



AIR POLLUTION AND PREMATURE MORTALITY: UNDERSTANDING THE HIDDEN CRISIS IN INDIA

Community Medicine

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ABSTRACT

Introduction: Most individuals on Earth are exposed to dangerous amounts of air pollution. Each year, millions of people die early, and many more live with crippling chronic conditions due to breathing polluted air. Air pollution has become a big concern in India which has huge health and socio-economic unfavourable impact. It is not limited to large cities. Small towns, villages, and cities have also been affected. Ten of the world's twenty most populous cities are located in India, according to WHO (2016) estimates. **Burden of Premature Deaths:** 8.1 million deaths in 2021—more than one in eight deaths globally—were caused by air pollution. **Epidemiology of NCDs Due to Air Pollution:** Based on the concentrations of PM_{2.5} emissions, India was the fifth most polluted country by WHO (2019). In India, NCDs are responsible for 66% of all fatalities, with 22% of those deaths occurring prematurely in 2019. Pathophysiology of various diseases due to Air Pollution: Research studies have provided strong evidence of the connections between air pollution and major NCDs. Systemic inflammation and oxidative stress are the major pathophysiologic change behind this. **Discussion:** Public health is seriously affected by air pollution, a worldwide environmental issue. Vulnerable groups, such as the elderly, children, and people with heart and lung conditions, are especially concerned about the detrimental health impacts of air pollution. Every major human organ system is impacted by air pollution exposure. **Conclusion:** Every life matters. Each one of us is affected by the human cost of air pollution, regardless of age or place of residence. India may strive toward a cleaner and healthier future for its people by enacting sensible laws, adopting clean technology, increasing public awareness, and cultivating a sustainable culture. In order to ensure that the air we breathe is safe for both present and future generations, all stakeholders must assume responsibility and actively minimize air pollution

KEYWORDS

INTRODUCTION

Most individuals on Earth are exposed to dangerous amounts of air pollution. Each year, millions of people die early, and many more live with crippling chronic conditions due to breathing polluted air. Although the threat posed by air pollution is not new, it is evolving. Air pollution has contributed to mortality and disease and has damaged economic prospects and community resilience for decades. 99% of the world's population lives in places with harmful levels of PM_{2.5} pollution. 34% of people reside in places where the WHO's interim air quality standards are exceeded. Countries in Asia, Africa, and the Middle East have the highest levels of ambient PM_{2.5}(1)

Ten of the world's twenty most populous cities are located in India, according to WHO (2016) estimates. Based on the concentrations of PM_{2.5} emissions, India was the fifth most polluted country by WHO (2019). This also states that 21 among the top 30 contaminated cities were in India. The Indian cities, on average, exceeded the WHO standard by an astounding 500%. (2)

Recent estimates based on the Global Exposure Mortality Model (GEMM) show that between 2000 and 2015, India's total premature mortality from ambient PM_{2.5} exposure increased by almost 47%. (3)

Forecasts indicate that by 2050, PM_{2.5}-related premature mortality will have increased by 24% compared to 2015 and air quality will continue to decline (4,5). Growing industrial emissions and rising temperatures brought on by climate change are also anticipated to raise surface O₃ concentrations, putting further strain on public health and agricultural productivity. (6)

This paper aims to evaluate the effects of air pollution on premature mortality in India by examining key pollutants, susceptible groups, and underlying environmental and sociodemographic factors in order to draw attention to the scope of this unreported public health emergency and discuss for practical prevention and control measures.

Burden of Premature Mortality

A) Due to Low Birth Weights and Preterm Births:

The most common cause of death for children under five is preterm delivery. Poor birth weight and preterm birth rates are highest in nations with poor SDI (Social Development Index). Air pollution undoubtedly plays a role in this, along with other factors such as starvation, low immunization coverage. (1)

Air pollution was a contributing factor in 572,000 neonatal deaths (95% UI: 480,000–681,000) in 2021, accounting for 26% of all newborn deaths. Exposure to indoor air pollution from cooking with solid fuels accounted for 72% of this burden. The largest consequences were noted in nations in Asia and Africa, where millions of people continue to rely on unclean traditional energy sources for cooking (1) 8.1 million deaths in 2021—more than one in eight deaths globally—were caused by air pollution. Air pollution was the second largest risk factor for death among children under 5 in 2021, after undernutrition. More than 700,000 deaths in children under 5 years of age occurred from diseases linked to air pollution in 2021. Of this, nearly 500,000 deaths were attributable to exposure to household air pollution. Air pollution is associated to almost one in three lower respiratory infection fatalities in children under five in several African and Asian nations. (1)

B) Due to NCD (Non-communicable Diseases):

Global Burden of Disease Study in 2017 developed a composite metric- DALYs (Disability adjusted life years), which is a that combines the years of life lost due to premature death (YLLs) and the years lived with disability (YLDs). DALY's due to air pollution is alarming globally as well as in India. (7,8)

Global Scenario: Noncommunicable diseases (NCDs) account for 74% of all deaths globally, killing 41 million people annually. Cancer, diabetes, cardiovascular disease (CVD), and chronic respiratory disease (CRD) are the four primary NCDs (4NCDs) that account for four-fifths of NCD deaths which result in substantial in disability and loss of healthy life., Four out of ten NCD before the age of 70, deaths are premature. Low- and middle-income nations account for 86% of all premature NCD fatalities (9,10). In the twenty-first century, premature deaths continued to be a major obstacle to global human progress, leading to decreased productivity and negative economic effects. (11)

Indian Scenario: India is suffering a tremendous burden of NCDs due to globalization, urbanization, population aging, unhealthy lifestyles, and social determinates. (12) Disability-adjusted life years (DALYs) owing to NCDs climbed from 30% to 55% during the years 1990 and 2016. (13) In India, NCDs are responsible for 66% of all fatalities, with 22% of those deaths occurring prematurely in 2019. (14)

Air Quality in India: Current Scenario

Air pollution has become a big concern in India which has huge health and socio-economic unfavourable impact. It is not limited to large cities. Small towns, villages, and cities have also been affected. India has an average PM2.5 level of 40-50 µg per cubic meter, roughly four times that of WHO advised limit of 10 µg.) Although the use of solid fuels for cooking has been declining in India, 25,26 56% of India's population was still exposed to household air pollution from solid fuels in 2017. (8) Only the direct and indirect effects of air pollution are thought to have contributed to 1.7 million deaths in India in 2019, or almost 18% of all deaths that year. Premature mortality and morbidity are thought to have cost India 1.36% of GDP. (15)

Sources of Air Pollution in India

Air pollution sources in India vary widely across geographical regions, including natural (pollen grains, desert dust, mineral dust, etc.) and anthropogenic sources.

Some of the primary anthropogenic sources are:

Sr.no	Causes	Sources	Pollutants
1.	Industrial emissions	factories manufacturing units, such as cement factories and brick kiln industries	particulate matter (PM) sulphur dioxide (SO2) oxides of nitrogen (NOx);
2.	Vehicular emissions	exhaust fumes	containing NOx, CO and volatile organic compounds (VOCs);
3.	Agricultural activities	Crop residue burning	CO PM10,2,5
4.	Domestic fuel:	Burning biomass fuels such as wood, dung, and crop residues	PM10,2,5 NO2
5.	Indoor sources	water ingress, pets, building materials, furniture and furnishings, smoking, paints, varnishes, glues, cleaning products, air freshener, deodorants, perfumes, pesticides, fungicides, burning mosquito coils, and candle or incense burning	PM10,2,5 NO2

Source: Anurag Kanaujia, Madhulika Bhati, et al, (15) , Kurmi OP,et al(16)

Epidemiology of NCDs Due to Air Pollution

The risk of NCDs is multiplied by exposure to air pollution, which is a major hazard to world health. Almost every organ in the body can experience systemic inflammation due to the tiny contaminants' ability to enter the bloodstream. These particles have the ability to enter the bloodstream after passing through the blood-gas barrier in the lungs. Thus, the contaminants can influence each and every organ in the body and worsen or exacerbate numerous undesirable health issues. (17)

In addition to the heart and lungs, air pollution has been linked to diabetes, cancer, stroke, neurological development problems in children, and neurological abnormalities in adults.(18) According to WHO estimates, ischemic heart disease (IHD) and stroke accounted for 37% of premature deaths caused by outdoor air pollution worldwide in 2019. Additionally, 18% of premature fatalities from chronic obstructive pulmonary disease (COPD), 23% from acute lower respiratory infections (LRI), and 11% from respiratory tract cancer were caused by exposure to outdoor air pollution. (19) Globally, the household air pollution leads to 32% of IHD, 23% of stroke, 21% of LRI, 19% of COPD and 6% of lung cancer. (18)

Research studies have provided strong evidence of the connections between air pollution and major NCDs. A person's susceptibility, exposure level, age, and pre-existing medical disorders (mostly

NCDs) all influence the negative impacts of air pollution. The principal NCDs induced or worsened by air pollution are: CVDs: Globally, there is significant evidence that exposure to fine PM 2.5 increases the risk of CVDs.

10 µg/m3 increase in long-term PM 2.5 exposure was linked to with an increased risk of 23% for IHD deaths, 24% for cerebrovascular mortality, 13% for stroke and 8% for myocardial infarction (MI). (20,21) There is data indicating a strong correlation between high levels of outdoor air pollution, greater systolic blood pressure (BP), and incident hypertension, given that high blood pressure (BP) is a significant risk factor for CVDs. (22) The GBD study (2019) found that air pollution was responsible for 16.2% of stroke deaths and 29.2% of IHD deaths in India. (23)

COPD: There is evidence on linkages of COPD with air pollution at global level. Exposure to indoor air pollution due to solid biomass fuels resulted in increased risk of COPD by 2.65 times and chronic bronchitis by 2.89 times as compared to non-biomass fuels. (24) A 10-µg/m3 increase in PM 2.5 concentration was associated 0.96% increase in COPD mortality. (25). An increase of NO2 concentration (by 12% per 10 µg/ m3 NO2) contributed to increased morbidity associated with COPD hospitalisation. (26)

In India, 32.5% of deaths due to COPD were attributable to air pollution in 2019. (23)

Asthma: As per research, NO2 concentration raised the probability for asthma patients to be hospitalised on the day of exposure by 10% for 10 µg/m3 NO2 increase. (27) Globally, it has been predicted that 4.0 million additional paediatric asthma cases could be related to NO2 pollution annually. (28) The majority of research in the Indian context focuses on the connections between asthma and indoor air pollution. Indoor suspended particulate matter (SPM) level was discovered substantially higher in the asthmatic children's dwellings in India. (29) Compared to adult women who live in homes with cleaner fuels, those who use biomass and solid fuels are much more likely to develop asthma. (30)

Cancers: Evidence from around the world points to a connection between exposure to specific air pollutants and the incidence of cancer or cancer-related mortality. Studies have shown that a 10 µg/m3 rise in PM 2.5 concentrations increases the risk of lung cancer incidence or mortality by 9%. (31) PM2.5 related to higher risk of mortality for several other types of cancers (along with lung cancer) like cancer of the upper digestive tract, pancreatic cancer and breast cancer in females. (31) In India, 1.7% of deaths due to lung cancer in 2019 were due to exposure to pollutants.

Diabetes: Higher air pollution levels are positively correlated with higher diabetes-related mortality, according to research conducted worldwide. Exposure to PM 2.5, PM 10, and NO2 has been associated to Type 2 Diabetes (T2D) prevalence. (32) 10 µg/m3 increase in PM2.5 was linked to with a 25% higher risk of T2D. (33) In India, 3.8% of deaths due to diabetes in 2019 were attributed to air pollution. (23)

Mental Health Conditions: Studies at global level have found evidence that exposure to NO2, NOx, PM2.5 and PM10 were linked with 32%, 31%, 7% and 9% increased risk for community mental health services events. (34)

Parkinson's Disease: The higher amounts of NO2, which are frequently generated by cars and power plants, were shown to be 40% more likely to cause Parkinson's disease than those with the lower levels of exposure, according to global research. (35,36) Earlier air pollution earlier was thought to be damaging for lungs but data on its association with other NCDs such mental disorders, CVDs, malignancies, and diabetes are emerging.

Low Birth Weight: Prematurity and intrauterine development retardation are linked to several harmful environmental exposures to pollutants. These include indoor and outdoor air pollution, second hand tobacco smoke, metals, and persistent organic pollutants. Significant morbidity and mortality in the neonatal age group are linked to LBW caused by either intrauterine growth retardation or preterm delivery. LBW has been related additionally to significantly more risk in adult life of hypertension, coronary heart disease, obesity, and type 2 diabetes. (37)

Pathophysiology of Various Diseases Due to Air Pollution

Sr.no	Disease	Pollutants	Pathophysiology
	CVD	<ul style="list-style-type: none"> PM combustion-derived nanoparticles 	<ul style="list-style-type: none"> Oxidative stress and inflammation Disrupt cellular homeostasis, Formation of free radicals Formation of series of cellular enzymes, such as nicotinamide adenine dinucleotide phosphate (NAD(P)H)-oxidase, myeloperoxidase, xanthine oxidase, and uncoupled nitric oxide synthase Exacerbation existing disease processes and potentially even triggering the acute cardiovascular events Loss of endothelial cell function Promotion of vasoconstriction, vascular remodelling, platelet aggregation and interaction of the vasculature with inflammatory cells (38)
	Respiratory Diseases	<ul style="list-style-type: none"> PM2.5 nitrogen dioxide (NO2) sulphur dioxide (SO2) O3 	<ul style="list-style-type: none"> Systemic inflammation and oxidative stress Impairment of mucociliary clearance, Increase in airway reactivity, Reduction in lung function Airway epithelial damage (39)

Sr.no	Disease	Pollutants	Pathophysiology
	Cancers	<ul style="list-style-type: none"> submicron combustion-related PM containing numerous toxic compounds including acids and heavy metal PM2.5 	<ul style="list-style-type: none"> Oxidative stress in epithelial cells, Generating reactive oxygen species that may damage DNA, proteins and lipids Oncogenic epidermal growth factor receptor (egfr) mutations Growth of lung stem cells -Alveolar type 2 cells (40)
	Parkinson's Disease, Stroke, Neurodegenerative disorders	<ul style="list-style-type: none"> PM2.5 	<ul style="list-style-type: none"> Neurotoxicity and Neuroinflammation The Air Pollution-Lung-Brain Connection. Air pollution induces pulmonary and systemic inflammation, which induces CNS inflammation. Air Pollution and Gut α-Syn. Air pollution causes gut inflammation and leakiness, which promotes local accumulation of α-syn. α-Syn (white) can then spread to the brainstem via the vagus nerve (enlarged). Air Pollution, the Microbiome, and the Brain. Air pollution alters gut microbiome (enlarged), which can lead to systemic inflammation, release of neuroactive molecules and neuroinflammation (42)

Mental disorders	<ul style="list-style-type: none"> PM2.5 	<ul style="list-style-type: none"> Oxidative stress and neuroinflammation in fronto-limbic brain areas with neurostructural and neurofunctional effects such as inflammation and oxidative stress, changes to neurotransmitters, neuromodulators and their metabolites, within multiple brain regions (24% of papers), the hippocampus (66%), prefrontal cortex (7%) and amygdala (1%). (43)
Low Birth Weight	<ul style="list-style-type: none"> Particulate matter, Formaldehyde, Carbon monoxide, Nitrogen oxide, Benzene, hydrocarbons, 	<ul style="list-style-type: none"> oxidative stress, inflammation, coagulation, impaired endothelial function and hemodynamic responses impaired placental function (44)

DISCUSSION

Public health is seriously affected by air pollution, a worldwide environmental issue. Vulnerable groups, such as the elderly, children, and people with heart and lung conditions, are especially concerned about the detrimental health impacts of air pollution. (45)

Every major human organ system is impacted by air pollution exposure. The new research keeps expanding our knowledge of how air pollution affects people of all ages. It is evident that air pollution has a catastrophic negative impact on health worldwide. (1)

Despite significant progress, household use of solid fuels for cooking remains an important source of exposure to air pollution, especially in countries in Asia and Africa. Another exposure that has been found to be harmful to children is second-hand smoke, defined as the involuntary exposure of nonsmokers to tobacco smoke from the smoking of others. There is no safe level of exposure to second-hand smoke. In many low- and middle-income countries, a significant proportion of the disease burden among children is linked to household air pollution, reflecting a lack of access to clean energy (1)

Breathing contaminated air for months or years can increase the risk of adverse birth outcomes, such as preterm births, stillbirths, and miscarriages, as well as cause illness and early death from heart and lung diseases and diabetes. Studies have shown that exposure to second-hand smoke can lead to several damaging health effects in children, such as respiratory infections, including pneumonia, ear infections, and exacerbation of asthma.(1)

PM, and combustion-derived nanoparticles in particular, have the capacity to cause multiple types of dysfunctions throughout the cardiovascular system, with the potential to instigate early events in disease, exacerbate existing disease processes and potentially even trigger the acute cardiovascular events associated with mortality. (38)

Fine PM_{2.5} penetrates deep into the lungs and bloodstream, triggering systemic inflammation and oxidative stress that worsens conditions like asthma, Chronic Obstructive Pulmonary Diseases (COPD), bronchitis, and pneumonia. Moreover, during episodes of high ambient air pollution, hospital admissions for acute respiratory infections including lower respiratory tract infections and exacerbations of chronic respiratory diseases show marked increases (39) Temporal analysis demonstrated that 3 years of exposure to PM2.5 may be enough to increase the risk of EGFR-driven lung cancer (40)

A transition to clean energy sources could address climate challenges and improve air quality and health. (1)

Challenges in Prevention and Control of Air Pollution

Management and control of air pollution is a complicated task requiring many stakeholders' sincere and coordinated efforts.

Some challenges that hinder air pollution control in India are:

- Lack of enforcement: Industries, car owners, and other polluting

entities fail to comply with environmental standards due to inadequate enforcement. India relies on country-specific norms, which are far higher than WHO-recommended guidelines, and lacks strict air pollution restrictions.

- Rapid urbanization: Urbanization in India has raised pollution levels, making air quality control extremely difficult. The causes are rising energy consumption, vehicle traffic, and industrial activity concentrated in urban areas.
- Socioeconomic factors: Insufficient infrastructure in rural regions, poverty, and a lack of access to clean energy sources all contribute to the persistence of HAP and AAP in India, making the issue of air pollution worse. (46)

Government Policies to Prevent and Control Air Pollution

The major policies that cover the air-pollution mitigation and move towards clean air are:

- The Air (Prevention and Control of Pollution) Act, 1981
- National Air Quality Monitoring Programme (NAMP)
- National Ambient Air Quality Standards (NAAQS)
- National Air Quality Index (AQI) Comprehensive Action Plan (CAP) in 2018 to identify timelines and implementing agencies for actions identified for prevention, control, and mitigation of air pollution in Delhi and NCR
- Graded Response Action Plan (GRAP) for prevention, control, and abatement of air pollution in Delhi and NCR.
- 42 Action Points
- The Jawaharlal Nehru National Solar Mission (JNNSM)
- Environment Pollution (Prevention and Control) Authority (EPCA)
- National Clean Air Programme (NCAP)
- Pradhan Mantri Ujjwala Yojana (15)

Other Initiatives:

Several Indian towns have put in place:

- Cleaner fuel regulations,
- Encouraging public transportation
- Setting up air quality monitoring systems to measure pollution levels and guide policy decisions

To address air pollution effectively, India must adopt comprehensive strategies and multifaceted approach to addressing transboundary pollution issues by learning from other nations

- strict regulations,
- technological advancements,
- public awareness campaigns, and
- international collaborations.
- including stricter enforcement of environmental regulations,
- investment in clean technologies,
- promoting sustainable urban planning, and
- public participation in pollution control efforts.

The long-term strategy should focus on transitioning to cleaner energy sources, improving public transportation infrastructure, enhancing green spaces in urban areas, and fostering a culture of environmental stewardship in the population. (16)

Unconventional Approaches to Combat Air Pollution

The issue of air pollution is too significant for any one sector or government to handle on its own. To use creative SMART (Specific, Measurable, Achievable, Relevant, and Time-Bound) solutions, all stakeholders must work together. Prioritizing creative ideas through unconventional thinking may result in effective and long-lasting solutions to reduce air pollution, enhance public health, and promote positive change. One-size-fits-all solutions may not be feasible given India's size and diversity; therefore, local solutions including active community participation are crucial. (16)

Some Unconventional Approaches Could be:

- Community-led air quality monitoring: Enabling local communities to use inexpensive sensors and smartphone applications to monitor the quality of the air in their neighbourhoods so they may push for policy changes and carry out interventions
- Green infrastructure initiatives: Vertical gardens, green roofs, and urban forests to help absorb pollutants and improve air quality in urban areas;
- Art and awareness campaigns: Working together with regional leaders and artists to develop compelling campaigns that increase public awareness of the negative effects of air pollution on health

and the necessity of taking action

- Mobile health clinics: Establishing mobile health clinics in heavily polluted locations to offer medical care, tests for different health outcomes such as respiratory ailments, and management and prevention education
- Innovative clean cooking solutions: Solar cookers, biogas stoves, and efficient biomass pellet-based cookstoves, to reduce indoor air pollution and improve health outcomes;
- Policy advocacy through data visualization: presenting data on air quality in an engaging and understandable manner and promoting stricter environmental laws and enforcement;
- School-based education programmes: Creating engaging educational programs for schools that instruct kids on the causes, consequences, and doable actions they may take to lessen their exposure to air pollution
- Corporate partnerships for clean air initiatives: developing a sense of corporate social responsibility by working with companies to carry out initiatives that enhance air quality in return for recognition and branding opportunities (16)

CONCLUSION

Every life matters. Each one of us is affected by the human cost of air pollution, regardless of age or place of residence. From people and families to entire societies, countries, and regions, pollution undermines productivity, stability, and health. Numerous lives are lost prematurely both in adults and children under 5 years of age due to causes related to household and outdoor air pollution in a single year.

Exposure to air pollution is linked to 1 in 8 deaths worldwide. Premature mortality from NCDs persists is still a big global challenge of the 21st century. Although premature mortality due to 4NCDs indicates a declining trend, the rate of lessening is not on par to achieve the WHO's recommended global "25 by 25" target as well as the SDG 3.4 target. Noncommunicable diseases account for nearly 90% of the total disease burden of air pollution.

Particulate matter air pollution (i.e., ambient and household PM_{2.5}) is the leading contributor to total DALYs followed by high blood pressure, smoking, low birth weight, and short gestation. Despite significant progress, household use of solid fuels for cooking remains an important source of exposure to air pollution

Despite all the efforts taken by us, there is still much to learn and critically, much to do.

In India, air pollution is a complicated and widespread issue that necessitates immediate and concerted action by the government, business, civil society, and individuals to lessen its detrimental impacts on the environment and public health. India may strive toward a cleaner and healthier future for its people by enacting sensible laws, adopting clean technology, increasing public awareness, and cultivating a sustainable culture.

In order to ensure that the air we breathe is safe for both present and future generations, all stakeholders must assume responsibility and actively minimize air pollution. Achieving this aim requires persistent stakeholder engagement, creative thinking, and active participation. The reduction of premature mortality can result in a significant economic gain due to the overall improvement in air quality. To summarise-"If air quality improves, so does population health"

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