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Breath-Less Growth: Analyzing the Hidden Costs of Air Pollution

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Abstract

Delhi, the bustling capital of India, grapples with a severe air pollution crisis that has garnered international attention. This research work delves into the alarming state of air quality in Delhi, revealing a grim reality marked by hazardous levels of particulate matter and harmful pollutants. The findings underscore the urgent need for comprehensive measures to combat air pollution, with a particular emphasis on adopting a sustainable transport system and transitioning to alternative energy sources. The vehicular emissions, notably from a burgeoning number of vehicles on Delhi's roads, contribute significantly to the elevated levels of carbon dioxide and other pollutants. A shift towards sustainable transport modes, such as electric vehicles and improved public transportation, emerges as a crucial strategy. Simultaneously, promoting the use of alternative energy, such as solar and wind power, can help reduce the carbon footprint. The evidence from my research advocates for swift and decisive action to address the air quality crisis in Delhi, emphasizing the imperative of sustainable practices for the well-being of the city's residents and the environment at large.

Keywords: Air quality index, Sustainable ecosystem, Alternate energy

Introduction

Air pollution, characterized by the introduction of chemicals, particulates, or biological agents into the atmosphere, poses a pervasive threat to global well-being. This environmental challenge engenders discomfort, diseases, and fatalities among humans, jeopardizes living organisms, including food crops, and exacts a toll on both the natural and built environments.

Surprisingly, the World Health Organization reveals that only 10% of the global population resides in areas where air pollution meets recommended safety levels. [1] This dire scenario translates into a staggering toll of 7 million deaths annually, accounting for one in eight global deaths. Alarming in its scope, air pollution surpasses other major avoidable causes of death, including tobacco use, alcohol consumption, road accidents, and communicable diseases such as AIDS, malaria, and tuberculosis. As air pollution escalates worldwide, particularly in low- and middle-income countries, the impending years may witness an ominous surge in these grim statistics (OECD, 2016). [2]

The consequences of air pollution on human health have spurred the implementation of increasingly stringent environmental regulations across the globe. While such regulations aim to mitigate the adverse health effects, they also spark debates over the optimal stringency levels. The imposition of environmental regulations is often viewed as a delicate balance, requiring trade-offs between health benefits and economic costs as resources shift from productive activities to pollution control measures.

Within this global panorama, India emerges as the focal point of the air pollution crisis. Ranking as the world's fifth-most polluted nation and harboring 21 of the 30 most polluted cities [1], India grapples with a severe environmental challenge. Despite ambitious government initiatives such as the National Clean Air Programme, which targets a 20-30% reduction in PM2.5 pollution by 2024, [2] the discourse surrounding air pollution primarily revolves around its profound public health implications.

Echoing the sentiments of the World Health Organization, air pollution stands as the world's largest single environmental health risk. This perilous factor contributes significantly to diseases resulting in disabilities and fatalities, encompassing cancers, lower respiratory infections, and cardiovascular ailments, with heart disease and strokes claiming a significant share of lives attributed to air pollution. [1]

Measuring health impacts

Health burden metrics estimated for the Global Burden of Disease (GBD) 2013 encompass various indicators such as deaths, years of life lost (YLLs), years lived with disability (YLDs), and disability-adjusted life years (DALYs). In GBD 2013, YLLs are computed for each country and cause of death by comparing them against a standard life table, which has been updated by GBD researchers to reflect recent demographic shifts and population projections.

It's noteworthy that, in this calculation, life expectancy is assumed to be the same for both men and women. YLDs per health outcome are determined by multiplying the number of prevalent cases by a disability weight, representing the public's assessment of the severity of health loss associated with that particular condition. Disability weights are on a relative scale, ranging from 0 (indicating no health loss) to 1 (equivalent to death). Finally, DALYs are derived by summing the values of YLLs and YLDs.

Willingness to Pay and Value of Statistical Life

In the realm of economic research, the concept of willingness to pay (WTP) delves into how individuals assess the value of mitigating risks associated with factors like pollution. Essentially, WTP seeks to quantify the monetary amount individuals are willing to spend to reduce their chances of undesirable outcomes, such as an increase in mortality risk due to pollution. This economic principle is illustrated graphically by analyzing the slope of an individual's indifference curve, showcasing their willingness to trade financial resources for a better probability of survival. Assigning a dollar value to this willingness to pay enables researchers to understand and quantify the economic impact of pollution on individuals' well-being.

The Value of Statistical Life (VSL) encapsulates the collective willingness of individuals to pay (WTP) for marginal reductions in their mortality risks. It doesn't represent the specific value assigned to an individual's life or death, nor does it reflect societal judgments on such values. Essentially, VSL is calculated as $\Delta W/\Delta P$, where, for instance, a small increase in pollution-related mortality risk (ΔP) is associated with the monetary amount individuals are willing to pay (ΔW) for a corresponding risk reduction [1].

An evaluation of the health impacts arising from elevated particulate levels in 126 global cities with annual mean levels exceeding 50 ug/m3 indicates potential damages leading to around 130,000 premature deaths, over 500,000 instances of chronic bronchitis, and numerous other health effects annually. In total, this corresponds to a loss of 2.8 million disability-adjusted life years (DALYs) for a population of nearly 300 million people, or 9 DALYs per 1000 exposed residents. The major contributors to these DALYs are highly polluted megacities in China and India, accounting for 82 percent, with 98 percent attributed to low- and middle-income countries. India, represented by its 12 largest cities in the sample, ranks second after China, bearing 30 percent of total DALYs lost, equivalent to 12 DALYs per 1000 residents in those cities. Comparatively, cities from high-income countries in the sample experience a burden of 2 DALYs per 1000 residents, while middle-income countries face 3 DALYs lost per 1000 urban residents. In monetary terms, health damages escalate from 3 percent of the sample average to 9 percent for India and 12 percent for China when expressed as a share of respective incomes (GDP/capita). This underscores that the societal costs, including direct productivity loss, due to air pollution in major Indian cities reach nearly one-tenth of the income generated from all economic activities. Despite inherent uncertainties in such estimates, this underscores the disproportionately substantial health impact of urban air pollution in India on an international scale.

Impact of Air Pollution

Mortalities and Morbidity from Air pollution

Air pollution represents a paramount global challenge, particularly poignant in developing nations. The health toll inflicted by ambient and household air pollution results in the loss of nearly 6 million lives annually[1]. The impact is far-reaching, causing diseases such as ischemic heart disease (IHD), stroke, lung cancer, chronic obstructive pulmonary disease (COPD), pneumonia, type 2 diabetes, and neonatal disorders. The majority of deaths associated with ambient and household air pollution stem from human exposure to fine inhalable particles, specifically referred to as fine particulate matter (PM) or PM2.5. This alarming reality underscores the urgent need for comprehensive efforts to address air quality concerns worldwide.

In a global context, deaths attributed to PM2.5 air pollution accounted for a significant 11.4 percent of all global deaths in 2019. [1] The economic toll of health damages caused by PM2.5 can be quantified, providing an estimate of the welfare cost associated with this form of pollution. In 2019, the global cost of health damages resulting from PM2.5 air pollution amounted to a staggering $8.1 trillion, equivalent to 6.1 percent of the global Gross Domestic Product (GDP) when adjusted for purchasing power parity (PPP). This estimated cost for 2019 reflects a substantial 40 percent increase in real terms compared to the estimate for 2013 as reported by the World Bank and IHME (2016). Notably, approximately 85 percent of the total global cost of health damages in 2019 is attributed to premature mortality, with the remaining 15 percent arising from morbidity. The share of costs due to morbidity varies widely across countries, ranging from as low as 4 percent to as high as 33 percent. The overwhelming health damages and costs associated with PM2.5 air pollution are particularly pronounced in developing countries, contributing to 6.4 million deaths and 93 billion days lived with illness globally in 2019, underscoring a welfare cost of $8.1 trillion, amounting to 6.1 percent of the global GDP (PPP adjusted).

Numerous studies have delved into the economic repercussions of the health impacts linked to air pollution. For instance, Keen and Altieri's (2016) investigation into South Africa's air pollution revealed over 21,000 annual premature deaths [1], constituting around 7.4% of total deaths and costing the economy approximately US$20 billion in 2017. Another study in China exposed a policy-induced surge in air pollution, resulting in over 2.5 billion years of life expectancy lost for 500 million residents in Northern China (Chen et al., 2013 [2]).

[1] https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health#:~:text=The%20combined%20effects%20of%20ambient,(COPD)%20and%20lung%20cancer.

On a global scale, welfare costs attributed to premature deaths exceeded US$3 trillion in 2010, with projections anticipating a surge to over US$25 trillion by 2060 (OECD, 2016). [3]. Beyond premature deaths, air pollution significantly impacts infant mortality. Research indicates that a one percent increase in carbon monoxide over a year leads to a 0.23% rise in infant mortality, while a similar increase in particulate matter (PM) results in a 0.42% increase (Arceo-Gomez, Hanna, and Oliva, 2012). [4]
Examining mental health consequences, a study found that elevated average PM1 concentrations were linked to an increased likelihood of scoring indicators associated with severe mental illness. Considering average health expenditures related to mental illness and treatment rates, air pollution imposed an annual health expenditure cost of US$22.88 billion.

Economic Loss Due to Air Pollution

In 2013, the global economy incurred welfare losses amounting to $5.11 trillion due to exposure to ambient and household air pollution [1]. Labor income losses, though comparatively lower, were significant in regions with younger populations. South Asian countries experienced labor income losses exceeding $66 billion in 2013, nearly 1 percent of their GDP. Globally, total labor income losses reached $225 billion in 2013 [3].
Furthermore, the costs associated with air pollution have escalated since 1990. Over this period, welfare losses nearly doubled, and labor income losses increased by 40 percent, despite advancements in economic development and health outcomes. In low-income countries, gains in reducing death rates were offset by population growth and heightened exposure to polluted air. Middle-income countries also witnessed increased total exposure and health impacts, with the majority of the rise in estimated welfare losses attributed to a greater societal value placed on reducing fatality risks.
Air pollution, encompassing household air pollution, ambient PM2.5, and ambient ozone, emerged as the fourth most significant risk factor in 2013, leading to premature death. It was linked to 5.5 million premature deaths in that year, constituting 1 in 10 deaths globally. Interestingly, air pollution accounted for a larger share of total years of life lost (YLLs) compared to years lived with disability (YLDs), contributing just over 1 percent of total YLDs in 2013. Its rank as a risk factor leading to premature mortality has remained consistent since 1990, when it was also the fourth leading cause, causing 4.8 million deaths. [1]
The economic impact of air pollution extends beyond direct consequences like premature deaths and health expenditures, encompassing subtle yet pervasive effects. In a study examining Mexico City, the closure of a major refinery, leading to a 19.7% reduction in pollution, correlated with a 3.5% (1.3 hour) increase in weekly work [2] hours, resulting in an estimated US$112 million gain in labor income in the first year alone.
Another investigation focused on white-collar workers in indoor settings, particularly call centers in China. Tracking daily calls, the study found that workers were approximately 6% more productive on days with low pollution compared to high pollution days, indicating that air pollution not only reduces working hours but also diminishes productivity per work hour (Chang et al., 2016) [3]. Exploring migration patterns in China, researchers observed that pollution played a role in migration flows. Highly educated individuals embarking on their professional journeys were willing to bear substantial costs to shield themselves from air pollution, suggesting a trend of talent leaving major cities (Chen, Oliva, and Zhang, 2017 [4]).

These studies collectively emphasize that air pollution carries inevitable consequences for economic growth. Any cost-benefit analysis that overlooks the impact of air pollution would significantly underestimate the overall economic and welfare costs. Addressing air pollution is crucial for economic growth, as interventions can lead to reduced mortality and health expenditure, increased total work hours, enhanced productivity per work hour, and the attraction of talented individuals to urban centers.

Recommendations

Implementing robust policies is imperative for combating air pollution and fostering sustainable development.

In the industrial domain, the adoption of clean technologies that curtail smokestack emissions has proven highly effective. Additionally, enhanced management of urban and agricultural waste, including harnessing methane gas as biogas, stands out as a practical alternative to incineration.

Tackling energy challenges involves ensuring access to affordable, clean household energy solutions for cooking, heating, and lighting. Prioritizing a shift to clean power generation methods and advocating for rapid urban transit, walking, and cycling networks, as well as cleaner heavy-duty diesel vehicles, emphasizes the significance of sustainable transportation.

Urban planning plays a pivotal role in alleviating air pollution. Improving the energy efficiency of buildings, promoting green and compact cities, and enhancing overall energy efficiency contribute significantly to fostering cleaner urban environments.

In power generation, increasing the use of low-emission fuels and embracing renewable, combustion-free sources like solar, wind, or hydropower are key strategies. Co-generation of heat and power, along with distributed energy generation through mini-grids and rooftop solar power, aligns with sustainable practices.

Efficient municipal and agricultural waste management strategies include waste reduction, separation, recycling, and reuse. Biological waste management, such as anaerobic waste digestion for biogas production, provides low-cost alternatives to open incineration.

Finally, healthcare activities must transition to a low-carbon development path to enhance resilience, reduce cost-efficiency, and reduce environmental health risks. By championing climate-friendly policies, the health sector can exhibit public leadership while simultaneously improving health service delivery. Adopting these diverse policy recommendations across sectors is paramount for mitigating air pollution and advancing a sustainable future.

Case Study: Air Pollution in Delhi

Background

Delhi, the national capital of India, has seen some of the most devastating levels of air pollution. The consequences are substantial, impacting the environment with increased particulate matter in the air, causing a reduction in life expectancy, and imposing significant economic burdens on the state. In 2019, New Delhi registered the highest ambient particulate matter pollution exposure in India [1]. The average annual PM 2.5 concentration across the entire country was 58.1 micrograms per cubic meter. In stark contrast, Delhi's average PM 2.5 concentration for the same year soared to 98.6 micrograms per cubic meter. What makes this statistic particularly alarming is that this recorded level is not only the highest among all capital cities in India but also surpasses any capital city globally.

Pollution in Delhi primarily arises from various sources, such as vehicle emissions, heavy industries, including power generation, small-scale enterprises like brick kilns, dust on roads due to traffic and construction, open burning of waste, and the use of fuels for cooking, lighting, and heating. Additionally, in-situ power generation via diesel generator sets contributes to the problem. The issue is further compounded by seasonal factors, including dust storms, forest fires, and open field fires during the harvest season. These seasonal influences intensify air pollution, subjecting millions of people in densely populated regions to prolonged exposure to dense, toxic smog. The collective impact is devastating, affecting the environment and public health and imposing significant economic costs on the state.

As the Delhi government initiates additional policy measures to address this persistent issue, this section aims to conduct an analysis of the air pollution situation in Delhi. Furthermore, the case study will examine the actions taken by the government thus far to alleviate this problem.

Key Factors Responsible

Burning of Agricultural Residue

Delhi shares its border with the states of Haryana, Rajasthan and Uttar Pradesh. One of the main reasons of increasing air pollution levels in Delhi is crop burning by the farmers in these states. Farmers burn rice stubbles in Punjab, Haryana and Uttar Pradesh. Burning typically reaches its peak in the first week of November when numerous farmers ignite residual rice stalks and straw, a practice referred to as stubble or paddy burning. This cost-effective method is employed to clear fields as the new harvest season begins. The burning of paddy on a large scale contributes to the formation of a dense smog layer over the Northern Plains, encompassing Delhi NCR. Farmers in Haryana, Punjab, Rajasthan, and Uttar Pradesh cultivate rice on 10.5 million hectares (26 million acres), resulting in the production of approximately 48 million tons of straw annually, with around 39 million tons being burned. [1] The severity of this issue has increased due to factors such as seed varieties and government policies promoting late harvesting to conserve groundwater. Additionally, the burning coincides with declining temperatures and slow wind speeds, creating meteorological conditions conducive to temperature inversions that trap smoke in place. The wind further carries all the pollutants and dust particles that have gotten locked in the air.

Construction Activities

Construction activities contribute significantly to this alarming pollution scenario, accounting for 30% of the total pollution in Delhi. The city's air quality has witnessed a considerable decline due to this substantial increase. Research conducted by IIT Kanpur unveiled that a seemingly routine process like concrete mixing plays a role in approximately 10% of the particulate matter PM2.5 present in Delhi [1].

The outskirts of Delhi host more than 360 brick kilns, further exacerbating pollution levels, particularly during the winter. [2] The issue is compounded by insufficient compliance, lax industry standards, and a lack of environmental regulations, particularly in waste and debris management. Delhi holds the dubious distinction of being the most polluted capital city globally, as indicated by both the World Health Organization (WHO) and the Delhi Pollution Control Committee (DPCC).

Pollution from Industries and Power Plants

Delhi hosts the largest concentration of small-scale industries in India, collectively contributing to 12% of air pollutants, alongside other industrial units. Assessments conducted by the Central Pollution Control Board (CPCB) reveal that the national capital and its surrounding areas host highly polluted industrial clusters that surpass limits on air, water, and soil emissions. An illustrative example is the Najafgarh drain basin in Delhi, encompassing industrial areas like Anand Parbat, Naraina, Okhla, and Wazirpur, ranking as the second most polluted cluster in India. This cluster's air and water quality falls into the "critical" category for toxic content, while its soil quality is labeled as "severe." With a significant concentration of 3,182 industries in the Delhi-National Capital Region (NCR), industrial pollution contributes approximately 18.6% to the overall poor air quality. [1] Providing respite to the capital territory, the Supreme Court imposed a ban in 2017 on the use of more affordable alternatives in the National Capital Region (NCR), such as petroleum coke and furnace oil. The court recommended the adoption of similar measures in other states as well. Despite this directive, these same fuels persist in use in neighboring states, and their emissions significantly contribute to Delhi's Air Quality Index.

Eleven coal-based power plants in Delhi are responsible for nearly 11% of the city's total air pollution. These power plants emit pollutants such as fly ash, PM2.5, nitrates, and mercury. To address environmental concerns, some of these power plants are temporarily shut down during the winter as they fail to meet the required emission standards and compliance.

Vehicular Emissions

Vehicular emissions stand as the largest contributor to air pollution in Delhi, accounting for over 38% of the city's overall particulate matter emissions[2]. This includes emissions from cars, trucks, autos, two-wheelers, and general road traffic. According to a 2018 report, the roads of Delhi NCR hosted approximately 10.9 million vehicles.[3] While the annual growth rate of vehicles in Delhi decreased from 8.13% in 2005-06 to 5.81% in 2017-18, the per capita vehicle count nearly doubled during this time period. Additionally, In 2018, cars originating from outside Delhi accounted for a substantial share, ranging from 25% to 45%, of the total emissions produced by four-wheelers.

Consequence of Poor Air Quality

The Global Burden of Disease Report underscores the severe impact of outdoor air pollution, ranking it as the fifth leading cause of death in India in 2017. [1] The high concentration of particulate matter (PM) has demographic consequences, reducing the life expectancy of 660 million urban Indians by 3.2 years. In the same year, India, with 18% of the global population, accounted for 26% of global disability-affected life years (DALY) attributable to air pollution. [2] Comparatively, India's DALYs from ambient air pollution in 2016 were 1887.6 per 100,000 individuals, exceeding China and the US [3]. Of the 480.7 million total DALYs in India in 2017, 8.1% were attributable to air pollution, with Delhi experiencing a notable increase in DALYs due to particulate matter concentration from 1995 to 2017. The economic cost of PM10 pollution in Delhi also surged during this period. Reducing pollution to WHO guidelines could add 9.4 years to Delhi residents' life expectancy, a critical improvement considering the city faces

[2] https://smartairfilters.com/en/blog/where-delhis-air-pollution-come-from/
[3] https://www.business-standard.com/article/pti-stories/number-of-vehicles-on-delhi-roads-over-1-crore-with-more-than-70-lakh-two-wheelers-economic-survey-119022300523_1.html

275 days of unhealthy air, marked by a sixfold increase in the sale of respiratory medicines during poor air quality days. This potential increase in life years would be most significant in north India, grappling with a high burden of both ambient particulate matter and household air pollution. Additionally, the city's pervasive air pollution problem took a hefty toll in 2019, amounting to a staggering USD 5.6 billion, equivalent to 6% of its GDP.

Economic Costs

Delhi's air pollution crisis costed it USD 5.6 billion (6% of its GDP) in 2019[4]. In concrete figures, Delhi's economic loss due to air pollution surpasses the cumulative impact experienced by Mumbai, Bengaluru, and Chennai. A significant portion of this economic burden, close to half, is directly linked to 11,310 premature deaths caused by pollution and the consequential loss of 12.2 million working days due to increased absenteeism.

According to a recent[5] survey involving 17,000 residents in Delhi, 40% expressed a preference to relocate from the city to evade the adverse impacts of air pollution on health. This data highlights a significant portion of the population considering migration as a response to the ongoing air quality challenges faced by Delhi. However, in a distinct study, it was revealed that approximately 57% of migrant workers in Delhi favor the living conditions in their hometowns over those in Delhi. The primary factor influencing their preference is the quality of the air, indicating that air pollution contributes significantly to the overall dissatisfaction of this demographic group.

Furthermore, air pollution poses a substantial risk to Delhi's standing as a vital hub for India's tourism sector. The adverse effects of air pollution impact tourists' ability to fully experience the numerous attractions in Delhi, leading to decreased appeal. Short-term concerns such as low visibility and health risks contribute to a diminished interest in the city's outdoor offerings. A tangible manifestation of this impact was observed in November 2019, when there was a notable 40% decline in online booking inquiries for Delhi. This decline coincided with a spike in PM2.5 levels, surpassing twice the annual average.

India allocates approximately 1.28 percent of its GDP to health expenditures [1]. However, the impact of air pollution resulting from the combustion of fossil fuels leads to a more significant economic setback, accounting for the loss of 5.4 percent of the country's GDP. A study conducted by the Indian Institute of Technology in Bombay revealed that air pollution imposed a substantial cost on Delhi, amounting to approximately US$10.66 billion in 2015 alone. This economic burden is significant for Delhi, given its status as a crucial hub for product manufacturing and enterprises, making it an attractive destination for foreign direct investment (FDI).

However, the deteriorating air quality in Delhi, as reported by ASSOCHAM, poses a threat to its appeal, potentially causing top corporate executives to relocate and work to shift to other urban centers in India or abroad. This could result in challenges in recruiting high-level talent in the National Capital Region (NCR), increased expenses for air purification systems and maintenance in office spaces, and reduced workplace efficiency during periods of heightened pollution due to employee sickness and absenteeism.

[4] https://www.cleanairfund.org/wp-content/uploads/01042021_Business-Cost-of-Air-Pollution_Long-Form-Report.pdf

[5] https://www.cleanairfund.org/wp-content/uploads/01042021_Business-Cost-of-Air-Pollution_Long-Form-Report.pdf

For instance, exposure to pollution only from fossil fuels is estimated to cause around 490 million days of work absence due to illness.

Health Costs

The alarming reality is that nearly 100% of India's population breathes air that fails to meet the quality standards set by the World Health Organization (WHO)[6]. This poses serious health risks, as prolonged exposure to unhealthy air accelerates lung aging, reduces lung capacity, and heightens the risk of respiratory diseases. Children, in particular, are highly vulnerable. According to the State of Global Air 2020 report, air pollution in India led to the tragic death of over 116,000 infants within a month of birth in 2019, contributing to a total of 1.67 million deaths in the country. Beyond mortality, exposure to poor air quality adversely affects children's brain development, impairs cognitive abilities, and increases their susceptibility to chronic diseases later in life. Fine particles, especially PM2.5, pose the most significant health risks due to their tiny size, allowing them to penetrate deep into the lungs and bloodstream. Exposure to these particles can impact lung function and exacerbate conditions like asthma and heart disease. Long-term exposure to PM2.5 has been associated with an increased incidence of chronic bronchitis, decreased lung function, and elevated mortality rates from lung cancer and heart disease.

Sir Ganga Ram Hospital in Delhi has observed a concerning trend: an increasing number of young, non-smoking individuals being diagnosed with lung cancer. The proportion of non-smokers with lung cancer has surged from 10 percent in the 1980s to 50 percent in the last decade. Additionally, PM10, with a diameter of less than 10 micrometers, are particularly hazardous as they can enter the lungs. Inhaling these particles can lead to various health issues, including coughing, wheezing, asthma attacks, bronchitis, hypertension, heart diseases, strokes, and premature death.

Environmental Consequences

Toxic air pollutants, including harmful chemicals, can lead to the formation of acid rain and dangerous ground-level ozone. These pollutants have destructive effects on trees, crops, farms, and animals, making water bodies hazardous for both humans and wildlife. Air pollution, especially from sulfur and nitrogen emissions, as well as ground-level ozone, negatively impacts the functioning and growth of natural ecosystems. This, in turn, has adverse consequences for human populations. For instance, pollutants can directly contaminate drinking water through groundwater seepage. Moreover, air pollution hinders the ecosystem's capacity to capture carbon, playing a crucial role in climate change mitigation.

Evaluation of Pollution Control Policies

The Odd-Even Initiative

The odd-even scheme, implemented by the Arvind Kejriwal-led Delhi government, is a traffic rationing measure where private vehicles with odd-digit registration numbers are allowed on roads on odd dates, and those with even-digit registration numbers (0, 2, 4, 6, 8) can operate on even dates. This rule also applies to vehicles with registration numbers from other states using Delhi roads.

[6] https://www.wired.com/story/breathing-is-a-luxury-in-indias-air-crisis/#:~:text=India's%20air%20pollution%20is%20a,by%20the%20World%20Health%20Organization.

During its initial phase, from January 1 to 15, 2016, the odd-even scheme successfully reduced air pollution in Delhi, experiencing the lowest pollution peaks compared to previous winter smog episodes. PM and nitrogen oxide loads from cars decreased by up to 40 percent during this period. However, the second phase, from April 15 to 30, 2016, saw counter-intuitive trends, with air pollution levels initially dropping in the first nine days but then spiking after April 22. PM2.5 levels increased by 23 percent, and PM10 increased by 22 percent compared to the previous fortnight.

Air quality data from the second and third rounds of the scheme in April 2016 and November 2017 indicated that Delhi's air quality deteriorated during the odd-even program. For instance, the average concentration of PM2.5 in Delhi during the second round from April 1 to 15, 2016, was 116 $\mu g/m^3$, while it was 82 $\mu g/m^3$ and 92 $\mu g/m^3$ during the same period in 2017 and 2018, respectively, without any special pollution control plan. Similarly, during the third round from November 13 to 17, 2017, average PM2.5 stood at 218 $\mu g/m^3$, compared to 171 $\mu g/m^3$ in 2016 and 140 $\mu g/m^3$ in 2018 without any traffic restrictions.

Despite these observations, the odd-even scheme was implemented again from November 4 to 15, 2019. An analysis of Air Quality Index (AQI) statistics revealed that Delhi's air quality did not improve during odd-even days in 2019. The average AQI from November 4 to 15 was 362, whereas in 2018, the average AQI for the same period without odd-even restrictions was 335. In other words, Delhi's air quality was 8 percent worse on odd-even days compared to the previous year. Given the significant air pollution problem in Delhi, the odd-even scheme is viewed as a temporary solution, and citizen compliance remains a challenge. Instead, there is a need for more permanent solutions with a robust institutional setup.

The National Clean Air Program

In January 2019, the government initiated the National Clean Air Program (NCAP), a five-year strategy aimed at mitigating air pollution, establishing a nationwide air quality monitoring network, and enhancing public awareness. This program focuses on developing city-specific action plans for 102 cities in India that surpass national air quality standards, with a target of reducing PM2.5 levels by 20–30 percent by 2024 compared to 2017 levels. However, in September 2022, the Union government advanced this target to a 40 percent reduction in pollution levels by 2026. The NCAP emphasizes the importance of collaboration and coordination among central ministries, state governments, and local bodies, aligning with existing policies like the National Action Plan on Climate Change, electric vehicle initiatives, and the Smart Cities Mission [1].

The NCAP outlines specific interventions for key sectors contributing to air pollution, including re-suspended road dust control, dust from construction and demolition, emissions from the power and industrial sectors, transportation emissions, agricultural emissions, and unsustainable waste management practices. With a budget of INR 300 crores, i.e., USD 42.6 million, for the first two years, the NCAP had allocated funds to 28 cities, including Varanasi, Lucknow, Hyderabad, Mumbai, Kolkata, and Bengaluru, that had failed to meet pollution limits.

According to Carbon Copy's NCAP dashboard, based on Right to Information Act data, the Central Pollution Control Board (CPCB) has disbursed INR 280 crores for activities such as expanding air quality monitoring, conducting source assessment studies, and implementing dust-control measures.[7]

[7] https://imgs.mongabay.com/wp-content/uploads/sites/30/2020/01/14224037/CarbonCopy-Statement.pdf

The 2020 Economic Survey by the Government of India highlights Union government spending on controlling agricultural crop burning and recycling construction and demolition waste in Delhi and as compared to the annual average PM2.5 levels of 2019, Delhi has seen a 7 per cent improvement in the last 4 years. However, concerns remain about the program's effectiveness due to unclear funding provisions, non-binding nature, and the absence of a legal framework.

Graded Response Action Plan

In 2017, the Supreme Court directed the Central Pollution Control Board (CPCB) to develop an emergency and comprehensive action plan, which was subsequently formulated and presented in December 2016. Following thorough analysis and consideration, the plan, known as the Graded Response Action Plan (GRAP), was endorsed for implementation in Delhi and the National Capital Region. Operating in stages, the GRAP involves specific measures corresponding to pollution concentration levels, aiming to achieve gradual pollution control. The plan includes defined thresholds related to air pollution levels, specifically pertaining to PM concentration. Whenever authorities identify that the concentration has met or surpassed a particular level, appropriate actions specific to that level will be promptly implemented to control pollution at its source.

The Graded Response Action Plan (GRAP) is designed to address varying pollution levels through specific actions. Under poor air quality conditions, actions such as banning diesel generators, increasing parking fees, and enhancing bus and metro services are outlined. However, these measures faced inadequacies, as the enhanced parking fees were not implemented due to the non-finalization of base charges, and the increased frequency of bus and metro services was deemed insufficient. In severe conditions, GRAP calls for a blanket ban on hot-mix plants and coal-based power plants. In emergency situations, measures like banning the entry of trucks into Delhi (except those carrying essential commodities), implementing a blanket ban on construction activities, and enforcing the odd-even scheme are prescribed. However, these actions faced challenges, as the ban on truck entry was not implemented and the odd-even scheme was applied only in Delhi, with numerous exemptions, including approximately 70 lakh two-wheelers. [1]

According to a Delhi Integrated Multi-modal Transit System (DIMTS) study, the overall traffic reduction during the odd-even scheme was only 2 percent, and the average peak hour speed increased by merely 5 percent. There is a growing consensus that addressing the air pollution issue should be a year-round effort, considering that pollution remains in the 'moderate' category even during the summer and rainy seasons. Urgency for innovative and comprehensive solutions is emphasized for long-term sustainability. The Supreme Court announced the initiation of GRAP from October 15, 2020, along with a ban on diesel generators, except for essential and emergency services in Delhi and neighboring cities like Ghaziabad, Noida, Greater Noida, Faridabad, and Gurgaon[8]. This year, in November 2023, GRAP IV was implemented, imposing restrictions such as the prohibition of polluting vehicles from other states, the requirement for 50 percent of employees to work from home, and the suspension of offline classes for primary school children.[9]

[8] https://www.hindustantimes.com/india-news/grap-to-kick-in-with-covid-crisis-in-the-air/story-offtFn4eAdRvCo93nVZbKP.html#:~:text=The%20winter%20phase%20of%20the,year's%20pre%2Dwinter%20pollution%20could

[9] https://economictimes.indiatimes.com/news/newsblogs/delhi-air-pollution-live-news-delhi-aqi-severe-thick-smog-in-delhi-ncr-air-quality-mumbai-punjab-farm-fires-latest-updates/liveblog/104995884.cms

Conclusion

Air pollution has not received the attention it deserves from governments, partly due to the perception that it is a "necessary evil" for economic advancement. The prevailing notion is that increased production, transportation, and consumption are integral to progress. Consequently, there is a reluctance to curb the burning of fossil fuels, as it is believed to be linked to economic growth. However, it's crucial to recognize that air pollution resulting from these activities has the potential to impede economic progress. Policymakers should consider this aspect, given that air pollution can inflict irreversible, long-term damage.

The government of the National Capital Territory of Delhi has implemented various measures over the past decade to mitigate air pollution, and the positive impact of these efforts is evident in current readings. However, there remains a pressing need to intensify and expand existing initiatives to achieve further reductions in air pollution levels. Governmental actions, though crucial, are insufficient on their own, emphasizing the pivotal role of community participation in making a tangible difference. Encouraging the use of public transport, particularly Metro rail, can be achieved by providing an ample number of feeder buses at Metro stations with regular frequency.

Enhanced scrutiny of pollution under control certificates by civic authorities is essential to ensuring that vehicles comply with emission standards. Public awareness campaigns should educate individuals about the importance of turning off their vehicles while waiting at traffic intersections. Addressing the upstream contributors to pollution is equally imperative. To alleviate the strain on the capital city of Delhi, efforts should focus on reducing the influx of migrants by creating employment opportunities in peripheral and suburban areas, thereby preventing further congestion.

Moreover, Delhi urgently requires an active electric bus service, despite the high initial cost. Electric vehicles offer numerous advantages, including low maintenance costs, a longer service life, and lower operational costs per kilometer. Most importantly, they contribute significantly to reducing pollution levels. Electric mobility is a definitive solution for achieving cleaner air without compromising functionality. Continuing with internal combustion engine (ICE) vehicles as before would impede progress toward achieving a satisfactory air quality index (AQI) in Delhi. Therefore, a long-overdue shift to electric mobility is essential for the city's environmental sustainability.

References

1. Jackson G Lu. 2020. Air pollution: A systematic review of its psychological, economic, and social effects. *Journal of Current opinion in Psychology* 32. 52-65. https://doi.org/10.1016/j.copsyc.2019.06.024
2. Jiang, Min, Euijune Kim, and Youngjin Woo. 2020. "The Relationship between Economic Growth and Air Pollution—A Regional Comparison between China and South Korea" *International Journal of Environmental Research and Public Health* 17, no. 8: 2761. https://doi.org/10.3390/ijerph17082761
3. Soheila Khoshnevis Yazdi & Bahman Khanalizadeh (2017) Air pollution, economic growth and health care expenditure, *Economic Research-Ekonomska Istraživanja*, 30:1, 1181-1190, DOI: 10.1080/1331677X.2017.1314823
4. Druzhinin P.V., Shkiperova G.T., Potasheva O.V., Zimin D.A. The assessment of the impact of the economy's development on air pollution. *Economic and Social Changes: Facts, Trends, Forecast*, 2020, vol. 13, no. 2, pp. 125–142. DOI: 10.15838/esc.2020.2.68.8

5. Pajooyan J, Moradhasel N. Assessing the relation between economic growth and air pollution. *QJER* 2008; 7 (4) :141-160
6. Usman, Muhammad, Zhiqiang Ma, Muhammad Wasif Zafar, Abdul Haseeb, and Rana Umair Ashraf. 2019. "Are Air Pollution, Economic and Non-Economic Factors Associated with Per Capita Health Expenditures? Evidence from Emerging Economies" *International Journal of Environmental Research and Public Health* 16, no. 11: 1967. https://doi.org/10.3390/ijerph16111967
7. Lin H, Tsai S, Lin F, Hsu Y, Chen S, Chou R, Lin C, Hsu C, Chang K, Prolonged Exposure to Air Pollution Increases Periodontal Disease Risk: A Nationwide, Population-Based, Cohort Study, *Atmosphere*, 10.3390/atmos12121668, 12, 12, (1668), (2021).
8. Niu, Yue, Renjie Chen, and Haidong Kan. "Air pollution, disease burden, and health economic loss in China." *Ambient Air Pollution and Health Impact in China* (2017): 233-242.
9. Ouyang, Xiao, Qinglong Shao, Xiang Zhu, Qingyun He, Chao Xiang, and Guoen Wei. "Environmental regulation, economic growth and air pollution: Panel threshold analysis for OECD countries." *Science of the total environment* 657 (2019): 234-241.
10. Giannadaki, Despina, Elias Giannakis, Andrea Pozzer, and Jos Lelieveld. "Estimating health and economic benefits of reductions in air pollution from agriculture." *Science of the total environment* 622 (2018): 1304-1316.
11. Pearce, David. "Economic valuation and health damage from air pollution in the developing world." *Energy Policy* 24, no. 7 (1996): 627-630.