



# Understanding the Burden: Human Health Impacts of PM<sub>2.5</sub> Pollution in India

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## Abstract: -

Air pollution stands out as a pressing contemporary issue due to its profound impact on both public and individual health, resulting in escalating rates of morbidity and mortality nationwide. In recent times, researchers have increasingly focused on the nexus between air pollution and human health, spurred by the rising levels of air pollution in both urban and rural areas across the country. This trend has led to a deterioration in air quality, manifesting in various health complications. Exposure to elevated levels of airborne particulate matter (PM) can exacerbate existing health conditions, leading to hospitalizations among individuals with asthma, coronary heart disease, and other ailments. Furthermore, prolonged exposure to PM heightens the risk of non-communicable chronic diseases affecting vital organs such as the brain, lungs, heart, liver, and kidneys. In 2022, the country witnessed a staggering 3,30,000 premature deaths attributed to airborne PM, exceeding the established regulatory norms. Understanding the mechanisms underlying the health issues stemming from airborne PM exposure is imperative, given the array of potential diseases associated with it. The study of PM<sub>2.5</sub>'s impact on human health holds particular significance today, offering insights to tackle the prevailing air pollution crisis. This paper aims to provide a comprehensive examination of the sources of particulate matter contributing to air pollution, the detrimental effects of PM<sub>2.5</sub> on human health, and propose actionable steps to mitigate particulate matter air pollution. It underscores the importance of individuals limiting their exposure to air pollution and calls for government agencies to develop an Index of Health-Related Pollutants.

**Keywords:** - Air pollution, particulate matter, excessive exposure, adverse health effects, communicable chronic diseases, premature deaths.

## Introduction:

In developing countries, air pollution severely impacts health and livelihoods [1]. In India, 98.8% of people are exposed to unsafe PM<sub>2.5</sub> levels, with 96.3% facing hazardous concentrations above 35 µg/m<sup>3</sup> [2]. The 2022 World Air Quality Report ranked India as the eighth most polluted country, with PM<sub>2.5</sub> levels over ten times WHO recommendation. Rapid urbanization and industrialization exacerbate this issue, particularly in smaller cities and rural areas [1].

Globally, air pollution is a major health threat, with 99% of people breathing unsafe air, causing 4.2 million deaths annually, and 91% in low- and middle-income nations [3]. PM<sub>2.5</sub>, composed of organic and inorganic particles from dust, fossil fuels, biomass, and traffic emissions [6], disproportionately affects vulnerable groups like children, elderly, and those with lung or heart conditions [7].

Urban PM<sub>2.5</sub>, primarily from vehicle emissions, is linked to severe health risks [8]. Due to its small size and large surface area, PM<sub>2.5</sub> can carry toxic materials deep into the lungs, bypassing natural filtration and affecting multiple organs [5]. Its ability to generate reactive oxygen further increases its pathogenicity, making it a significant public health concern [5].

### Sources of Particulate Matter (PM<sub>2.5</sub>) in India

PM<sub>2.5</sub> originates from natural and anthropogenic sources, forming through chemical reactions involving gases like SO<sub>2</sub>, NO<sub>x</sub>, and organic compounds. These particles can be emitted directly (primary particles) and penetrate deep into the human body, causing severe health impacts.

1. **Vehicular Emissions:** A major contributor (25-30%) due to the increasing number of vehicles and inadequate emission controls, especially in urban areas [10].
2. **Industrial Activities:** Includes manufacturing, construction, and fossil fuel combustion, significantly impacting major cities and industrial hubs [11].
3. **Biomass Burning:** The combustion of wood, crop waste, and dung releases PM<sub>2.5</sub>, CO, VOCs, and NO<sub>x</sub>, worsening smog, acid rain, and climate change by emitting CO<sub>2</sub> and CH<sub>4</sub> [5].
4. **Construction & Road Dust:** Activities like excavation, material handling, and unpaved roads resuspend fine dust, especially in dry, windy conditions, making it a major urban pollutant [12].
5. **Open Waste Burning:** Poor waste management leads to the burning of municipal waste, plastic, and rubber, emitting PM<sub>2.5</sub> and increasing respiratory and cardiovascular risks [13].
6. **Agricultural Practices:** Crop residue burning releases PM<sub>2.5</sub>, affecting both rural and urban air quality as smoke travels long distances [14].
7. **Diesel Generators:** Used in urban and industrial areas, especially during power outages, worsening air quality due to frequent operation [15].
8. **Coal Combustion:** A primary energy source in India, emitting substantial PM<sub>2.5</sub> and pollutants that degrade surrounding air quality [16].
9. **Natural Sources:** Includes wind-blown dust, soil erosion, pollen, sea salt aerosols, and forest fires, which contribute to seasonal and regional PM<sub>2.5</sub> variations [17].

### Air Pollution and Human Health – Overview

India faces a rapid rise in air pollution, with PM<sub>2.5</sub> as the third leading risk factor nationally and the fifth globally [8]. High PM<sub>2.5</sub> levels, especially in urban and industrial areas, stem from industries, vehicles, construction, and agriculture. Seasonal factors like solid fuel use and crop burning further elevate pollution [1]. WHO's PM<sub>2.5</sub> limit is 10 µg/m<sup>3</sup>, but many Indian cities far exceed this (average 54.4 µg/m<sup>3</sup>), posing severe health risks [13]. Rapid urbanization has worsened exposure, particularly for vulnerable groups like children, the elderly, pregnant women, and those with pre-existing conditions [18].

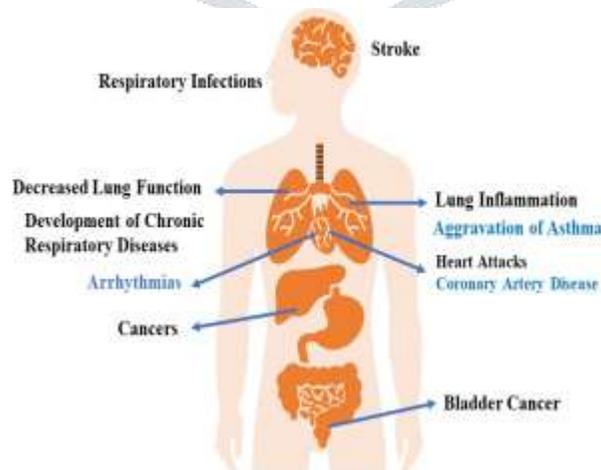
A large population lives in areas exceeding the NAAQS limit of 40 µg/m<sup>3</sup> [18]. Short-term exposure (24 hrs.)

increases risks of premature death, hospitalizations, asthma, and respiratory issues. Long-term exposure (months-years) is linked to early mortality, heart/lung disease, and impaired lung development in children [5].

### Effect of Particulate Matter (PM<sub>2.5</sub>) on Human Health: -

1. **Lung Inflammation:** PM<sub>2.5</sub> penetrates deep into the lungs, triggering inflammation and worsening bronchitis, COPD, and asthma [19].
2. **Aggravation of Asthma:** Increases airway sensitivity, causing more frequent and severe asthma attacks, especially in children [20].
3. **Respiratory Infections:** PM<sub>2.5</sub> weakens immunity, increasing risks of pneumonia and bronchitis by carrying pathogens deep into the lungs [5].
4. **Decreased Lung Function:** Long-term exposure reduces forced expiratory volume (FEV<sub>1</sub>) and vital capacity (FVC), impairing breathing efficiency [21].
5. **Chronic Respiratory Diseases:** Raises risks of COPD, bronchitis, and emphysema by narrowing airways and damaging lung tissue [22].
6. **Increased Mortality:** Linked to premature deaths in India, exacerbating heart and lung diseases, especially in vulnerable populations [3].
7. **Heart Attacks & CAD:** Promotes plaque build-up in arteries, increasing risks of heart attacks and coronary artery disease [7].
8. **Stroke:** PM<sub>2.5</sub>-induced inflammation accelerates atherosclerosis, restricting brain blood flow and raising ischemic stroke risk [22].
9. **Hypertension:** Narrowing of blood vessels and oxidative stress elevate blood pressure, particularly in high-risk individuals [23].
10. **Arrhythmias:** Disrupts heart signals, increasing the risk of irregular heartbeats, especially in elderly individuals [5] [24].

**Figure 1– Effects of Particulate Matter (PM<sub>2.5</sub>) on Human health**



## reventive Actions to reduce PM2.5:

Preventing and reducing PM2.5 pollution in India demands a multifaceted strategy encompassing government policies, technological innovations, public education, and community engagement. Given the myriad sources of PM2.5 pollution in the country, a comprehensive approach is vital to safeguard public health and the environment. Here are some strategies for prevention and mitigation.

### 1. Air Quality Regulations and Enforcement:

Strengthen emission limits for industries, vehicles, and power plants with strict monitoring, robust air quality tracking, and enforcement through inspections and penalties [25].

### 2. Clean Energy Transition [26]:

Promote renewable energy (solar, wind, hydropower) to reduce fossil fuel reliance. Expand EV adoption and charging infrastructure. Encourage cleaner cooking fuels like LPG and biogas to curb biomass burning and PM2.5 pollution.

### 3. Industry and Construction Practices:

Encourage cleaner industrial technologies [27], enforce dust control at construction sites [28], and promote green building practices to reduce emissions [26].

### 4. Transportation Management:

Expand public transport [29], enforce stricter vehicle emission standards, and promote cleaner fuels like CNG and EVs to reduce urban PM2.5 emissions [25].

### 5. Waste Management [30]:

Invest in waste-to-energy technologies to reduce open burning. Promote waste segregation and recycling to minimize landfill waste and curb PM2.5 pollution.

### 6. Green Spaces and Urban Planning [31]:

Expand urban greenery, establish green belts around industries, and promote sustainable urban planning with walkable spaces, bike paths, and efficient public transport to reduce PM2.5 pollution.

### 7. Public Awareness and Education [32].

Raise awareness on PM2.5 health risks through campaigns, empower individuals to act, and encourage citizen participation in air quality monitoring, reporting, and advocacy.



**Figure 2 – Preventive Actions to reduce PM2.5 Pollution****Conclusion: -**

India's high PM2.5 levels and growing population pose major public health and environmental challenges. Addressing air pollution requires a long-term, multi-faceted approach. PM2.5 exposure leads to inflammation, reduced lung function, respiratory diseases, lung cancer, heart attacks, stroke, and hypertension, demanding urgent action for sustainable development and public health.

Urgent action is needed to combat PM2.5 pollution due to its severe health risks. Prioritizing clean air policies, sustainable development, and public health initiatives can ensure a healthier future. The time to act is now—for our health and the planet.

Preventing PM2.5 pollution in India requires coordinated efforts from all sectors. Key steps include strict regulations, clean energy promotion, improved transport, waste management, public awareness, policy advocacy, global cooperation, and investment in innovative technologies to safeguard public health.

Despite challenges, our knowledge of PM2.5 exposure and its health effects is enough to drive action. Political, financial, or technical obstacles cannot outweigh the risks of worsening diseases, higher child mortality, reduced life expectancy, and harm to future generations. Urgent action is essential to protect public health and the environment.

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