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The Hidden Cost of Air Pollution in Mumbai: An AQLI Based Estimation with a Local Ecosystem Case Study

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ABSTRACT

Air pollution continues to threaten public health and economic development in major Indian cities. This paper uses the Air Quality Life Index to study the impact of PM2.5 pollution on life expectancy in Mumbai. With annual concentrations around 45 micrograms per cubic meter, nearly nine times the World Health Organization guideline, residents may lose about four years of life. By applying the Value of Statistical Life used in India, the paper estimates the monetary cost of these losses, which ranges from 32 trillion to 960 trillion rupees depending on the model. The paper also explores the potential protective role of Mumbai's mangrove ecosystems, which may help reduce exposure to pollutants. The findings indicate that both policy interventions and natural ecosystem protection are necessary for improving air quality and safeguarding public health in Mumbai.

Keywords: Air pollution, AQLI, PM2.5, Mumbai, Value of Statistical Life, Mangroves

1. Introduction

Air pollution poses a serious threat to health and economic stability around the world. In many Indian cities, residents are exposed to fine particulate matter that enters the lungs and bloodstream, contributing to chronic illness and premature mortality. The Air Quality Life Index developed by Greenstone and his team provides a clear way to express the effects of PM2.5 pollution by showing how it reduces life expectancy [1]. This approach helps policymakers understand the long term consequences of pollution in terms that are measurable and meaningful.

Mumbai, one of India's largest cities, experiences pollution from traffic, construction, industry, and waste burning. Despite its coastal location, which often helps disperse pollutants, the city consistently records PM2.5 levels far above World Health Organization recommendations.

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Accurately estimating the health and economic consequences of this pollution is essential for informing policies that protect public health and guide future urban planning.

2. Literature Review

Air pollution has been widely studied across environmental science, public health, and economics due to its long term effects on mortality, disease burden, and productivity. PM2.5, or fine particulate matter, is considered especially harmful because it can enter the lungs and bloodstream. Foundational epidemiological work by Pope and Dockery demonstrated strong links between PM2.5 exposure and increased cardiovascular and respiratory mortality [7]. Burnett et al. expanded global mortality estimates using updated exposure models, finding that PM2.5 contributes to more deaths than previously understood [9]. Apte and Marshall also showed that millions of premature deaths could be avoided if countries met WHO PM2.5 guidelines [8].

The Air Quality Life Index translates these relationships into estimates of lost life expectancy, providing a clear policy tool that quantifies the impact of pollution on lifespan [1]. AQLI findings across India show significant reductions in life expectancy, particularly in highly polluted states.

In India, air pollution remains an urgent public health issue. National studies estimate that Indians lose nearly five years of life due to PM2.5 pollution, and citizens of Delhi lose up to twelve years [2]. While Mumbai is less polluted than Delhi, its PM2.5 levels still far exceed WHO guidelines. Reports show that the city’s 2019 PM2.5 concentration was approximately 45 micrograms per cubic meter, nine times the WHO standard [3]. More recent CPCB data shows frequent violations of PM10 limits during early 2025 [4][5].

Although national analyses exist, fewer studies focus specifically on Mumbai. The city’s coastal geography, construction patterns, vehicle emissions, and extensive mangrove ecosystems create unique pollution dynamics. Mangroves offer sediment trapping, pollutant filtering, and microclimate regulation benefits, which may influence air quality [11]. However, their role in reducing airborne particulates remains understudied. This gap supports the need for a city level study integrating AQLI, economic valuation, and ecosystem analysis.

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Table 1. Key Findings from Literature on PM2.5 and Life Expectancy

Study	Region	Main Finding
Pope and Dockery (2006) [7]	Global	PM2.5 exposure linked to higher mortality
Burnett et al. (2018) [9]	Global	Updated global mortality burden of PM2.5
Apte et al. (2015) [8]	Global	Millions of deaths avoidable under WHO standards
AQLI (Greenstone, 2017) [1]	Global & India	Life expectancy decreases with higher PM2.5
CPCB Reports (2023) [10]	India	Frequent violations of air quality standards
UNEP (2020) [11]	Global	Mangroves filter pollutants and stabilize ecosystems

3. Methodology

This study applies the Air Quality Life Index to estimate how much life expectancy is lost due to PM2.5 exposure in Mumbai. The AQLI is based on epidemiological evidence showing that long term exposure to PM2.5 directly shortens lifespan [1][7][9]. The WHO guideline for PM2.5 is 5 micrograms per cubic meter. Mumbai's average concentration is approximately 45 micrograms per cubic meter, which exceeds the guideline by 40 micrograms per cubic meter [3]. The AQLI estimates that every increase of 10 micrograms per cubic meter above the guideline reduces life expectancy by roughly one year [1]. From this, the estimated loss for Mumbai residents is about four years.

The population of Mumbai is estimated at 12 million. Multiplying this population by the per person loss gives a total of about 48 million life years lost.

To estimate the economic value of these losses, the study uses the Value of Statistical Life commonly applied in India, which is about 20 million rupees per life. This method is widely used

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in environmental economics and policy analysis to measure the economic cost of mortality caused by pollution. Calculating the cost per life year and scaling it by the total years lost provides a range for the total economic burden.

4. Results and Discussion

4.1 PM2.5 Exposure and Life Expectancy

Mumbai's average PM2.5 concentration of roughly 45.3 micrograms per cubic meter is far above the WHO guideline of 5 micrograms per cubic meter. According to the AQLI, every 10 microgram increase above this guideline corresponds to roughly one year of lost life expectancy [1]. This suggests that Mumbai residents may lose about three to four years of life due to long term exposure. With a population of approximately 12 million, the total life years lost across the city is around 48 million.

Table 2. PM2.5 Exposure and Estimated Life Expectancy Loss in Mumbai

Indicator	Value
Annual Average PM2.5	45.3 micrograms per cubic meter
WHO Guideline	5 micrograms per cubic meter
Excess Above Guideline	40.3 micrograms per cubic meter
Estimated Life Expectancy Loss	3 to 4 years
Population Exposed	12 million
Total Life Years Lost	48 million life years

4.2 Economic Burden

The Value of Statistical Life for India is estimated at around 20 million rupees. Using this metric, the economic burden of pollution related mortality in Mumbai is extremely large. A conservative

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approach distributes VSL across lost life years, while a full VSL model applies VSL directly to mortality equivalents.

Table 3. Estimated Economic Burden Due to PM2.5 Exposure in Mumbai

Economic Measure	**Estimated Value**
Value of Statistical Life	20 million rupees
Life Years Lost	48 million
Conservative Cost Estimate	32 trillion rupees
Full VSL Estimate	960 trillion rupees
Contributing Factors	Healthcare costs, productivity loss, premature mortality

4.3 Public Health and Productivity

Air pollution contributes to increased hospital visits, especially for asthma and heart disease. It also causes reduced productivity due to illness and absenteeism. This has been documented in both Indian studies and international research [7][8]. These combined costs affect households, employers, and government health systems. The overall economic and social burden is severe and requires immediate attention.

5. Case Study: Mangroves as Natural Protection

Mumbai contains one of the most significant urban mangrove systems in India, covering areas such as Vikhroli, Thane Creek, Gorai, Malwani, and the Sewri Flamingo Sanctuary. These mangroves form an important ecological buffer between the Arabian Sea and heavily populated neighborhoods. They provide a variety of environmental services, such as stabilizing coastlines,

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reducing flooding risks, supporting diverse bird and fish species, and improving water quality by trapping sediments and absorbing certain pollutants [6][11].

Recent discussions in environmental studies have suggested that mangroves may also influence air quality. Although mangroves are traditionally studied for their water filtration and sediment capturing abilities, their dense root systems and thick canopies can limit dust movement and reduce the resuspension of soil particles. Mangrove areas tend to have higher humidity and lower temperatures than surrounding urban zones, which can help reduce the concentration of airborne particulates. Wet leaves can also trap some pollutants before they disperse into the air. While these mechanisms are still being studied, they point to the possibility that mangroves offer benefits beyond their well known coastal functions.

In Mumbai, preliminary observations indicate that coastal and mangrove adjacent areas often have slightly lower particulate levels compared to dense inland neighborhoods such as Kurla, Sion, and Andheri. This pattern suggests that mangroves may indirectly reduce pollutant exposure by acting as natural barriers. UNEP research supports this idea by showing that mangrove vegetation can absorb heavy metals and trap contaminants carried by wind or water before they spread further into human settlements [11]. These environmental functions may help explain why areas near Thane Creek and Gorai sometimes show better air quality during peak pollution seasons.

Mangrove loss, however, threatens these benefits. Encroachment, land reclamation, and construction reduce mangrove cover and limit their ability to buffer pollution. As these natural systems shrink, inland neighborhoods face increased exposure to dust, suspended particles, and industrial pollutants. Preserving mangroves therefore becomes not only an ecological priority but also a public health strategy. Protecting and restoring these ecosystems could complement regulatory approaches to air pollution by providing a natural and cost effective barrier that supports cleaner air, particularly in densely populated and vulnerable areas.

By integrating natural ecosystem services with air quality policies, Mumbai has the opportunity to develop a more comprehensive approach to pollution reduction. This case study shows that mangroves may play an important role in reducing exposure to harmful particulates, but it also highlights the need for more targeted research. A combination of scientific monitoring, ecological conservation, and policy intervention is necessary to fully understand and strengthen the role of mangroves in urban air quality management.

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Table 4. Relative Pollution Levels in Select Mumbai Regions

Region	Key Characteristics	Relative PM2.5 Levels
Thane Creek	Mangrove belt, coastal winds	Lower
Vikhroli	Mangrove cover, water bodies	Lower to Moderate
Gorai	Coastal green zone	Lower
Kurla	Dense construction, traffic congestion	High
Andheri	Industrial activity, transport hubs	High
Sion	Mixed residential and industrial	High

6. Policy Implications

Mumbai's air quality challenges require strong and coordinated policy responses. Reducing emissions from traffic, construction, and waste burning should be top priorities. Additions such as stricter enforcement of dust control rules, expansion of public transport, and cleaner fuel standards can significantly reduce pollution levels.

Economic valuation tools help policymakers understand the scale of the problem and choose interventions that provide the greatest benefits. When the economic costs of life lost due to pollution are properly measured, investments in clean air become more justifiable.

Natural ecosystems such as mangroves should be recognized as valuable environmental assets. Preserving and restoring mangroves could complement technological and regulatory approaches

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to reducing pollution. Integrating natural solutions into urban planning can help Mumbai build resilience and protect public health.

7. Conclusion

This study applies the Air Quality Life Index to estimate the health and economic burden of air pollution in Mumbai. The results show significant losses in life expectancy and economic well being due to PM2.5 exposure. The findings also highlight the potential value of natural ecosystems, especially mangroves, in reducing pollution exposure. Addressing Mumbai's air quality challenges will require strong policies, public engagement, and the integration of both technological solutions and natural infrastructure. Improving air quality is essential for protecting the health of residents and supporting the city's long term development.

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