Dissertation training
At

International Institute of Health Management and Research, Delhi

Clean Air for Delhi: An Analysis of Barriers to NCAP Targets and Recommendations for Improvement

By

Dr. Shreya Srivastava
PG/22/117

Under the guidance of
Dr. Ratika Samtani

PGDM (Hospital and Health Management)
2022-2024

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The certificate is awarded to

Dr. Shreya Srivastava

in recognition of having successfully completed her internship

and has successfully completed her project on

Clean Air for Delhi: An Analysis of Barriers to NCAP Targets and Recommendations for Improvement

Date: 15 June 2024

At

International Institute of Health management and Research

New Delhi

She come across as a committed, sincere & diligent person who has a strong drive and zeal for learning.

We wish her all the best for future endeavours

Dr. Ratika Samtani
Mentor
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TO WHOMSOEVER IT MAY CONCERN

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The candidate has successfully carried out the study designated to her during internship training and her approach to the study has been sincere, scientific and analytical.

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I wish her all success in all her future endeavours.

Dr. Sumesh Kumar
Associate Dean, Academic and Student Affairs
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Certificate of Approval

The following dissertation titled **“Clean air for Delhi: An analysis of barriers to NCAP targets and recommendations for improvement”** at **“IIHMR Delhi”** is hereby approved as a certified study in management carried out and presented in a manner satisfactorily to warrant its acceptance as a prerequisite for the award of **PGDM (Hospital & Health Management)** for which it has been submitted. It is understood that by this approval the undersigned do not necessarily endorse or approve any statement made, opinion expressed, or conclusion drawn therein but approve the dissertation only for the purpose it is submitted.

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This is to certify that **Dr. Shreya Srivastava**, a graduate student of **PGDM(Hospital & Health Management)** has worked under our guidance and supervision. She is submitting this dissertation titled '**Clean Air for Delhi: An Analysis of Barriers to NCAP Targets and Recommendations for Improvement**' at 'International Institute of Health Management and Research' in partial fulfilment of the requirements for the award of the PGDM (Hospital & Health Management).

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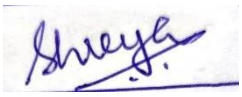

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Abstract

This report investigates the persistent poor air quality and global ranking of Delhi, despite the comprehensive implementation of the National Clean Air Programme (NCAP). Delhi remains a non-attainment city, reflecting the ineffectiveness of current measures. The research focuses on identifying the factors preventing Delhi from achieving NCAP targets. The analysis includes a detailed examination of the primary pollution sources, regulatory enforcement challenges, and the socio-economic dynamics that contribute to the ongoing air quality issues. To provide actionable insights, the report compares Delhi's situation with successful case studies from Seoul and Beijing, which have significantly improved their air quality through targeted interventions. Recommendations based on these case studies are proposed to enhance Delhi's air quality management strategies. These include stricter enforcement of pollution control laws, investment in green infrastructure, adoption of advanced pollution monitoring technologies, and public awareness campaigns. By addressing the identified obstacles and implementing the suggested measures, Delhi can make substantial progress towards meeting NCAP targets and improving its air quality.

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List of abbreviations

GBD	Global Burden of Disease
WHO	World Health Organisation
PM	Particulate Mater
EU	European Union
SDG	Sustainable Development Goal
AQG	Air Quality Guidelines
GDP	Gross Domestic Product
NCR	National Capital Region
CVD	Cardiovascular Disease
NAMP	National Air Quality Monitoring Program
NEERI	National Environmental Engineering Research Institute
CPCB	Contral Pollution Control Board
SPCB	State Pollution Control Board
PCC	Pollution Control Committee
NAAQS	National Ambient Air Quality Standards
AQI	Air Quality Index
GRAP	Graded Response Action Plan
MSW	Municipal Solid Waste
C&D	Construction And Demolition
LPG	Liquified Petroleum Gas
NCAP	National Clean Air Program
MOEFCC	Ministry of Environment Forest and Climate Control
AQLI	Air Quality Life Index

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Clean Air for Delhi: An Analysis of Barriers to NCAP Targets and Recommendations for Improvement

Background

Air pollution has become an urgent global problem with major impacts on health and wellbeing of humans and the environment. Air pollution ranges from many sources, like industry, transportation and domestic energy use, to natural causes such as dust storms and wildfires. There are two categories of pollutants that contribute to air pollution: primary pollutants and secondary pollutants. Primary air pollutants are those released directly by cars, industrial activities, and power plants. Examples include carbon monoxide, sulphur di-oxide, nitrogen oxides, and particulate particles. These contaminants can have an immediate and localised effect on air quality. Secondary air pollutants, on the other hand, are produced by chemical interactions between primary pollutants and other atmospheric components. For example, ground-level ozone, a significant component of smog, is a secondary pollutant generated when nitrogen oxides and volatile organic compounds react with sunlight. Similarly, particulate matter can be generated by the chemical transformation of gaseous contaminants. Secondary pollutants can spread across long distances, contributing to regional air quality issues.

Particulate matter (PM), ozone, nitrogen oxides, sulphur oxides, carbon monoxide, and volatile organic compounds are the main pollutants that contribute to this problem. Particulate matter is produced by vehicle emissions, industrial operations, and dust; ground-level ozone is produced when sunlight reacts with pollutants; and nitrogen oxides are a consequence of combustion. Air pollution can have an impact on everyone's health, but specific populations, such as children, the elderly, and those with pre-existing diseases, are particularly vulnerable.

About 238,000 premature deaths in the EU-27 in 2020 were attributed to PM2.5 exceeding WHO guidelines. The number of premature deaths due to PM2.5 in the European Union in 2021 is 253,000. In contrast, PM10, with particles smaller than 10 microns, generally cannot reach the lungs easily, but can irritate the arteries and cause serious diseases such as asthma. Long term exposure to either type of PM can lead to heart disease, stroke, and even cognitive decline. These pollutants destroy ecosystems, causing acid rain to harm plants and wildlife. Ground-level ozone harms vegetation and reduces crop production. Air pollution must be reduced by tackling its causes through stronger emission rules, developing cleaner energy sources, and encouraging sustainable practices.

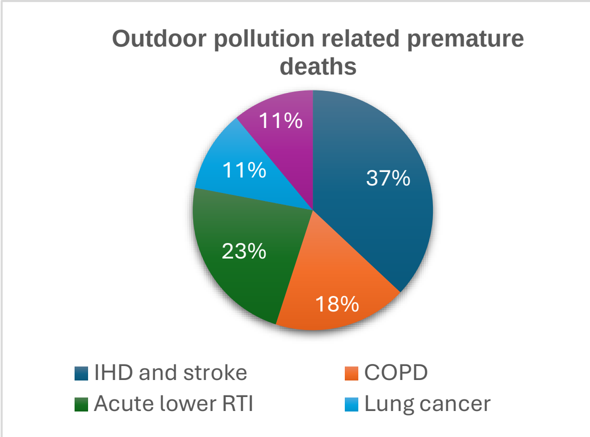

Figure 1:Outdoor pollution related deaths

Air pollution – a threat to the globe

Effective pollution prevention necessitates a multifaceted approach that includes reducing existing pollution sources, shifting to clean energy alternatives, and establishing sustainable behaviours in industries and communities. Despite these efforts, a large section of the global population is still exposed to harmful air quality on a regular basis. According to the GBD report, air pollution is now the second leading cause of premature death worldwide and will replace hypertension by 2021. It was the fourth leading cause, accounting for nearly 4.5 million deaths in 2019. This burden is not limited to outdoor pollution, indoor air pollution is also a major cause of death, especially in low-income countries where families depend on air pollution for cooking and heating. The areas most affected by the air pollution are low- and middle- income countries, where indoor and outdoor air pollution is

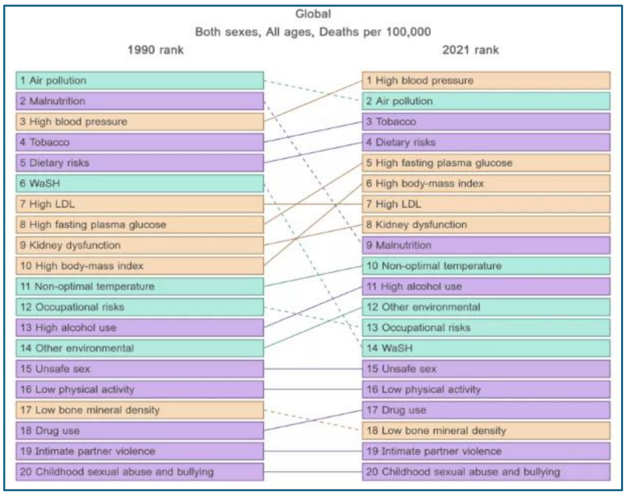

Figure 2: Global burden of disease

at higher levels. For instance, India and China bear the greatest burden due to air pollution; India alone accounts for an estimated 980,000 premature deaths in 2019.

According to the World Health Organisation (WHO), nearly all the world's population (99%) breathes air that exceeds WHO guidelines, with low- and middle-income countries having the highest exposures; and estimates that air pollution causes 3.2 million premature deaths each year, mostly in low- and middle-income countries and more than 27% of deaths among children under 5 age group. Air pollution is associated with a variety of health issues, including heart disease, stroke, lung cancer, and chronic respiratory disorders. It also has substantial environmental consequences, such as acid rain, haze, ozone depletion, and climate change.

Climate change

Air pollution and climate change are intrinsically linked, each exacerbating the effects of the other. The burning of fossil fuels, industrial processes and deforestation causes the release of many greenhouse gases into the atmosphere, especially carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). Gases trap heat, causing global temperatures to rise, the phenomenon is called the greenhouse effect, ultimately leading to global warming. When particulate matter, such black carbon, is formed on ice and snow, it decreases the Earth's albedo, increasing the absorption of sunlight and heating the atmosphere. A secondary pollutant called ground-level ozone traps heat and suppresses plant life, upsetting the carbon cycle. Additionally, pollutants change the characteristics of clouds, which affects the distribution of heat and the patterns of precipitation. The greenhouse effect is exacerbated by these combined effects, which significantly alters patterns of the world's climate.

Globally, people are already experiencing the negative effects of climate change. Population living at coastal regions are at risk from rising of sea levels brought on by melting of glaciers and ice caps, while extreme weather events like storms, droughts, floods, and heatwaves are occurring more frequently and with dangerous intensities. Moreover, the disturbance of ecosystems by climate change is leading to changes in the distribution of species and raising the possibility of extinction for several flora and fauna.

The United Nations has incorporated concerns about air pollution and climate change in its framework for Sustainable Development Goals. While SDG 11 concentrates on building sustainable urban settings, with improved air quality as a crucial component, SDG 13 demands for fast action on climate change. The UN's understanding of the urgent need to address these interrelated environmental concerns is reflected in these goals.

The state of air pollution and climate change mitigation differs throughout continents. Europe and North America have made progress towards enforcing more stringent pollution regulations and encouraging the use of renewable energy sources. Nonetheless, fast industrialization, urbanisation, and a lack of resources for adopting sustainable practices continue to pose serious problems for many emerging nations, including portions of Asia and Africa.

WHO air quality guidelines

Air Quality Guidelines (AQGs), formulated by World Health Organization, offers recommendations for interim targets and air quality standards for six key contaminants. Also, they provide qualitative assessments of the best ways to manage particular kinds of particulate matter (PM), like particles from sand and dust storms, black carbon/elemental carbon, and ultrafine particles, for which there is not enough quantitative data to establish AQG values. Based on the most recent scientific information, the standards specify the limits of air quality required to preserve human health around the world.

The AQGs also serve as a reference for determining if and by how much a population's exposure exceeds limits that could raise health concerns. They encompass some of the most closely monitored contaminants that are crucial to human health, and the information on the health impacts of exposure has advanced the greatest in the last fifteen years. The guidelines target classical pollutants, including particle matter ($PM_{2.5}$ and PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and carbon monoxide (CO). When measures are done to minimise these traditional pollutants, they have an impact on other pollutants. These principles are critical for governments and civil society in mitigating human exposure to air pollution and its negative impacts. They offer evidence-based references for developing legally binding standards and targets for air quality management at the international, national, and local levels. The standards also serve as a practical tool for creating effective methods to reduce pollution emissions and concentrations, eventually preserving human health.

Pollutant	Averaging time	2005 AQGs	2021 AQG level
$PM_{2.5}$, µg/m³	Annual	10	5
	24-hour[a]	25	15
PM_{10}, µg/m³	Annual	20	15
	24-hour[a]	50	45
O_3, µg/m³	Peak season[b]	–	60
	8-hour[a]	100	100
NO_2, µg/m³	Annual	40	10
	24-hour[a]	–	25
SO_2, µg/m³	24-hour[a]	20	40
CO, mg/m³	24-hour[a]	–	4

Figure 3: WHO air quality guidelines

Introduction

Air pollution in India

Air pollution levels in India are among the highest in the world, posing a significant danger to the country's health and economy. India is projected to be the third most polluted country by 2023. All 1.4 billion people in India are exposed to hazardous levels of ambient PM 2.5, the most harmful pollutant, which comes from a variety of sources. In 2019, air pollution caused 1.67 million fatalities in India, accounting for 17.8% of all deaths. The National Capital Region (NCR), particularly New Delhi, as well as industrial hubs including as Mumbai, Kolkata, and Chennai, and cities on the Indo-Gangetic plain such as Kanpur, Lucknow, and Patna, are among the worst affected by extreme air pollution.

A significant financial burden on the economy is borne by the health effects of pollution. In India in 2019, economic costs resulting from air pollution-related illness and premature deaths totalled $8 billion and US$28.8 billion, respectively. The entire loss, amounting to $36.8 billion, represented 1.36% of India's GDP. Emissions from burning biomass, such as wood, charcoal, or crop residues, and fossil fuels, such as coal or oil, are some of the most frequent sources. Additionally, dust from highways, factories, building sites, and natural dust sources can be carried by the wind and contribute to PM 2.5 levels.

In a "secondary" process, various gaseous pollutants from one place, such ammonia (NH_3), interact with other gaseous pollutants from another, like sulphur dioxide (SO_2) and nitrogen oxides (NO_x), to produce almost half of India's PM 2.5 emissions in the upper atmosphere. Agriculture, industry, power plants, residences, and transportation significantly contribute to secondary PM2.5 creation. This secondary form disperses more extensively than primary PM2.5, traversing states, cities, and jurisdictions. Particulate pollution is India's gravest health threat, cutting life expectancy by 5.3 years on average. Conversely, CVDs reduce the average Indian's life expectancy by 4.5 years, while maternal and child malnutrition decrease it by 1.8 years.

Air pollution in Delhi

Delhi, India's capital city, has been dealing with severe air pollution for several years. The city has continuously been named among the most polluted in the world, emphasising the critical need for comprehensive steps to solve the environmental catastrophe. Delhi's air quality consistently scores low on worldwide air pollution indices. According to IQAir's World Air Quality Report, Delhi has constantly ranked as the most polluted capital city in the world between 2018 and 2023. In the most recent 2023 study, Delhi was placed as the world's most polluted capital city and the third most polluted city overall, indicating the severity of the problem. A Greenpeace

Figure 4: Delhi territorial map

Southeast Asia analysis of IQAir data from a live Cost Estimator, which examines real-time air quality data from IQAir, found that PM2.5 air pollution caused approximately 54,000 deaths in India's capital in 2020. The city's air quality typically ranges from poor to severe throughout the year, with levels between 200-400. According to the Air Quality Life Index, adhering to WHO standards could increase the life expectancy of Delhi residents by 11.9 years.

Source apportionment

Air pollution in Delhi arises from a multitude of sources, each contributing to the city's degraded air quality. Vehicle exhaust from petrol, diesel, and gas combustion accounts for 10-30% of the annual PM2.5 concentration. Dust from roads and construction activities also contributes a significant 10-30% to the PM2.5 levels. Industrial sources, including power plants, are major contributors to the overall pollution levels. Residential cooking and heating, coupled with vehicle exhaust and industrial fuel combustion, are considered significant sources of air pollution. The transport sector is the largest contributor to PM2.5 in Delhi, with its contribution ranging from 17.9% to 39.2%. Vehicular pollution is particularly significant, accounting for 67% of this pollution. Road dust also plays a major role, being the largest contributor to PM10 with a contribution ranging from 35.6% to 65.9% and contributing to

CPCB Study (2010)	
Source	**% contribution (PM_{10}): Range for 10 monitoring locations**
Vehicles	8.7–20.5
Road dust	14.5–29.0
Construction	22–23.1
Industries	6.3–9.3
Garbage burning	10.5–24.4
Domestic	2.7–9.4
DG sets	6.8–12.3

IIT Kanpur Study (2015)				
Source	**Average for six monitoring locations**			
	% contribution (PM_{10})		**% contribution ($PM_{2.5}$)**	
	Winter	**Summer**	**Winter**	**Summer**
Vehicles	19.7	6.4	25.1	8.5
Secondary particulates	24.6	10.15	29.9	14.9
Biomass burning	16.7	6.8	25.8	12.2
Industries	0.65	1.05	0.8	1.2
Coal and fly ash	12.1	37.2	4.8	25.95
Construction material	3.1	4.1	1.5	3.0

Figure 5: Source apportionment in Delhi

PM2.5 between 18.1% and 37.8%. Industrial sources, such as power plants and factories, are significant contributors to air pollution, particularly PM2.5, with their contribution ranging from 11% to 20%. These industries emit pollutants like SO2, NOx, and particulate matter.

Construction activities, especially large-scale projects, add to air pollution through the emission of particulate matter and other pollutants. Stubble burning in neighbouring states like Punjab, Haryana, and Rajasthan is another major source, significantly contributing to smog formation during the winter months. Additionally, other sources of air pollution in Delhi include wood-burning fires, cow dung cake combustion, and fires in industrial and commercial areas.

These various sources collectively exacerbate Delhi's air quality issues, making it one of the most polluted cities in the world and posing severe health risks to its residents. Addressing each of these pollution sources is crucial for improving the city's air quality and public health.

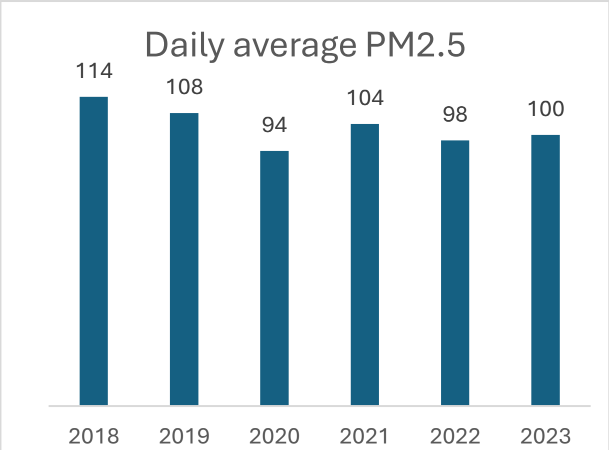

Figure 6: Daily average PM2.5 in Delhi from 2018-2023

Open waste burning, exacerbated by Delhi's high population density and waste generation, is another concerning source. Agricultural waste burning, a seasonal phenomenon peaking during post-harvest periods, escalates pollution levels, particularly in the winter months. Additionally, natural events like dust storms can further worsen the air quality. Notably, Delhi's pollution problem extends beyond its administrative boundaries, as contributions from surrounding areas highlight the regional nature of this issue.

The major pollutants contributing to Delhi's air pollution are particulate matter (PM2.5 and PM10), nitrogen dioxide (NO2), and ozone (O3). PM2.5 is the most hazardous pollutant, with levels often exceeding the World Health Organization (WHO) guideline value of 5 µg/m^3. In

2023 the average annual PM2.5 concentration was 100 µg/m^{3}, which is much higher than the set limits.

Seasonal variation

Air quality in Delhi varies significantly seasonally, owing mostly to climatic conditions and emission patterns from a variety of sources. Delhi's most severe air pollution occurs throughout the winter months of December to February. Low wind speeds and temperature inversions concentrate pollutants near the ground, resulting in dangerously high pollution levels.

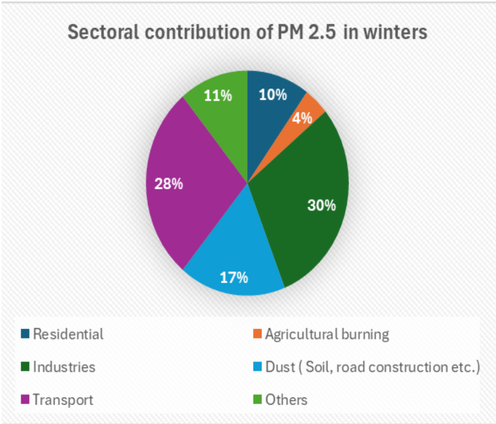

Figure 7: Sectoral contribution of PM 2.5 in winters

Stubble burning in surrounding agricultural districts contributes to higher particulate matter concentrations, while domestic heating and increased traffic emissions due to poor dispersion conditions worsen the situation.

The summer season, which lasts from March to June, usually provides some relief since higher wind speeds and improved dispersion of pollutants enhance air quality. However, dust storms from the Thar Desert can cause temporary increases in particulate matter levels. Construction activity and vehicle emissions continue to be substantial sources to air pollution throughout this time period. The monsoon season, which lasts from July to September, improves air quality by washing pollutants out of the atmosphere. However, waterlogging and construction operations can stir up dust and debris, raising particulate matter levels. The post-monsoon period, which lasts from October to November, sees the commencement of stubble burning in adjacent states, which has a substantial impact on Delhi's air quality.

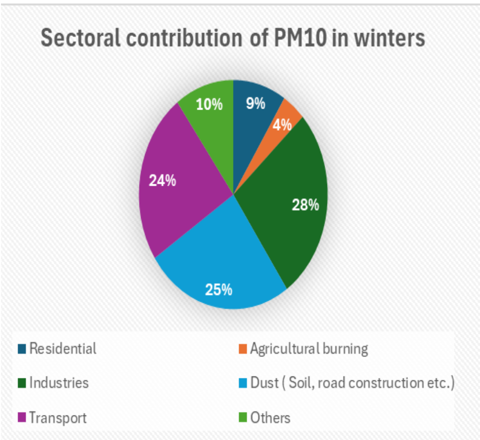

Figure 8: Sectoral contribution of PM10 in winters

Government initiatives

Government has taken numerous measures in the past to curb the problem of air pollution.

1. NATIONAL AIR QUALITY MONITORING PROGRAM

The government has initiated the National Air Quality Monitoring Program to monitor ambient air quality. This program comprises 703 manual stations located in 307 cities and towns across 29 states and six Union Territories in India. NAMP specifically monitors four air pollutants: sulfur dioxide (SO_2), nitrogen dioxide (NO_2), suspended particulate matter (PM_{10}), and fine particulate matter ($PM_{2.5}$).

The objectives of NAMP are to:

1. Evaluate the current state and trends of ambient air quality.
2. Identify potential violations of established air quality standards.
3. Identify cities that do not meet air quality standards.
4. Gather information to develop preventive and corrective measures.
5. Study the natural processes involved in pollution dilution, dispersion, wind-based movement, dry deposition, precipitation, and the chemical transformation of pollutants.

The National Environmental Engineering Research Institute (NEERI), State Pollution Control Boards (SPCB), Central Pollution Control Board (CPCB), and Pollution Control Committees (PCC) collaborate to monitor air quality. The CPCB maintains uniformity and consistency in the air quality data, offering financial and technical support to sustain the monitoring stations.

2. NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS)

Ambient air quality refers to the state of the outdoor air environment. The Central Pollution Control Board (CPCB) establishes standards for this quality, known as the National Ambient Air Quality Standards (NAAQS). These standards, which pertain to various recognized pollutants, are specified in the Air (Prevention and Control of Pollution) Act, 1981. The three main objectives of NAAQS are to:

1. Define the air quality thresholds needed to protect health, property, and vegetation.
2. Provide a standardized method for measuring air quality across the country.
3. Determine the necessary extent of air quality monitoring.

The annual standards are based on the arithmetic mean of at least 104 measurements taken at a specific location twice a week, consistently over 24-hour intervals. These measurements can be 24-hourly, 8-hourly, or 1-hourly values, as applicable. The standards must be met 98% of the time each year.

3. NATIONAL AIR QUALITY INDEX (AQI)

The Prime Minister launched the Air Quality Index (AQI) in April 2015, initially covering 14 cities and now expanded to 71 cities across 17 states. The AQI provides a clear and concise way to communicate the current air quality status. It categorizes air quality into six levels: acceptable, satisfactory, moderately polluted, poor, extremely poor, and severe. This is achieved by condensing complex data on various pollutants into a single index value, with specific names and color codes.

The eight pollutants that comprise the AQI are PM10, PM2.5, NO2, SO2, CO, O3, NH3, and Lead (Pb). These pollutants have individual National Ambient Air Quality Standards that are only good for a maximum of 24 hours. Sub-indices for these pollutants are derived as linear functions of ambient concentrations, with specific breakpoints indicating their possible health consequences.

4. ENVIRONMENT POLLUTION (PREVENTION AND CONTROL) AUTHORITY (EPCA)

The Environment Pollution (Prevention and Control) Authority (EPCA) is a committee established by the central government to tackle air pollution in the National Capital Region (NCR) as per the Environment Protection Act of 1986. EPCA's principal responsibility is to monitor and manage air quality in the NCR region, which includes issuing directives to states, performing site inspections, and levying fines for noncompliance.

5. FORTY-TWO ACTION POINTS

Section 18 (1) (b) of the Air (Prevention and Control of Pollution) Act, 1986 empowers the Central Pollution Control Board (CPCB) to provide comprehensive guidelines for the implementation of 42 measures to reduce air pollution in major cities, including Delhi and the National Capital Region (NCR). These measures address various sources of air pollution, such as the burning of biomass and municipal solid waste (MSW), industrial pollution, control and reduction of vehicular emissions, re-suspension of road dust and other fugitive emissions, and construction and demolition (C&D) activities. Initially required for the NCR, these 42 actions were later extended to state boards for implementation in additional non-attainment cities. T

6. GRADED RESPONSE ACTION PLAN (GRAP)

The government has instituted a graded response action plan for Delhi and the NCR region, which specifies targeted remedies for each pollution source based on Air Quality Index (AQI) categories. This plan also includes general health recommendations for each AQI level, as adopted by the Government of India. The approach was developed with a focus on the primary pollution sources in Delhi and the NCR region. It considers all aspects of these sources and outlines appropriate actions for each pollution level as indicated by the AQI.

7. OTHER MEASURES

Regarding waste-related pollution, updates have been made to five regulations concerning solid waste, plastic waste, e-waste, hazardous waste, and biomedical waste. In 2016, new notifications were introduced addressing regulations for construction and demolition debris, recognized as a major source of dust pollution. Furthermore, burning municipal solid waste (MSW), biomass, and leaves has been prohibited by law.

The Indian government has implemented further initiatives to enhance energy efficiency and mitigate air pollution. a few of which are mentioned below:

- **Vehicle Emission and Fuel Quality Standards**: Implemented BS-IV standards in 2017 and BS-VI standards in 2020 for improved vehicle emissions and fuel quality.
- **Fleet Modernization and Scrappage Programme**: Plans to launch a voluntary programme for fleet modernization and scrappage of old vehicles.
- **National Electric Mobility Mission Plan 2020**: Initiated to encourage electric mobility.
- **Automotive Fuel**: Introduced gas as an automotive fuel in various cities.
- **Public Transport Systems**: Enhanced and expanded network of metro-rail and bus-based public transport systems in selected cities.
- **Ujjwala Scheme**: Government program to accelerate the penetration of LPG for household cooking
- **Electrification**: Promoted electrification to reduce kerosene use for lighting.
- **Energy-Efficiency Labelling**: Implemented an energy-efficiency labelling programme for energy-intensive home appliances, such as air conditioners.
- **Standards for Diesel Generators**: Announced new stringent standards for diesel generator sets used for standby power generation.

The recent changes in policy are said to have resulted in a little improvement in the quality of the air in a few major cities, albeit this improvement cannot yet be considered a trend. This is insufficient, and it is necessary to take more targeted, time-bound action at the city and rural levels in order to address the problem thoroughly on a national scale. In light of this, there is a need for a National Clean Air Programme (NCAP) as a national approach to lower air pollution levels in both regional and metropolitan areas.

The Indian government's National Clean Air Programme (NCAP) represents a major initiative aimed at tackling the challenge of deteriorating ambient air quality. Introduced by the Ministry of Environment, Forests, and Climate Change in 2019, NCAP is a comprehensive endeavor to combat the pressing issue of air pollution across the country. By 2024, at least 102 non-attainment cities are expected to have had a 20–30% decrease in particulate matter (PM) concentrations from 2017 levels. Delhi, despite having launched the National Clean Air Programme (NCAP), a major effort to reduce air pollution nationwide, has not been able to attain even a small portion of the desired decrease in particulate matter concentrations since the program's beginning.

Rationale

Delhi, India's capital city, has faced severe air pollution for an extended period, consistently receiving low rankings on global air quality indices. With its high population density and rapid economic development, Delhi's air pollution crisis has garnered global attention, impacting the country's image as a rapidly developing economy. The government's implementation of the National Clean Air Programme (NCAP) aimed to address this issue, but despite years of efforts, a significant improvement in Delhi's air quality has not been observed.

As India continues its rapid economic growth, there is a keen focus on the country's capability to achieve a harmonious balance between development and environmental sustainability. The persistent air pollution in Delhi raises concerns and highlights the need for a comprehensive evaluation of the NCAP's implementation and its effectiveness in achieving the desired targets.

Objective

This study aims to identify the hindrances and challenges that have restricted Delhi from attaining the NCAP targets and to provide actionable recommendations derived from the experiences of capital cities in other countries that share similarities with Delhi in terms of air pollution challenges. By drawing insights from those cities that have successfully reduced air pollution levels and significantly improved air quality, the study seeks to offer practical and informed recommendations tailored to Delhi's context.

This comparative approach will enable the identification of effective strategies, best practices, and valuable lessons learned from cities that have overcome comparable air quality issues, thereby providing a robust framework for Delhi to effectively combat air pollution and achieve sustainable improvements in air quality.

Research Question

- What are the key factors hindering Delhi's achievement of the National Clean Air Programme (NCAP) targets, despite five years of programme implementation?

- What actionable recommendations can be formulated to address the key challenges hindering Delhi's achievement of National Clean Air Programme (NCAP) targets and accelerate progress towards improved air quality?

This study employs a descriptive qualitative research design to investigate the air pollution situation in Delhi, Seoul, and Beijing. The methodology utilized is based on descriptive research methods, where data is gathered through a thorough examination of various sources.

The primary data collection involves an extensive search across multiple search engines, including Google, Google Scholar, PubMed, and Scopus. Additionally, government official websites, portals, published reports and repositories, and official websites of international agencies like WHO, UNEP, IQAir, and indices like AQLI are thoroughly explored.

The literature search is conducted using relevant keywords such as "Air pollution Delhi," "Ambient air pollution India," "NCAP India," "PM2.5," "PM10," "Climate change," "Smog," "Air quality," "Indoor air pollution," "respiratory diseases," "Vehicular emissions," and others related to the study's scope.

To ensure the inclusion of recent and relevant information, the study focuses on literature published on or after 2010. This approach allows for the analysis of up-to-date data and findings, providing a comprehensive understanding of the current air pollution scenario in the study areas.

The collected data is then critically analyzed and synthesized to provide a comprehensive overview of the air pollution status, contributing factors, health impacts, and the effectiveness of existing policies and measures in the selected cities. The findings from this qualitative research study will contribute to the development of strategies and recommendations for addressing air pollution in these urban centres.

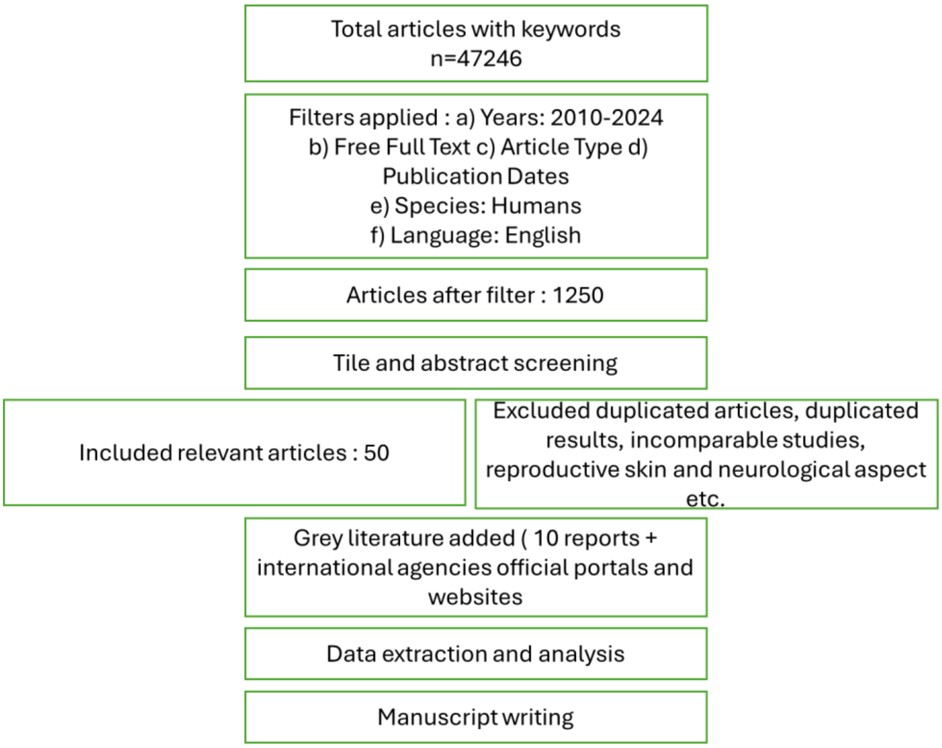

Figure 9: Methodology of study

Results

Overview of NCAP

India, a rapidly rising country, has experienced urbanisation and rapid industrialization over the last three decades, resulting in substantial air pollution challenges. The combustion of fossil fuels is a major source of pollution, which has an impact on many industries and sectors including transportation, power, building, and agriculture. Cities in northern India are often among the most polluted in the world, which leads to a great deal of respiratory ailments, early deaths, financial losses, and legal actions. India's poor air quality and insufficient solutions have been criticised by the World Health Organisation (WHO), which calls for a comprehensive national policy. To tackle air pollution across the country, the Indian government responded by launching the National Clean Air Programme (NCAP).

The NCAP was developed after extensive consultations with a range of stakeholders, including ministries, state governments, and foreign specialists. The programme was approved in October 2018 with the goal of meeting national average annual ambient air quality criteria within a predefined amount of time.

The fact that air pollution reduction measures are city-specific is demonstrated by international instances. considerable reductions in PM2.5 were attained in five years by cities like Beijing and Seoul, and during a two-decade period, considerable improvements were observed in Santiago and Mexico City. Motivated by these illustrations, the NCAP sets a base year of 2017 and by 2024, aims reduction in PM2.5 and PM10 levels by 20–30%.

NCAP's goals include strengthening the network of air quality monitors, enforcing strict mitigation measures, raising public awareness, and developing capability. Based on mid-term reviews, the program—which was originally slated to be a five-year action plan beginning in 2019—may be extended to 20–25 years.

The strategy capitalises on the smart cities framework, integrates current policies like the NAPCC (National Action Plan on Climate Change), and coordinates across sectors. The NCAP will always change in response to new scientific and technical knowledge as well as global best practices.

The three primary sections of the action plan are institutional strengthening, mitigation activities, and knowledge and database augmentation. Developing city-specific air quality management plans, promoting clean technology, enforcing pollution control, and growing the network of air quality monitors are important steps. Public awareness, training, data analysis, and technological assessment are the main focuses of institutional initiatives. 131 cities have received funding aggregating about Rs 9650 Cr, subject to certain requirements for money release and use. Through real-time data gathering and analysis, the PRANA site is essential for monitoring NCAP implementation, encouraging cooperation, and facilitating informed policy decisions. PRANA's all-encompassing strategy serves as a model for efficiently controlling air pollution in other non-attainment cities.

Hinderances

Unfavourable meteorological conditions and geographic location.

Delhi is surrounded by the Himalayas to the north, the Aravalli hills to the south, and the Thar Desert to the west. This geographic location in the Indo-Gangetic Plain causes a "bowl" effect that traps pollutants and prevents them from dispersing naturally, allowing them to build. North-westerly winds from Rajasthan, Pakistan, and Afghanistan aggravate this problem by bringing dust and other pollutants into the area, where the Himalayas trap them. When cold air moves across northern India in the winter, warm air cannot rise and disperse pollutants, which traps pollution near the surface and intensifies its effects on human health.

Seasonal variations also impact the sources of pollution: in the winter, road dust, fly ash, and biomass burning are more significant; in the summer, the sources of pollution are primarily caused by vehicles, firecrackers, stubble burning, municipal solid waste burning, and secondary particles.

The landlocked location and dry alluvial soil of the Indo-Gangetic Plain, along with other topographical disadvantages, provide a continuous and severe air quality challenge for Delhi by contributing heavily to wind-blown dust and air pollution.

Cross border non coordination

The National Clean Air Programme's (NCAP) aims are significantly hampered by Delhi's lack of regional coordination with its neighbouring states. The creation of efficient air quality control plans is hampered by the lack of a unified strategy and inadequate information exchange between governments and towns. This is especially true for Delhi, where the problem of stubble burning in the nearby states of Uttar Pradesh, Rajasthan and Punjab greatly exacerbates the city's problems with air pollution.

However, the successful deployment of NCAP is hampered by the lack of a defined mechanism to handle this cross-border issue. This issue is made worse by the program's uneven execution in various states and localities, which results in variations in the initiatives made to enhance the quality of the air. A patchwork of progress has been achieved, undermining the program's main objectives, since certain cities have made good use of the funds allotted to them while others have lagged.

Furthermore, accountability and enforcement are hampered in the absence of a legal requirement for the implementation of clean air programmes. The problems caused by regional non-coordination are made worse by the frequent delays or inadequate implementation of NCAP plans in the absence of a defined legislative framework. To successfully address the transboundary character of air pollution, a comprehensive strategy involving legislative reforms, information sharing channels, and increased cooperation between Delhi and its neighbouring states is needed.

Underutilization of allocated funds

Underutilization of provided funds is seriously impeding Delhi's ability to meet National Clean Air Programme (NCAP) targets. Delhi has barely used 28 percent of the ₹38.21 crore allotted, or ₹10.77 crore. In particular, the city has only used 23.32% of the funding designated for NCAP's crucial air quality monitoring programme. Delhi recorded the highest annual average PM2.5 concentration of 102 µg/m3 in 2023 among 92 Indian cities, highlighting how this pollution challenge directly impacts Delhi's progress toward achieving its air quality targets. In contrast, cities like Kolkata and Mumbai have utilized their NCAP funds effectively, with utilization rates of 72.48% and 93%, respectively.

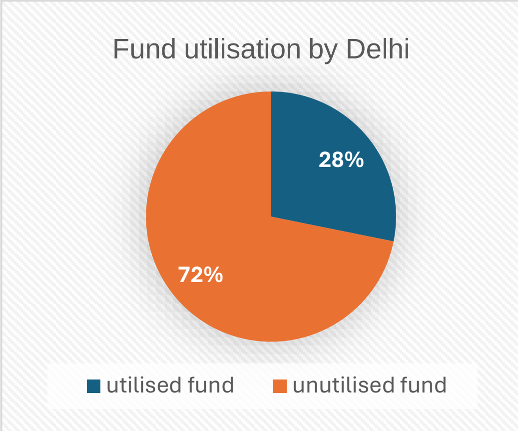

Figure 10: Fund utilization by Delhi

The poor utilisation of finances in Delhi has been linked to bureaucratic bottlenecks and inefficiencies, such as problems with tenders, procurement, and the absence of standard operating procedures. Because of this financial mismanagement, citizens are at serious risk for health problems due to pollution, particularly those who already have respiratory conditions. Furthermore, it impedes efforts to achieve cleaner air.

Case studies

Seoul has lifted its smog

Seoul, South Korea's capital, has seen considerable increases in air pollution levels over the last few decades. The city experienced serious air quality problems in the later half of the 20th century as a result of its fast industrialization and urbanisation. The growing manufacturing sector, rising car emissions, and reliance on coal for energy were the main causes of the elevated levels of pollutants such particulate matter (PM), sulphur dioxide (SO_2), and nitrogen oxides (NO_x). Due to the high population density and dense urban environment, air pollution has become a serious public health hazard. The problem had gotten to the point where it was attracting public and governmental attention by the 1990s.

Even though Seoul's air quality has much improved recently compared to its highest pollution levels, there are still serious problems, especially with tiny particulate matter (PM2.5) continuing to be a major problem. Periodic surges in local pollution are a result of transboundary pollution from China, a neighbouring country. By 2024, Seoul's PM2.5 levels would have exceeded the World Health Organization's (WHO) recommended level by 3.2 times, adding an estimated $3.3 billion in annual economic expenses and 2,700 premature deaths to the city's air pollution.

Seoul's air quality has significantly improved recently compared to its maximum pollution levels, but there are still significant issues, particularly with PM2.5, or fine particulate matter, remaining a big concern. Transboundary pollution from China, a neighbour, causes periodic spikes in local pollution. By 2024, Seoul's PM2.5 levels would have risen 3.2 times above the World Health Organization's (WHO) recommended threshold, contributing to the city's air pollution and an estimated $3.3 billion in yearly economic costs and 2,700 premature deaths.

Several measures have been implemented to address air pollution, including the enactment of the Special Act on Improving Air Quality in the Seoul Metropolitan Area in 2005, the introduction of the first Comprehensive Plan for Air Quality Improvement in 2006, the establishment of the Ministry of Environment in 1990, and the expansion of the Air Pollutant Emission-Cap Regulation in 2009.

Reducing reliance on coal, implementing higher emissions regulations, and boosting public transport and green technologies have been the main goals of transition and technological measures. The transportation sector has benefited greatly from the significant $9 billion in investments made in air quality management between 2007 and 2020. $3.2 billion was also set aside for gathering data and educating the public about air quality-related issues.

To encourage low-carbon, environmentally friendly transportation, foster an environment-friendly driving culture, and improve both local and international collaboration, certain projects have been started. In order to lower PM2.5, efforts are being made to convert intra-city buses to CNG hybrid buses, conduct low-emission programmes for diesel cars, set targets to keep levels at 20 $\mu g/m^3$ by 2018 and 15 $\mu g/m^3$ by 2030, and build up comprehensive PM2.5 monitoring systems.

Subway air quality improvement plans include building ventilation systems, employing pollution-absorbing mats, replacing gravel roadbeds with concrete, and establishing real-time indoor air quality monitoring in subway stations in an effort to reduce pollution by nearly 30% by 2026. These extensive actions demonstrate Seoul's continued dedication to reducing air pollution and enhancing public health.

Conclusion

While significant progress has been made in improving air quality in Seoul, sustained investment and continued implementation of effective policies are crucial. The city's experience underscores the complexities of management of urban air pollution in the context of regional and global environmental dynamics. Ensuring cleaner air for Seoul's residents will require ongoing vigilance, innovation in environmental policy, and cooperation at both national and international levels.

Beijing’s war against pollution

In recent decades, Beijing has experienced extreme air pollution mostly caused by combustion of coal, industrial pollutants, and vehicular emissions. To address this serious issue, Beijing undertook a comprehensive "Clean Air Action Plan" from 2013 to 2017, which achieved amazing achievement.

The Clean Air Action Plan focused on several key areas:

1. Coal Combustion Reduction: Beijing's "coal-to-gas" policy, initiated in 2005, which resulted in a reduction of almost 11 million tons of coal combustion by 2017.
2. Industrial Restructuring: The plan optimized the industrial structure by closing old and polluting enterprises.
3. Residential Sector Interventions: Clean fuels were promoted in residential areas, reducing emissions from household heating and cooking.
4. Vehicle Emission Control: Stringent measures were taken to control vehicle emissions, including eliminating old and polluting vehicles.

Coordination with Surrounding Areas: In 2013, Beijing spearheaded the creation of the Mechanism for Coordinated Prevention and Control of Air Pollution in the Beijing-Tianjin-Hebei and Surrounding Areas, aligning air pollution control efforts with Tianjin and Hebei province. This initiative involved coordinated planning, standardized regulations, unified emergency response protocols, and information sharing among seven provinces. This regional approach resulted in substantial improvements in air quality, with emissions of SO2, NOx, and PM2.5 decreasing by 60%, 22%, and 42%, respectively, from 2013 to 2017. Over the same period, the annual average PM2.5 concentrations across the region decreased by nearly 25%.

Air quality in the Beijing-Tianjin-Hebei region has significantly improved due to coordinated planning, uniform standards, collaborative emergency response procedures, and effective information sharing. For example, an information sharing platform was developed to offer real-time data on air quality and key pollution source emissions in seven provinces: Shanxi, Hebei, Beijing, Tianjin, Henan, Shandong, and Inner Mongolia. Except for VOCs, significant air pollutant emissions in these "Areas Surrounding Beijing" fell dramatically in 2017 compared to 2013 levels: SO2 by 60%, NOx by 22%, and PM2.5 by 42%. In general, the integrated regional approach resulted in a reduction of approximately 25% in annual average PM2.5 concentrations in Beijing-Tianjin-Hebei and surrounding areas from 2013 to 2017.

In addition to these measures, Beijing adopted a comprehensive strategy focusing on sustainable mobility and advanced monitoring systems. Key initiatives included:

1. Sustainable Transportation:
    - Expansion of the urban rail network.
    - Establishment of low-emission zones.
    - Promotion of public transportation, cycling, and electric vehicles.
    - Scrapping incentives for older, high-emitting vehicles.
    - Incentives for adopting new energy vehicles.
2. Advanced Monitoring Systems:
    - Establishment of an integrated Air Quality Index (AQI) monitoring network.
    - Installation of over 1,000 sensors to identify highly polluted areas and periods.
3. Environmental Conservation:
    - Extensive afforestation projects to increase the city's green cover.

Remarkable results were achieved:

1. Reduction in Pollutant Concentrations:
    - PM2.5: Annual average concentration decreased by 35.6%, reaching 58μg/m³ in 2017.

- SO_2: Emissions decreased by 83% during 2013-2017.
- NO_x: Emissions decreased by 43% during 2013-2017.
- VOCs: Emissions decreased by 42% during 2013-2017.
- PM2.5: Emissions decreased by 55% during 2013-2017.

2. Regional Improvements: From 2013 to 2017, there was a nearly 25% decrease in annual average PM2.5 concentrations in the Beijing-Tianjin-Hebei region and its surrounding areas.
3. Increased Funding: Beijing's budget for air pollution control increased significantly, rising from 1.7 billion Yuan in 2009 to 18.22 billion Yuan in 2017, marking a tenfold increase.
4. Health Impact: The reduction in PM2.5 levels is expected to increase life expectancy by 4.6 years for residents.

Long-Term Trends: From 1998 to 2018, Beijing's air quality showed consistent improvement, with annual average concentrations of SO_2, NO_2, and PM10 decreasing by 93.3%, 37.8%, and 55.3%, respectively.

Conclusion: Beijing's Clean Air Action Plan, which was executed from 2013 to 2017, was a huge success, not only lowering pollution levels in the city but also boosting regional cooperation and improving air quality throughout Beijing-Tianjin-Hebei and nearby areas. This feat was made possible by a multifaceted approach that included regulatory interventions, industrial restructuring, clean energy projects, and greater financing for environmental protection.

Discussion

Air pollution is a global concern, and Delhi is a chronic sufferer, with its residents experiencing a decreased life expectancy of 11 years due to poor quality of air. The National Clean Air Programme (NCAP) is a comprehensive initiative aimed at tackling this issue, but its implementation in Delhi faces significant challenges. After detailed analysis of the available literature and NCAP program, several roadblocks are found.

One major obstacle is the underutilization of allocated funds. Despite sufficient funding, only a fraction is used, hindering the deployment of necessary measures and technologies to reduce pollution.

Another obstacle is Delhi's geographical location in the Indo-Gangetic Plain, surrounded by natural barriers, which exacerbates its pollution problem by trapping pollutants. While we cannot change this geography, we can better manage its effects by understanding meteorological factors and seasonal variations and taking appropriate actions accordingly.

Another significant challenge is cross-border coordination. Pollution from neighbouring states, such as burning of stubble in Punjab and Haryana, contributes heavily to Delhi's air quality issues. Without effective collaboration with these neighbouring regions, efforts within Delhi alone are insufficient and the benefits of implemented measures are significantly diminished.

Countries in Asia are more affected by air pollution due to rapid industrialization and urbanization. However, some capitals comparable to Delhi have made significant progress in improving air quality. For the further discussion, the following case studies are prepared by thorough literature review and analysis, which highlight the measures taken by Beijing, the capital of China, and Seoul, the capital of South Korea, to reduce air pollution. These cities have implemented various strategies to address their pollution issues and have seen notable improvements in air quality, serving as potential models for other cities facing similar challenges

Recommendations

Adequate utilization of allocated funds

The experiences of Beijing and Seoul demonstrate how important it is to use finances granted properly to reduce air pollution. Although these cities had similar pollution issues as Delhi, they were able to enhance the quality of the air by allocating more funds and putting suggested strategies into practice. On the other hand, over a five-year period, Delhi has only used 29% of the funds that were allotted to it, which has a direct impact on the availability of the infrastructure and technology that are required to combat air pollution.

The underutilization of funding impedes the execution of critical measures such as improving air quality monitoring systems, enacting stronger emission limits, and supporting green infrastructure. Furthermore, the money allocation procedure requires that the next tranche of funds be issued only after 100% of previously allotted funds have been used, resulting in a cycle of inefficiency and underperformance.

As a recommendation, the government can closely examine the fund utilization pattern and implement or modify certain norms to ensure effective utilization of allocated resources. These norms could include:

1. Mandating the utilization of a certain minimum percentage of the allocated funds within a given financial year, promoting timely and efficient spending.
2. Dividing the annual fund allocation into quarterly instalments, encouraging a consistent and systematic approach to fund utilization throughout the year.
3. Dedicating a specific portion of the allocated funds solely for the maintenance and upkeep of previously implemented measures, ensuring the long-term sustainability and effectiveness of existing pollution control initiatives

4. Continuous monitoring and evaluation of the effectiveness of the utilized funds should be undertaken, accompanied by a comprehensive assessment and identification of emerging issues that necessitate the implementation of new measures to address air pollution effectively.

Proper allocation and utilization of funds can support the deployment of advanced pollution control technologies, increase public awareness campaigns, strengthen regulatory frameworks, and facilitate cross-border coordination to address transboundary pollution. By learning from the successful strategies of Beijing and Seoul and improving fund utilization practices, Delhi can enhance its capacity to tackle air pollution and protect public health.

Meteorology and Geographic location mitigation action

The geographic location of Delhi, nestled in the Indo-Gangetic Plain and surrounded by natural barriers like the Himalayas, Aravalli hills, and Thar Desert, creates a bowl or valley effect that traps air pollutants, exacerbating its air quality issues. To mitigate these effects, innovative strategies can be employed. Some of the recommendations are as follows:

1. Introducing high smog towers and vertical forests can help in reducing pollution levels by acting as air purifiers and green lungs within the city.
2. Increasing the number of Air Quality Index (AQI) monitoring stations, akin to Beijing's extensive network of 1000 stations, would enhance real-time data collection for better decision-making.
3. Incorporating artificial intelligence (AI) for early prediction and management of high smog or bad air quality days can enable proactive measures.
4. scaling up afforestation projects would not only increase oxygen production but also stabilize soil, thereby reducing dust in the air.

5. Additionally, accelerating trials of cloud seeding and cloud bursting techniques could offer potential solutions to mitigate severe air pollution episodes.

By implementing these measures, Delhi can effectively address the meteorological and geographical challenges that hinder air pollution reduction. These initiatives not only tackle the immediate effects of pollution but also support long-term environmental sustainability and public health improvement efforts in the area. Strategically implementing these comprehensive approaches is vital for achieving substantial and sustainable improvements in Delhi's air quality.

Cross border coordination

Cross-border collaboration is critical for lowering air pollution in Delhi by addressing transboundary sources of pollution. Collaboration with neighbouring states, like as Uttar Pradesh, Punjab, and Haryana, is critical, as stubble burning adds significantly to Delhi's air quality challenges. Coordinated action plans can reduce regional emissions and standardise regulatory requirements across borders. Sharing data, conducting collaborative monitoring activities, and encouraging policy alignment all contribute to integrated pollution-reduction plans. Working cooperatively, Delhi and its neighbouring regions can effectively reduce cross-border pollution sources and aim to improve air quality for all people.

Some of the recommendations based on Beijing- Tianjin – Hebei coordination strategy are:

1. Establishing a collaborative committee with authorities from Delhi and the three surrounding states.
2. Developing unified planning and policies applicable across all neighboring regions.
3. Creating a common portal for sharing data and providing technical and financial support.
4. Implementing joint responses to heavy pollution episodes.
5. Coordinating efforts to control vehicle pollution, including joint inspections and penalties for violations outside the vehicle's registered city.

Sustainability and optimization of infrastructure and vehicles

Promoting sustainability and optimising infrastructure in Delhi can greatly help to reduce air pollution. This includes switching to cleaner energy sources, such as renewable energy, and encouraging energy-efficient technologies in industries, transportation, and homes. Improving public transport and increasing the use of electric vehicles can help to reduce automotive emissions. Furthermore, expanding green spaces with urban forestry and rooftop gardens reduces pollution and improves air quality. Implementing stringent energy-efficient building rules and supporting green construction practices help to further sustainability efforts. By implementing these steps, Delhi can not only lower its carbon footprint but also provide a better and more sustainable urban environment for its citizens, lessening the negative consequences of air pollution.

Some of the recommendations based on case studies of Beijing and Seoul are:

1. Infrastructure optimization:

- Dust-free roads through regular cleaning and maintenance.
- Replacing gravel roads by concrete
- Pressure washing of roads
- Expansion of public transport fleet and metro rail routes to encourage modal shift.

2. Strict Regulations:

- Stringent regulations against construction and demolition activities to mitigate dust emissions.
- Strict emission standards and periodic checks for pollution-causing vehicles.
- Implementation of low-emission zones and vehicle restrictions in highly polluted areas.

3. Sustainable Transportation:

- Incentives for the adoption of electric vehicles and promotion of shared mobility services.
- Development of dedicated cycling infrastructure and pedestrian-friendly zones.

- Expansion of public transport infrastructure powered by renewable energy.

Public awareness and participation

Public awareness and participation are essential for the success of any program, as residents are key stakeholders whose actions significantly influence policy outcomes. In the context of the NCAP , citizen involvement is critical.

Recommendations for citizen engagement include:

- Promoting car sharing and offering incentives for public transport usage.
- Raising awareness about economic and environmentally friendly driving practices.
- Encouraging reduction of car idling to minimize emissions.
- Providing incentives for scrapping old vehicles and promoting the use of clean fuel vehicles.
- Educating residents about eco-friendly methods of stubble clearing and offering incentives for their adoption.

These initiatives rely on informed and proactive citizen participation to enhance the effectiveness of NCAP policies and contribute to improving air quality in Delhi.

Conclusion

Reducing air pollution in Delhi is not only crucial locally but also essential on a global scale. The city's well-documented air quality issues have not only posed significant public health risks but also damaged its international standing. Improving air quality will bolster Delhi's global reputation as a responsible and sustainable metropolis, making it more attractive to investments and tourism. The National Clean Air Programme (NCAP) plays a pivotal role in this transformation by setting ambitious targets and implementing comprehensive strategies to mitigate sources of pollution such as vehicular emissions, industrial activities, and agricultural practices.

The effective implementation of NCAP will have profound benefits for the health of Delhi's residents. Poor air quality has been linked to respiratory and cardiovascular diseases, leading to premature deaths and imposing substantial healthcare costs while reducing productivity. By reducing pollution levels, NCAP aims to alleviate these health burdens, thereby enhancing quality of life and life expectancy for millions of Delhiites.

Furthermore, cleaner air contributes to economic prosperity. A healthier workforce tends to be more productive, resulting in reduced absenteeism and healthcare expenditures. Moreover, a cleaner environment enhances the city's attractiveness to businesses and investors, fostering economic growth and job creation. Sustainable practices promoted under NCAP, such as the adoption of renewable energy and green technologies, also stimulate innovation and entrepreneurship, further bolstering the economy.

In addition to these benefits, reducing air pollution aligns with global climate objectives, demonstrating Delhi's commitment to environmental sustainability and climate action. It sets an example for other cities worldwide grappling with similar challenges, encouraging collective efforts towards cleaner air and a healthier planet.

In conclusion, effective implementation of NCAP is not merely about tackling pollution; it is about safeguarding public health, enhancing economic resilience, and ensuring a sustainable future for Delhi and its inhabitants. By prioritizing improvements in air quality, Delhi can emerge as a leading global city that balances growth with environmental stewardship, benefiting both current and future generations.

References

1. The world bank. Catalyzing Clean Air in India [Internet]. World Bank. 2021. Available from: https://www.worldbank.org/en/country/india/publication/catalyzing-clean-air-in-india

2. World Health Organization. What are the WHO Air quality guidelines? [Internet]. World Health Organization. 2021. Available from: https://www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines

3. NCAP NATIONAL CLEAN AIR PROGRAMME [Internet]. Available from: https://moef.gov.in/wp-content/uploads/2019/05/NCAP_Report.pdf

4. National Clean Air Programme (NCAP) to improve air quality in 131 cities by engaging all stakeholders [Internet]. pib.gov.in. 2023. Available from: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1909910

5. Guttikunda SK, Dammalapati SK, Pradhan G, Krishna B, Jethva HT, Jawahar P. What Is Polluting Delhi's Air? A Review from 1990 to 2022. Sustainability. 2023 Feb 26;15(5):4209.

6. Garg A, Gupta NC. The Great Smog Month and Spatial and Monthly Variation in Air Quality in Ambient Air in Delhi, India. Journal of Health and Pollution. 2020 Sep;10(27):200910.

7. Sharma D, Soni VK, Pradhan S. Assessment of variation in air quality over Delhi and neighbouring cities of Noida and Greater Noida. Proceedings of the Indian Academy of Sciences Earth and planetary sciences/Journal of earth system science. 2022 Jul 4;131.

8. Chauhan P. AN OVERVIEW ON AIR POLLUTION IN INDIA AT PRESENT SCENARIO. International Journal of Research -GRANTHAALAYAH. 2015 Sep 30;3(9SE).

9. Tracing the Hazy Air 2024: Progress Report on National Clean Air Programme (NCAP) [Internet]. Centre for Research on Energy and Clean Air. 2024 [cited 2024 Apr 17]. Available from: https://energyandcleanair.org/publication/tracing-the-hazy-air-2024-progress-report-on-national-clean-air-programme-ncap/#:~:text=The%20National%20Clean%20Air%20Programme

10. Bordoloi B, Saharia S. Climate Change and Emerging Vector-Borne Diseases in India. International Journal of pharma and Bio Sciences. 2021 Mar 22;11(2):190–3.

11. Sharma D, Mauzerall D. Analysis of Air Quality Data in India between 2015 and 2019. Aerosol and Air Quality Research. 2022;22(2):210204.

12. Managing future air quality in megacities: A case study for Delhi. Atmospheric Environment [Internet]. 2017 Jul 1;161:99–111. Available from: https://www.sciencedirect.com/science/article/pii/S1352231017302856

13. Kandlikar M, Ramachandran G. THECAUSES ANDCONSEQUENCES OFPARTICULATEAIRPOLLUTION INURBANINDIA: A Synthesis of the Science. Annual Review of Energy and the Environment. 2000 Nov;25(1):629–84.

14. Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E. Environmental and health impacts of air pollution: A review. Frontiers in Public Health [Internet]. 2020;8(14):1–13. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7044178/

15. Bush KF, Luber G, Kotha SR, Dhaliwal RS, Kapil V, Pascual M, et al. Impacts of Climate Change on Public Health in India: Future Research Directions. Environmental Health Perspectives [Internet]. 2011 Jun;119(6):765–70. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3114809/

16. Sharma SK, Mandal TK. Elemental Composition and Sources of Fine Particulate Matter (PM2.5) in Delhi, India. Bulletin of Environmental Contamination and Toxicology. 2023 Mar 1;110(3).
17. Majra JP, Gur A. Climate change and health: Why should India be concerned? Indian journal of occupational and environmental medicine [Internet]. 2009;13(1):11–6. Available from: https://www.ncbi.nlm.nih.gov/pubmed/20165606
18. Ganguly T, Selvaraj KL, Guttikunda SK. National Clean Air Programme (NCAP) for Indian cities: Review and outlook of clean air action plans. Atmospheric Environment: X. 2020 Dec;8:100096.
19. Nasir H, Goyal K, Prabhakar D. Review of Air Quality Monitoring: Case Study of India. Indian Journal of Science and Technology. 2016 Nov 30;9(44).
20. Sarkar S, Singh RP, Chauhan A. Crop Residue Burning in Northern India: Increasing Threat to Greater India. Journal of Geophysical Research: Atmospheres. 2018 Jul 10;123(13):6920–34.
21. Ghose MK, Paul R, Banerjee SK. Assessment of the impacts of vehicular emissions on urban air quality and its management in Indian context: the case of Kolkata (Calcutta). Environmental Science & Policy. 2004 Aug;7(4):345–51.
22. Feng S, Gao D, Liao F, Zhou F, Wang X. The health effects of ambient PM2.5 and potential mechanisms. Ecotoxicology and Environmental Safety. 2016 Jun;128:67–74.
23. Sagar A, Balakrishnan K, Guttikunda S, Roychowdhury A, Smith KR. India Leads the Way: A Health-Centered Strategy for Air Pollution. Environmental Health Perspectives. 2016 Jul;124(7).
24. Feng L, Liao W. Legislation, plans, and policies for prevention and control of air pollution in China: achievements, challenges, and improvements. Journal of Cleaner Production

[Internet]. 2016 Jan;112:1549–58. Available from: https://www.sciencedirect.com/science/article/pii/S0959652615011026

25. Nongkynrih B, Gupta S, Rizwan S. "Air pollution in Delhi: Its Magnitude and Effects on Health." Indian Journal of Community Medicine. 2013;38(1):4.
26. Kulshreshtha P, Khare M, Seetharaman P. Indoor air quality assessment in and around urban slums of Delhi city, India. Indoor Air. 2008 Dec;18(6):488–98.
27. Firdaus G, Ahmad A. Indoor air pollution and self-reported diseases - a case study of NCT of Delhi. Indoor Air. 2011 Apr 18;21(5):410–6.
28. Greenstone M, Lee K, Sahai H. Indoor Air Quality, Information, and Socio-Economic Status: Evidence from Delhi [Internet]. papers.ssrn.com. Rochester, NY; 2021. Available from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3767009
29. Balmes JR. Household air pollution from domestic combustion of solid fuels and health. Journal of Allergy and Clinical Immunology. 2019 Jun;143(6):1979–87.
30. Mani S, Jain A, Tripathi S, Gould CF. Sustained LPG use requires progress on broader development outcomes. Nature Energy. 2020 Jun 5;
31. Mani S, Jain A, Tripathi S, Gould CF. The drivers of sustained use of liquified petroleum gas in India. Nature Energy [Internet]. 2020 Jun 1 [cited 2022 Jan 5];5(6):450–7. Available from: https://www.nature.com/articles/s41560-020-0596-7
32. Fiore AM, Naik V, Leibensperger EM. Air Quality and Climate Connections. Journal of the Air & Waste Management Association. 2015 May 15;65(6):645–85.
33. Orru H, Ebi KL, Forsberg B. The Interplay of Climate Change and Air Pollution on Health. Current environmental health reports [Internet]. 2017;4(4):504–13. Available from: https://www.ncbi.nlm.nih.gov/pubmed/29080073
34. Nassikas NJ, McCormack MC, Ewart G, Balmes JR, Bond TC, Brigham E, et al. Indoor Air Sources of Outdoor Air Pollution: Health Consequences, Policy, and

Recommendations: An Official American Thoracic Society Workshop Report. Annals of the American Thoracic Society. 2024 Mar 1;21(3):365–76.

35. Tian Y, Jiang Y, Liu Q, Xu D, Zhao S, He L, et al. Temporal and spatial trends in air quality in Beijing. Landscape and Urban Planning. 2019 May;185:35–43.
36. Air quality management policy and reduced mortality rates in Seoul Metropolitan Area: A quasi-experimental study. Environment International [Internet]. 2018 Dec 1 [cited 2021 Apr 19];121:600–9. Available from: https://www.sciencedirect.com/science/article/pii/S0160412018315654
37. Kim YP, Lee G. Trend of Air Quality in Seoul: Policy and Science. Aerosol and Air Quality Research. 2018;18(9):2141–56.
38. Temporary reduction in fine particulate matter due to “anthropogenic emissions switch-off” during COVID-19 lockdown in Indian cities. Sustainable Cities and Society [Internet]. 2020 Nov 1;62:102382. Available from: https://www.sciencedirect.com/science/article/pii/S221067072030603X
39. Jo H, Kim SA, Kim H. Forecasting the Reduction in Urban Air Pollution by Expansion of Market Shares of Eco-Friendly Vehicles: A Focus on Seoul, Korea. International Journal of Environmental Research and Public Health. 2022 Nov 19;19(22):15314–4.
40. Kumar P, Jain S, Gurjar BR, Sharma P, Khare M, Morawska L, et al. New Directions: Can a “blue sky” return to Indian megacities?. Atmospheric Environment. 2013 Jun;71:198–201.
41. Dutta A, Jinsart W. Air pollution in Delhi, India: It’s status and association with respiratory diseases. Xu Y, editor. PLOS ONE. 2022 Sep 20;17(9):e0274444.
42. Kim J, Park JM, Hu H, Crippa M, Guizzardi D, Satoru Chatani, et al. Long-term historical trends in air pollutant emissions in South Korea (2000–2018). Asian Journal of Atmospheric Environment. 2023 Oct 6;17(1).

43. Ho CH, Heo JW, Chang M, Choi W, Kim J, Kim SW, et al. Regulatory measures significantly reduced air-pollutant concentrations in Seoul, Korea. Atmospheric Pollution Research [Internet]. 2021 Jul 1 [cited 2023 May 11];12(7):101098. Available from: https://www.sciencedirect.com/science/article/pii/S1309104221001641

44. Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E. Environmental and health impacts of air pollution: A review. Frontiers in Public Health [Internet]. 2020;8(14):1–13. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7044178/

45. Chetna, Dhaka SK, Gagandeep Longiany, Vivek Panwar, Kumar V, Malik S, et al. Trends and Variability of PM2.5 at Different Time Scales over Delhi: Long-term Analysis 2007–2021. Aerosol and Air Quality Research. 2023 Jan 1;23(5):220191–1.

46. Nirwan N, Siddiqui A, Kannemadugu H baba shaeb, Chauhan P, Singh RP. Determining hotspots of gaseous criteria air pollutants in Delhi airshed and its association with stubble burning. Scientific Reports [Internet]. 2024 Jan 10 [cited 2024 Mar 22];14(1):986. Available from: https://www.nature.com/articles/s41598-023-51140-x

47. Tyagi B. India's economic growth and disease burden in relation to air pollution. The Lancet Regional Health - Southeast Asia. 2022 Dec;7:100081.

48. UNEP. Air Pollution Note – Data you need to know [Internet]. www.unep.org. 2021. Available from: https://www.unep.org/interactives/air-pollution-note/

49. WHO. Air Pollution Data Portal [Internet]. www.who.int. World Health Organization; 2023. Available from: https://www.who.int/data/gho/data/themes/air-pollution

50. Almetwally AA, Bin-Jumah M, Allam AA. Ambient air pollution and its influence on human health and welfare: an overview. Environ Sci Pollut Res Int. 2020 Jul;27(20):24815-24830. doi: 10.1007/s11356-020-09042-2. Epub 2020 May 3. PMID: 32363462.

51. Seoul's action, a starting point for global air quality improvement efforts | Climate & Clean Air Coalition [Internet]. www.ccacoalition.org. Available from:

https://www.ccacoalition.org/news/seouls-action-starting-point-global-air-quality-improvement-efforts

52. Once enough to stain shirt collars, smog is lifting over greater Seoul [Internet]. UNEP. 2024. Available from: https://www.unep.org/news-and-stories/story/once-enough-stain-shirt-collars-smog-lifting-over-greater-seoul#:~:text=In%20addition%2C%20governments%20in%20the
53. Household air pollution [Internet]. www.who.int. [cited 2024 Jul 16]. Available from: https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health?gad_source=1&gclid=CjwKCAjwrvyxBhAbEiwAEg_KgjSDlVwOX0uo48ocqVvlFxIKXgZobrXagtF95ZAX5JBDsWCcEJvM9hoCONMQAvD_BwE
54. South Korea Analysis: Air Pollution Cuts Lives Short by More Than A Year [Internet]. AQLI. Available from: https://aqli.epic.uchicago.edu/news/south-korea-analysis-air-pollution-cuts-lives-short-by-more-than-a-year/
55. Environment UN. Achieving clean air for blue skies in Seoul, Incheon and Gyeonggi, Republic of Korea [Internet]. UNEP - UN Environment Programme. 2023. Available from: https://www.unep.org/resources/publication/achieving-clean-air-blue-skies-seoul-incheon-and-gyeonggi-republic-korea
56. Once enough to stain shirt collars, smog is lifting over greater Seoul [Internet]. UNEP. 2024. Available from: https://www.unep.org/news-and-stories/story/once-enough-stain-shirt-collars-smog-lifting-over-greater-seoul
57. Seoul Metro initiates plans to reduce air pollution by over 30% - [Internet]. Official Website of the. 2024. Available from: https://english.seoul.go.kr/seoul-metro-initiates-plans-to-reduce-air-pollution-by-over-30/
58. Environment UN. Achieving clean air for blue skies in Seoul, Incheon and Gyeonggi, Republic of Korea [Internet]. UNEP - UN Environment Programme. 2023. Available from:

https://www.unep.org/resources/publication/achieving-clean-air-blue-skies-seoul-incheon-and-gyeonggi-republic-korea

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