBD_2021_DATA-7baf5a43-1.csv
2000 + All countries + Age (all + standardized) + Sex (Both)
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IHME-GBD_2021_DATA-db69c1e8-1.csv
2010 + All countries + Age (all + standardized) + Sex (Both)
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2020 + All countries + Age (all + standardized) + Sex (Both)
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2021 + All countries + Age (all + standardized) + Sex (Both)
https://vizhub.healthdata.org/gbd-results?params=gbd-api-2021-permalink/337e92e538d09c5d3d80640ee324032e
IHME-GBD_2021_DATA-ce582a59-1.csv
(1990,2000,2010,2020,2021) + GBD countries except costume + Age standardized + Sex (Both)
https://vizhub.healthdata.org/gbd-results?params=gbd-api-2021-permalink/0afce2e9094f891f22453111c6986ffb
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