CSIR-NIScPR Discussion Paper Series

Air Pollution in India:
A Critical Assessment and Suggestive Pathways for Clean Air

Discussion Paper # 01

CSIR-NIScPR
National Institute of Science Communication and Policy Research

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(In alphabetical order)

NIScPR-Discussion Paper #01

NIScPR Discussion Papers intend to provide a forum to highlight the research undertaken by the institute in the different domains of policy research and communication which are of contemporary relevance. It also encourages the different stakeholders connected with the institute to jointly write on the discussion papers; to bring cross-disciplinary perspective on the various issues that can further help to reach out to the policy makers, scholars and community at large. The feedbacks and comments may be directed to: Prof. Ranjana Aggarwal, Director CSIR-NIScPR; Email: director@nistads.res.in

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Air Pollution in India: A Critical Assessment and Suggestive Pathways for Clean Air

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(*In alphabetical order*)

Abstract

Air pollution problem has become a major concern globally! High concentration of air pollutants are putting millions of people's health at risk. India is one of the countries that is severely affected by air pollution. As many as 22 out of 30 most polluted cities in the world are located in India. Its adverse impact on population is pervasive; on human health, environment, economy and social well-being. Indian government has taken several initiatives to combat air pollution. Many other stakeholders such as NGO's, international organisations etc. have joined to address this challenging situation. However, inspite of so many action plans and programs, the situation has not improved and has shown alarming trends.

The discussion paper, draws attention to the issues that influence air pollution and highlights the various initiatives of the government and other actors. It underscores some of the

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important initiatives taken by different countries to combat air pollution. What are the measures we need to take to strengthen our fight against air pollution? What can be the lessons learnt from different countries that can be revisited in this context? What are the long-term pathways that the country has to take? The paper concludes with policy suggestions and recommendations.

Keywords: Air Pollution, India, Clean Air, Clean Fuel, Green Technologies, Policy Interventions

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Highlights

- Air pollution has become a major problem in India which has huge health and socio-economic adverse impact. It is not restricted only to mega cities. It has spread to small cities, towns and villages.
- Air pollution is showing alarming trends in spite of many initiatives undertaken by the government and other stakeholders. Indian cities are among the major cities that are ranked as globally most polluted. Many of the solutions such as transition to cleaner fuels, modes of transport, changing construction practices, relocation of the industries from urban centres are costly and difficult to implement. Changing the behavioural pattern of people in accepting green solutions is also a major barrier to achieve clean air.
- Local factors such as straw burning are recurrent problems that have severe seasonal impact on the pollution levels in nearby cities compounded by the weather patterns. The regional factors as above in straw burning case have socio-economic aspects embedded within it which is a challenge for decision makers to implement a more directed policy as such.
- New policies and implementation framework are trying to address the problems. Sustained investment for increasing the capacity for renewable energy, ranking of cities in terms of various parameters including clean air, smart city project, transition towards Bharat VI fuel, clean coal are some important initiatives government has taken to address the pressing problem of air pollution.

- Government is also making efforts to create coordination and synergy among different agencies involved in air pollution control. Various new initiatives are taken for regular monitoring of air quality and city-wise mapping of sources of major pollutants. Coordination committee are trying to develop new mechanisms for efficient collaboration between inter-state and inter-ministerial teams for formulation of policies and their implementation
- Well researched case studies, more informed assessment of success and failures of measures undertaken for controlling air pollution, learning from international good practices, long term strategy that is developed with participation of different stakeholders is needed to address the challenges.
- Citizen participation, solutions that involve the society at large are needed. This can help in larger acceptance of the programs and measures undertaken for clean air.

1. Introduction

Air pollution poses a multi-faceted risk due to its adverse impact on health. It is the leading contributor of mortality from cardiovascular diseases, stroke, chronic obstructive pulmonary disease and lung cancer. DALYs (Disability adjusted life years) due to air pollution is alarming, which is a composite metric that combines the years of life lost due to premature death (YLLs) and the years lived with disability (YLDs) developed by the Global Burden of Disease Study in 2017 (Global Burden of Disease Study 2017, Siddique et al. 2011) (Table 1). Air pollution has also severe adverse impacts on flora and fauna in different regions, threatening the environment and ecosystem and even leading to extinction of some species. The populations are affected not only by exposing to outdoor pollution but also the indoor air pollution is very high across different vulnerable regions. The socio-economic impact of air pollution affects the population in different ways, particularly economically deprived people in a more vulnerable way. It is estimated that 9 out of 10 people worldwide are exposed to air pollution. According to WHO,[2] air pollution kills around 7 million people every year worldwide.

India is one of the most affected countries by air pollution and there are increasing evidences of adverse effects on health due to air pollution. Several studies have shown short and long-term impacts of air pollution on human health. Global Burden of Disease Study 2017, state-wise analysis of Indian state carried out to study the impact of air pollution on deaths, disease burden, and life expectancy, has shown significant impacts of air pollution

[2]https://www.who.int/health-topics/air-pollution#tab=tab_1

(Global Burden of Disease, 2017). Figure 1 shows the average $PM_{2.5}$ count in populated areas globally. This figure draws attention to the fact that India has an average $PM_{2.5}$ level of 40-50 μg per cubic meter, approximately four times that of WHO prescribed limit of 10 μg. The air pollution in Indian cities, on average, exceeded the WHO recommended safe limit threshold by an alarming 500% (Gurjar 2021). Among 30 most polluted cities in the world, 22 cities of India were found to be most polluted (World Air Quality report 2020). WHO (2019) ranked India as the fifth most country affected by air-pollution based on the $PM_{2.5}$ concentrations. It is estimated that about 1.7 million deaths in 2019 occurred in India due to direct and indirect effect of air pollution only (Dandona 2021); which is about 18% of the total deaths during the period. It is estimated that about 1.36% of GDP has been lost due to premature deaths and morbidity in India which is equivalent to about Rs. 2,78,640 crore (approx. 36.8 billion USD) (Dandona 2021); which is more than four times of the allocation for healthcare in the Union budget for 2020-21. Diseases attributed to air pollution has adversely affected economic growth through reduced productivity, decreased labor supply, health expenditure, etc. (Chang 2016, Hansen-Lewis 2018, World Bank 2016, Quah and Boon 2003). This economic loss has been estimated to affect state GDP ranging from 0.67% to 2.15%. The impact has been more severe in the low per capita GDP States like Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh and Chhattisgarh. Delhi had highest per capita economic loss due to air pollution which is followed by Haryana (Dandona 2021).

2. Sources of Air Pollution in India

The challenges associated with air pollution in India, especially in urban areas are due to its complexity of monitoring and controlling the air pollution emerging from varied sources. Regulating air pollution and for developing an effective air quality management system, an accurate knowledge of the source contribution is important. This knowledge of air pollution and thier sources with potential interventions to curb air pollution may help to reduce the air pollution problem in long run. Several studies have been conducted to assess the contribution of various sources in air pollution and the most commanly identified sources are vehicles, manufacturing and electricity generation industries, construction activities, road dust, waste and agriculture burning, combustion of oil, coal and biomass in the households, and marine/sea salt (Guttikunda et al. 2014). A study was conducted by Central Pollution Control Board (CPCB) in the year 2010 to understand the causes of urban air pollution and the results showed that there are other sources along with road transport that lead to air quality problems in the cities (Figure 2).The Source Apportionment for Delhi from major sources to PM_{10} pollution is given in Table 2. Population growth, rapid urbanization, industrialization and increasing economic activities have also contributed to an increase in the level of air pollution in the metropolitan cities, tier II cities, towns and villages. Along with these, rapid increase in number of vehicles, construction activities, and energy consumption have resulted in serious environment of health concerns.

Table 1: Deaths and DALYs attributable to air pollution in India in 2019.				
Items	**Number of Deaths (millions)**	**Percentage of total deaths**	**Number of DALYs (million)**	**Percentage of total DALYs**
Air pollution	1.67 (1.42-1.92)	17·8% (15·8–19·5)	53·5 (46·6–60·9)	11·5% (10·2–12·8)
Ambient particulate matter pollution	0.98 (0.77-1.19)	10·4% (8·4–12·3)	31·1 (24·6–37·5)	6·7% (5·3–8·0)
Household air pollution	0.61 (0.39-0.86)	6·5% (4·3–9·0)	20·9 (14·1–28·7)	4·5% (3·0–6·1)
Ambient ozone pollution	0.17 (0.08-0.26)	1·8% (0·9–2·7)	3·06 (1·51–4·83)	0·7% (0·3–1·0)

Sources: Dandona, 2021

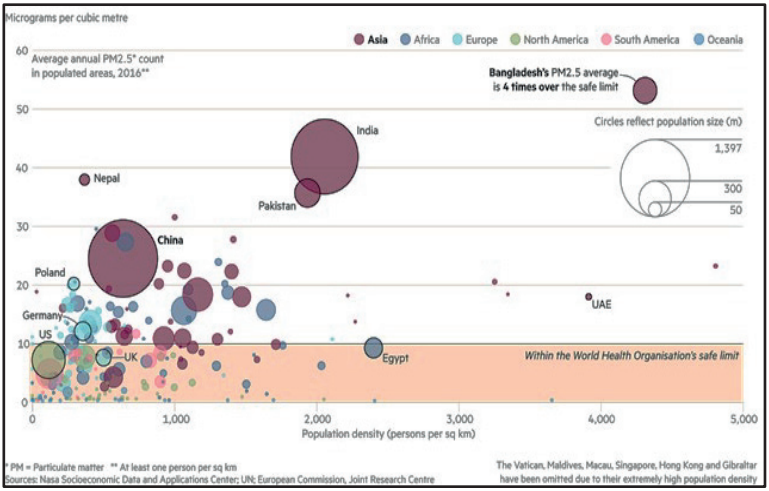

Figure 1. Average $PM_{2.5}$ count of different countries. **Source:** NASA Socioeconomic Data and Application Centre; UN; European Commission, Joint Research Centre

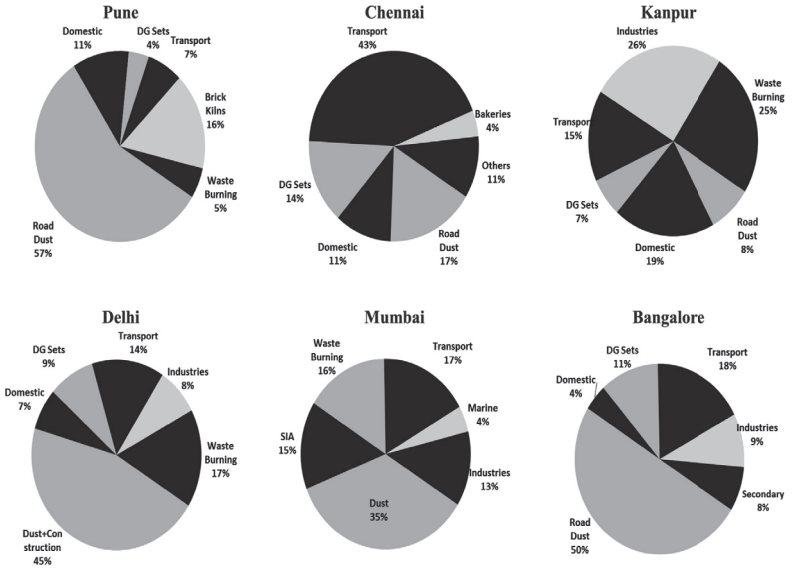

Figure 2. Average percent contributions of major sources to PM_{10} pollution. **Source:** CPCB, 2010.

Table 2: Source Apportionment of Delhi to Air Pollution	
Source	% Contribution in PM_{10}
Construction	22-23.1
Road dust	14.5-29.0
Waste burning	10.5-24.4
Vehicles	8.7-20.5
Diesel Generator (DG) sets	6.8-12.3
Industries	6.3-9.3
Domestic	2.7-9.4

Source: CPCB study 2010

In recent years, air pollution has spread in small cities and towns. They are becoming major concerns for city administrators and

policy makers in regard with the health of citizens. In large cities and metropolitan areas, excessive smog has forced closure of schools, offices and a certain population were been guided to stay indoors. Novel initiatives have been undertaken by several governments, for instance in Delhi, odd-even days was implemented for vehicle use, smog tower installation, etc. to control air pollution. However, the usefulness of these measures needs to be properly assessed. Continuous degradation of ambient air pollution in the mega cities and spread in small cities, towns and villages in India demands effective measures to curb air pollution. The lack of infrastructure facilities, inadequacy of financial resources to implement advance infrastructural innovations, difficulty in relocation of the industries from the urban centres and the behavioural pattern of people in accepting the green solutions are some crucial major challenges on the road to curb air pollution.

Increase in level of air pollution leads to increase in expenditure on health infrastructure, diminished the labour productivity and agricultural productivity. Death and illness from air pollution are caused by tiny particles those penetrate to the human body. These tiny particles (called particulate matter or PM) get dispersed in the atmosphere and carried with the wind getting concentrated in the hotspots deteriorating the local air quality. There is a need that policy makers at national level and regional level take decisive steps to address this serious issue.

3. Major air pollutants and its impact

Particulate matters (PM_1, $PM_{2.5}$, PM_{10}), NO_X, SO_x, CO, Ozone, and Pb etc., are the major pollutants impacting the air quality (See Figure 3). The share of these pollutants varies in terms of percent contribution from different sources of pollution. The data generated from National Air quality programme, $PM_{2.5}$ and PM_{10} are the major pollutants which are found to be exceeding National Ambient Air Quality Standard (NAAQS) across the country more specifically in urban areas of Indo-Gangetic Plain and a major challenge for policy makers to curb the emission level of these pollutants. NO_X, SO_x, and Ozone are observed within National Ambient Air Quality Standards (NAAQS).

In urban areas, the road traffic emissions are one of the major contributors to air pollution. While road dust is a majtributor to PM emission in the mega cities like Delhi (37%), Mumbai (30%), and Kolkata (61%). Similarly, road transport is also largest contributor to $PM_{2.5}$ in Bengaluru (41%), Chennai (34%), Surat (42%), and Indore (47%).

Box 1. Trends in concentration of air pollutants

National average concentration with 90^{th} percentile and 10^{th} percentile for SO_2, NO_2 and PM_{10} indicated that SO_2 concentration has decreased over the years; NO_2 concentration remained stable over the years with a slight decrease in last few years despite increase in sources like vehicles. PM_{10} concentration revealed a fluctuating trend and a stable trend was observed in $PM_{2.5}$. The reason for this may be various interventions measures that have taken place, such as improvement in vehicle technology and other vehicular pollution control measures (CPCB 2020).

Table 3. List of major air pollutants, sources and the potential effects.

Air pollutant	Source		Effects
	Natural	Anthropogenic	
SO_2	Volcanic eruptions (67%)	• Combustion of fossil fuel (coal, heavy fuel oil in thermal power plants, office, factories) • Paper Industry • Excavation & distribution of fossil fuels Petroleum refining, combustion process in diesel, petrol, natural gas driven vehicles	• Respiratory illness, visibility impairment, aggravate existing heart and lung diseases • Acid rain
NO_2	• Lightning • Forest fires • Bacterial activity of soil	• High temperature combustion (internal combustion engines, fossil fuel-fired power stations, industrial) • Burning of Bio-mass and Fossil Fuels	• Irritates the nose and throat increase susceptibility to respiratory infections

PM_{10}	• Windblown dust such as road dust, fly ash, soot, agricultural processes • Physical processes of crushing, grinding and abrasion of surfaces • Non-combustible materials released when burning fossil fuels.	• Road traffic emissions particularly from diesel vehicles • Industrial combustion plants and some public power generation • Commercial and residential combustion • Non-combustion processes (e.g. quarrying) • Agricultural activities	• Cardio-pulmonary problems • Asthma, bronchitis, and pneumonia in older people
$PM_{2.5}$	• Formed by nucleation, which is the initial stage in which gas becomes a particle. • Grow up to a size of 1μm either through condensation, when additional gas condensates or coagulation	• Vehicular emission • Industrial combustion plants and some public power generation • Commercial and residential combustion	• Oxidative stress • Respiratory symptoms such as irritation of the airways, coughing, or difficulty breathing • Decreased lung function and aggravated asthma • Chronic bronchitis • Irregular heartbeat, cardio-pulmonary disorder • Premature death in people with heart or lung disease

[10]

CO	• Produced during normal animal metabolism in low quantities and has some normal biological functions (signalling molecule) • volcanic activity • forest and bushfires	• Exhaust of internal combustion engines, especially of vehicles with petrol engines • Burning of carbon fuels • organic combustion in waste incineration • power station processes • Iron smelting • burning of crop residues	• Persons with heart disease are sensitive to CO poisoning and may experience chest pain • Adverse effects on the foetus of a pregnant woman • Infants, elderly persons, and individuals with respiratory diseases are also particularly sensitive. • Anti-inflammatories, vasodilators and encouragers of neovascular growth
Ozone	Ozone is present in the atmosphere in the stratosphere, in a region also known as the ozone layer between about 10 km and 50 km above the surface	• formed by the reaction of sunlight on air coining hydrocarbons and nitrogen oxides, emitted by car engines, industrial operations, chemical solvents to form ozone • electronic equipment such as photocopiers	• Lung function deficits and respiratory illness • Premature death, asthma, bronchitis, heart attack, and other cardiopulmonary problems. • Ground-level ozone and pollution which interferes with photosynthesis and stunts overall growth of some plant species

Pb	Food (lead is absorbed by plants)	• Waste incineration • Metal processing • Paint Industry • lead solder in food cans, breast milk, drinking water, Cosmetics, ceramic pottery, burning of firewood or kerosene, indigenous remedies, tobacco and tobacco products, contaminated drinking water, toys, industrial effluents, lead acid batteries, ammunition, paints and varnishes, water pipes • Automobile exhaust	• Adverse effects on the central nervous system, the cardiovascular system, kidneys, and the immune system • Causes blood disorders like anaemia and increase in blood pressure • Potent neurotoxin that accumulates both in soft tissues and the bones • Causes nephropathy, and colic-like abdominal pains. • Weakness in fingers, wrists, or ankles. • Miscarriage and reduction of fertility in males, delayed puberty in girls • Permanently reduce the cognitive capacity of children

Source: CPCB (2020). National Ambient Air Quality Status & Trend 2019. Central Pollution Control Board, Ministry of Environment, Forest & Climate Change, Govt. of India

4. Major policy initiatives by the Indian Government

Various initiatives have been taken by the Indian government to control air pollution. The shift over the years can be seen moving towards involving diverse stakeholders, engaging public participation, adopting new clean air technologies, strengthening the monitoring system, creating strategic global partnerships.

One can also see many focussed new schemes/programs that have been created such as Clean Fuel Research Initiative, National Mission for Cleaner Coal utilisation, transition to cleaner fuel, special mission on clean fuel, promoting indigenous clean air technologies, start-ups in this area etc. Many programs have strong central-state synergic partnership, has public-private partnerships, involvement of international organisations/foundations. The major policies that cover the air-pollution mitigation and move towards clean air are:

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

Central Pollution Control Board

One of the key stakeholder of the Government is the Central Pollution Control Board (CPCB), a statutory organization under the Ministry of Environment, Forest and Climate Change. It was constituted in September 1974 under the Water (Prevention and Control Pollution) Act 1974 which was further entrusted with

powers and functions under the Air (Prevention and Control Pollution) Act 1981. It was established with the aim to improve the quality of air and to prevent, control or abate air pollution in the country. The increasing urbanisation, economic growth that has led to increasing consumption driven economy, multi-fold growth of vehicles, etc has had an adverse impact on environment leading to climate change, air pollution, water depletion, etc. CPCB has expanded its scope, programs and policies to address the new challenges. It plays an important and key role in abatement and control of air pollution in the country and active role in generating, compiling and collating data, providing scientific information, rendering technical inputs for formation of national policies and programmes, training and development of manpower and through activities for promoting awareness at different levels of the Government and Public at large.

Among the major initiatives are the NAMP and NCAP. Some salient aspects of these two initiatives and related aspects are highlighted to draw attention to the role they are playing for clean air.

National Air Quality Monitoring Programme (NAMP)

National Air Quality Monitoring Programme (NAMP), started in 1984, is a nation-wide program being executed by the Government to determine the prominence of ambient air quality exposed to three different air pollutants, SO_2, NO_2, and PM_{10} at all locations. The NAMP comprises of 703 manual operating stations in 307 cities of the country. The other parameters like $PM_{2.5}$, Carbon monoxide (CO), Ammonia (NH_3), Lead (Pb), Ozone (O_3), Benzene (C_6H_6), Benzo (a)pyrene (BaP), Arsenic (AS) and Nickel (Ni) are being monitored at selected locations and slowly being added in the monitoring network of NAMP. This program is being carried

out with the help of State Pollution Control Boards (SPCBs), Pollution Control Committee (PCC), National Environmental Engineering Research Institute (NERRI) and Central Pollution Control Board. These agencies are consistently providing technical and financial support for operating the monitoring stations.

National Ambient Air Quality Standards (NAAQS) specify essential air quality levels and the air quality margins for the wellness of lives. One of the important initiatives for air quality evolution is Air Quality Index (AQI) launched by Prime Minister Narendra Modi in 2015. AQI is a tool for transformation of complex air quality data of various pollutants into a single number, to keep people informed about the status of air quality. The Central Pollution Control Board (CPCB) has delivered directions to the implementation of 42 measures to mitigate air pollution in major cities. Environmental Pollution (Prevention and Control) Authority (EPCA) was constituted to look into the pollution in NCR region. Recently, the National Clean Air Program (NCAP) was launched by the government. This program aims at reducing $PM_{2.5}$ and PM_{10} concentrations in 122 cities in India by 20-30% by 2024 compared to the corresponding levels in 2017.

A set of system wide interventions have been introduced by these policies, in order to curb air pollution levels in different areas. These encompass industries (relocation of polluting industries), transport (introduction of improved emission norms for vehicles, phasing out lead from petrol, reduction of sulphur in diesel and benzene in petrol, introduction of cleaner gaseous fuels like CNG, LPG etc., banning of 15-year-old commercial vehicles, restriction of transit fright traffic), and civil activities (banning burning of biomass, promotion of green crackers). Special emphasis has also been given to setting up of monitoring network for assessment of

ambient air quality. Government has also defined the National Air Quality Standards and launched Air Quality Index in different Cities of India.

One recent initiative is the high-tech Air Quality Early Warning System for forecasting extreme air pollution developed by Indian Institute of Tropical Meteorology (IITM), India Meteorological Department and National Centre for Medium Range Weather Forecasting (NCMRWF) under Ministry of Earth Sciences. This system can predict the extreme pollution events and give alerts to take necessary action. To predict air quality at block level, the government has unveiled fastest and first Multi Petaflop supercomputer "PRATYUSH" High Power Computing (HPC) system at Indian Institute of Tropical Meteorology (IITM). System of Air Quality and Weather Forecasting Research known as "SAFAR" has also been introduced by the Government for greater metropolitan cities of India to provide location specific information on air quality in near real time and to forecast 1-3 days in advance for the first time in India, which is combined with the early warning system on weather parameter.

National Clean Air Programme (NCAP)

Government of India initiated this flagship programme in 2019, with the aim for comprehensive mitigation action, monitoring, awareness and capacity building. Under the twenty point NCAP, the government has pledged INR 6370 Million (US $8.66 Million) and it includes monitoring of rural air pollution in addition to the 102 cities. Based on Air Quality data from 2014-2018, NCAP has identified 122 cities as non-attainment cities. City action plans have been prepared for creating a robust ecosystem for monitoring, reducing vehicular/industrial emissions, increasing public awareness etc. Committees at Central and State level for

monitoring and implementation of the city action plan has been created. One important timeline set is 2024 in which it targets 20% to 30% reduction in particulate matter concentration with reference to 2017 parameters. The emission standards have also notified for industries and vehicles (in-use and new), Gensets, etc. They have also started relocation of polluting industries, phasing out older polluting vehicles, introduction of mass rapid transportation, etc. across the country.

Along with these initiatives, use of alternate fuels like CNG, LPG, Bio-diesel, Hydrogen are also promoted. To control the air pollution spread and mitigate its impacts on human health as well as on economy, the potential interventions like urban public transportation facilities, travel demand management, emission regulations for vehicles and power plants, clean technologies, management of road dust, waste management to control open burning, etc have been emphasized.

5. The Smart City Initiative

India has taken a bold initiative towards transformation of cities to Smart Cities. Internet of things (IoT) based Interventions are the core of an effective smart city. Many Indian institutions are actively partnering in this programme i.e. 'Smart City' projects. A new positive development is the entry of technology-based start-ups in this domain. The smart city can help in control of air pollution in various ways.

Box 2: Salient Aspects of India's Smart City Initiative

Smart City mission aims to develop cities that incorporate sustainable development and inclusive innovation to remodel Indian cities with a focus is on e-governance, energy management, urban mobility, digital transformation, waste management, and water management.

There are six holistic key strategic indicators in the pathway to becoming a truly smart city are: Smart Government, Smart Economy, Smart Environment, Smart Living, Smart Mobility, and Smart people. In India, the smart city concept is based on six fundamental principles: Community at the Core; More from Less; Coorporative & Competitive Federalism; Integration, Innovation, Sustainability; Technology as means, not the Goal; Convergence.

It calls for integration of different technologies in a seamless ecosystem for governance and service delivery. The smart city framework is being seen as an enabling ecosystem that would provide new opportunities for citizens. It is also promoting renewable sources of energy (mainly solar) which is already leading to reduction in the emissions from households, large establishments (industry and office buildings) and vehicular exhausts.

Technology driven approach for development of infrastructure is enabling start-ups in waste management, for example start-ups are processing municipal solid waste through automated systems, Power Grid management is programmed through Data Analytics, sustainable transportation systems are being developed, electric vehicles and efficient pollution control measures are being adopted.

Smart Solutions for pollution control under the Smart Cities Mission		
Energy Management	Waste Management	Urban Mobility
• Smart Meters & Management • Renewable Sources of Energy • Energy Efficient & Green Buildings	• Waste to Energy & fuel • Waste to Compost • Waste Water to be Treated • Recycling and Reduction of C&D Waste	• Smart Parking • Intelligent Traffic Management • Integrated Multi-Modal Transport

➢ More information on Smart cities mission can be found at https://smartcities.gov.in/

As it is seen, use of technology in novel ways can provide effective solutions to air pollution. IoT can significantly make a major difference IoT refers to the network of everyday objects (also called "things") connecting intelligent sensors that exchange information about themselves and their surroundings (Atzori et al. 2010, Bhattacharya et al. 2020). There are many systems based on IoT technologies for measuring and management of environmental pollution in cities to develop smart solutions (Munera, 2021). In this context, several proposals have come to light targeting different aspects of the problem. For instance, air pollution monitoring in a smart city helps to improve health in citizens when alerts are created if the contamination overpasses a specific threshold. Smart devices constitute a key component of the IoT technology, thus allowing the connection of objects over existing networks. They aim at enhancing city operations (such as transport, healthcare, education, water, communication, and energy) and competitiveness, in order to improve the quality of life and wellbeing of citizens. Smart cities use IoT technology to connect a city in an intelligible way with minimal human intervention, while assuring that present and future generations have resource availability, where cities' resources have to be optimally managed. India's policy articulation on IoT has this vision. CPCB and other stakeholders need to create task force that can bring this novel technology-based intervention in pollution control.

6. Sector Specific Challenges and Interventions

6.1 Transportation

The transport sector accounts for more than 16 percent of total carbon equivalent emissions and over 33 percent of the PM pollution. Promoting greater use of public transport, improved vehicle fuel efficiency, developing proper highways and roads, etc.

can help in significant reduction of air pollution. The large increase in vehicles have become a major contributor to air pollution. In 2020, India was world's fourth largest vehicle market with the sale of 26.3 million vehicles. India adopted a number of new standards and rules to reduce the level of pollution from the transportation sector. The BS-VI (Bharat Standard) norms for vehicular and fuel emission standards were adopted in 2020. The changes introduced by these include cleaner fuel with ultra-low sulphur content (10 ppm) from the 50 ppm permissible limit under BS-IV standards, a reduction of 40 percent in PM and 43 percent in NO_x emissions from automobile engines over the previously effective BS-IV standards. The National Policy on Biofuels had been announced in 2018, and aims to achieve 20 percent blending of ethanol in petrol and 5 percent blending of biodiesel in diesel by 2030. Additionally, a national electric mobility mission plan 2020 has also been introduced and it aims at increasing the adoption of electronic vehicles. The target of the government is to have a complete ecosystem of E-mobility by 2030, enabling a share of more than 30 percent for the electric vehicles among the total. This however is an area where numerous challenges are to be addressed. These include technology (accessibility and high prices of components such as battery, its import and manufacturing), Infrastructure (charging stations affordable and compatible to both AC and DC charging), Resource availability (lithium and cobalt are the two essential elements of lithium batteries and the prices of these metals is rising rapidly due to increased demand), Disposal of end of life batteries (a lack of recycling facilities in India means that almost all the batteries mainly lithium ion, end up in landfills or dump sites. The larger batteries used in vehicles are estimated to account for 90 percent of the lithium-ion battery market by 2025 and pose a major recycling challenge for the world).

6.2 Agriculture

The Indian Agriculture sector has been at the center of discussions regarding the air pollution and climate change. The various factors that contribute to the worsening of air quality due to agricultural activities include, seasonal burning of crop residues, emissions of greenhouse gases such as methane (CH_4), Ammonia (NH_3), Nitrous Oxide (N_2O) and Carbon Dioxide (CO_2) from farming and/or cattle rearing. As the population grows, the requirement of improved land productivity, alongside reduction in the overall carbon footprint will become more important. Significant changes are required in agricultural for sustainable growth.

Box. 3: Government Action Plan against Crop residue burning

In 2014, Government formulated the national policy on residue burning namely 'National Policy for management of Crop Residue (NPMCR)' with the following objectives:

• Control of burning of crop residue to prevent environmental degradation and loss of soil nutrients and minerals by promotion of in-situ management (incorporation in soil, mulching, baling/binding for use as domestic/industrial fuel, fodder) of crop residue;

• Diversified use of crop residue for various purposes like charcoal gasification, power generation, as industrial raw material for production of bio-ethanol, packing material, paper/board/panel industry, composting and mushroom cultivation etc.;

• Capacity building and awareness about ill effects of crop residue burning and its effective utilization and management; and

• Formulation and implementation of suitable law and legislative/policy measures to curb burning of crop residue

As per the NCAP report[3] of 2020, burning of crop residues can contribute to a rise of 70 percent in carbon dioxide concentration, 7 percent in carbon monoxide and 2.1 percent in nitrogen dioxide. The smoke from burning of crop residues at the onset of winter (after harvesting Kharif crops) in areas surrounding the national capital gets carried to along with the prevailing westerly winds, which converge around Delhi due to low pressure zone. As the problem has worsened in past decade, stronger steps are being taken by the state and national government to reduce the practice of burning and promote alternative methods of value addition. A blanket ban on burning has socio-economically disruptive effects and hence has proven ineffective in past few years. A set of non-disruptive management solutions are being explored. A new central sector scheme on 'Promotion of Agricultural mechanization for in-situ management of crop residues in the states of Punjab, Haryana, Uttar Pradesh and NCT of Delhi' for a period of two years was implemented and a sum of INR 11,518 million (US $156.53 million) was invested in the scheme. The financial assistance provided under this scheme focused on the setting up of farm machinery banks, for custom hiring of the equipment and for processing of crop residues. Products such as Prali-Char, bio char, pellets, briquettes, bioCNG, bioethanol, as alternate fuels for brick kilns, Industrial boilers, paper and packaging, coal fired thermal power plants and transport sector etc. is also mandated under the 2014, National Policy for Management of Crop Residues.

Many alternative technology-based solutions are being tried such as Pyro former- a waste to energy technology developed by European Bioenergy Research Institute (EBRI) researchers.

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[3] National Clean Air Programme, Ministry of Environment, Forest & Climate Change Government of India, 2019

Other available solutions (e.g., PUSA Decomposer - a composting kit developed by Indian Council of Agricultural Research's - Indian Agriculture Research Institute (ICAR-IARI)) rely on biochemical processes and have been promoted in the last 2 years with little to no data on their real-world impact. Although, these are positive steps towards better management of crop residues, burning is still the dominant stubble management practice and requires interventions to reduce its impact.

Box 4: Possible solutions to reduce agricultural emissions

Many innovative solutions have been proposed to reduce stubble burning. Some researchers have called for crop diversification, conversion of stubble into value added products, etc. In exploring crop diversification, use of alternative crops instead of only restricting to rice cultivation in North India is one of the disruptive proposal that can have a major impact if implemented. The rationale behind this is that rice cultivation leads to large stubble left to burn. One of the main alternatives is maize, which requires 90% less water and 70% less energy than rice and stubble does not remain after sowing. This can lead to both economic and climate benefits. This has already been experimented in 116 farms by International Maize and Wheat Improvement Centre, Punjab State Agriculture Department. Such diversification has been proved to yield extra two quintals of wheat yields per acre, when sown after maize. Alternate crops like Tur dal and soybean are also being explored. However, it is important that any solution must look deeply into the socio-economic impact as disruptive solutions can make transitions for many difficult to implement. Few agricultural practices like seed planting instead of seedlings possibly reduce methane emissions.

Some studies have also called for significant shift in the agricultural crop pattern for reducing air pollution (Box 4). New Approaches for large scale implementation require socio-economic studies and also a critical assessment of long-term effect of implementing.

A recent database from SAFAR revealed that in the case of Delhi, stubble burning contributed to 8% of the $PM_{2.5}$ concentration levels during 30th October 30 to 3rd November 2021, which increased to 30% between 9th and 13th November 2021. In the last week of November, $PM_{2.5}$ emissions from stubble burning were 4%. As per the satellite data, after the second week of November, the number of farm fires reduced each week. This again confirms that aside from stubble burning, meteorological conditions play a significant role in increasing the pollution levels.

We argue that for effective deployment of any new measure, foresight study need to be done in a systematic manner and should be integral to the implementation plan. Pilot studies with proper assessment should be done before scaling up.

6.3 Industry

Manufacturing and construction are major industries that are contributing towards air pollution in large scale. Volatile organic compounds (VOCs), hazardous air pollutants (HAPs) and solid particulate matter (PM) are some major pollutants that is generated by the manufacturing industries. The manufacturing sector may reduce air pollution by switching to clean energy sources, use of technology interventions, use of non-toxic materials to manufacture the goods etc. International Institute for Energy Conservation (IIEC) is helping two Indian states-Gujarat and Odisha to build air quality monitoring and tracking capacity among government, industrial and utility partners and deliver cost-

effective air pollution reduction strategies. CPCB has developed 'Range of pollution Index' for classification of Indian industries. The industries having Pollution Index Score of 60 and above in listed in Red category. The industries having Pollution Index Score between 41 to 59 and above in listed in Orange category; Industries having Pollution Index Score between 21 to 40 are listed in Green category; while Industries having Pollution Index Score up to 20 are listed in White category. This is very useful index. It helps to map the industries that are contributing to high pollution and can also help policy/decision makers in policy planning. *More macro-level indications within each industry particularly those in Red category will further help in directing action*. Orange category indicate that these industries are contributing to maximum pollution and so need strong corrective action. Further delineation would show within them which industry(s) would need the strongest regulatory action.

7. Clean Fuel Initiatives

India's demand for fossil fuel has tripled between the years 2009–2019 and thus the energy consumption from coal has increased. The fossil fuel being the largest contributor of CO_2 has reached 1 billion tonnes in 2010 and is steadily increasing. In long term, the aim of the government is for replacing coal combustion with less polluting fossil fuels and eventually with renewable energy sources, improving the characteristics of coal vial coal washing and briquetting. The Environment (Protection) Amendment Rules, 2015 stipulated standards for various emissions (Table 4). These rules mandate upgrading the thermal power plants by December 2022. The government also is exploring the possibilities of utilization of Flash from TPPs (Thermal Power Plants) in efficient manner. Switching to cleaner fuel alternatives for residential

cooking in both urban and rural areas, particularly LPG is found to be a promising approach for energy production in India. Such schemes are implemented via providing subsidy for LPG by the Indian Government. This initiative resulted in the doubling of LPG cylinders between 2009 and 2018.

7.1 Adoption of Renewable Sources of Energy

The government has put special focus on renewable energy and cleaner fuels for power generation. India aims to generate 175GW of energy from renewable sources (100GW from Solar). The ministry of new and renewable energy (MNRE) has proposed that this be achieved through installation of medium scale solar projects (60GW) and rooftop solar projects (40GW).Many government schemes have been implemented to promote the use of Solar Energy. The International Solar Alliance co-launched by India and France is one such strategic partnership where the mission is to provide dedicated platform for cooperation among countries with high potential to tap into the solar energy. On national level, the schemes such as providing subsidies for installation of solar panel-based energy systems, increasing the pan India penetration of cleaner fuels, promoting manufacturing and use of hybrid and electric vehicles etc. are direct measures being taken by the government.

Investments in India's renewable power sector have steadily risen in recent years, reaching almost USD 18 billion in 2019. By August 2020, utility-scale solar PV installed capacity reached nearly 33 GW while wind stood at 38GW (MNRE 2020). The Institute for Energy Economics and Financial Analysis (IEEFA) 2020 report cites record-low solar power tariffs, plunging solar module costs, record-low interest rates, and the security of government-backed, 25-year power purchase agreements (PPAs)

among factors making the renewables investment in India particularly attractive.

Table 4: The Thermal Power Plants emission standards under Environment (Protection) Amendment Rules, 2015.	
Parameter	**Standards**
TPPs (units) installed before 31st December, 2003	
Particulate Matter	100 mg/Nm^3
Sulphur Dioxide (SO_2)	600 mg/Nm^3 (Units smaller than 500 MW capacity units) 200 mg/Nm^3 (for units having capacity of 500 MW and above)
Oxides of Nitrogen (NOx)	600 mg/Nm^3
Mercury (Hg)	0.03 mg/Nm^3 (for units having capacity of 500 MW and above)
TPPs (units) installed after 1st January, 2003, up to 31st December, 2016	
Particulate Matter	50 mg/Nm^3
Sulphur Dioxide (SO_2)	600 mg/Nm^3 (Units smaller than 500 MW capacity units) 200 mg/Nm^3 (for units having capacity of 500 MW and above)
Oxides of Nitrogen (NOx)	300 mg/Nm^3
Mercury (Hg)	0.03 mg/Nm^3
TPPs (units) installed after 1st January, 2017	
Particulate Matter	30 mg/Nm^3
Sulphur Dioxide (SO_2)	100 mg/Nm^3
Oxides of Nitrogen (NOx)	100 mg/Nm^3
Mercury (Hg)	0.03 mg/Nm^3

Sources: Ministry of Environment, Forest and Climate Change notification dated 7 December 2015.

Clean Coal Research and Development Centre that has been established at Indian Institute of Science[4], one of the leading universities in India by the Department of Science and Technology. Recently, India has joined hands with USA to explore clean coal technologies and collaborate on "advanced high-efficiency coal technologies with low-to-zero emissions" through carbon capture, utilization and storage (CCUS). The US DOE's National Energy Technology Laboratory pointed out that the clean coal can be achieved if the coal plants implement proper pollution control measures. The new coal plant to be developed through this collaboration is aimed at reducing NO_x, SO_2 and $PM_{2.5}$ by 83%, 98% and 99.8%, respectively.

In India, energy consumption for transport has almost doubled in a decade, with a maximum of 62% accounting for diesel oil consumption. High speed diesel oil contributed about 39.3% of total consumption among all types of petroleum products. This fuel consumption growth rate is an alarm for peak in NO_x and soot emissions. There are several characteristics affecting the NO_x and PM emissions from diesel transport. One important among them is fuel sulphur content, which is directly related to PM emission. India has already reduced the sulphur content in diesel engines from 10,000 ppm in 1999 to 50 ppm in 2017 by BS-IV emission norms. The estimated average on-road sulphur content in diesel engines is 16-50 ppm in 2019. With the implementation of BS-VI emission norms from April 2020 onwards, at fuel stations only low sulphur fuel that complies with BS-VI standards are sold. This is expected to reduce the sulphur content to 10 ppm nationwide and reduce the vehicular emissions significantly.

[4] DST, National Centre for Clean Coal Research & Development at IISc Bangalore, 2020

7.2 Green-house gas (GHG) reductions

India is the third largest country emitting greenhouse gases after China and USA. The energy intensity from coal power plants, which is the most intensive energy-carrier and agriculture burning has resulted in high emission levels, with an increase of CO_2 emissions to 335.33% since 1990 (World Energy Outlook, 2018) In order to pledge with the Paris agreement, India has set independently 'Nationally Determined Contributions (NDC) which embodies sustainable lifestyles, cleaner economic development, reducing emission intensity of gross domestic product, increasing the share of non-fossil fuel based electricity, enhancing carbon sink, adaptation and mobilizing finance and green technology transfer and capacity building (MoEFCC). Unlike other countries, India's NDC has a strong focus on climate change adaptability. The adaptation strategies aim at providing potential alternatives to reduce air pollutants and improve air quality, even with climate change. Greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs) and hydrofluorocarbons (HFCs) are currently declared as priority air pollutants. Besides these gases, nitrous oxide (N_2O), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) are extremely potent and persistent greenhouse gases which are widely used in many applications and should be declared as priority air pollutants. As implemented by South African government, manufacturers involved in the production processes of these gases should submit pollution prevention plans to the Government and undertake regular monitoring and evaluation of such plans (National Environmental Management: Air Quality Act, 2004). A third-party should be involved in verification of this and provide report to the government on a quarterly basis.

The diesel vehicle exhaust is an important source of Black Carbon (BC) emissions, which is a potent greenhouse gas. Studies show

that HDVs are responsible for 78% of BC emissions on road. Since the BC emissions have adverse effects on climate, reducing BC emissions from older technology diesel engines will be a key factor to avoid 0.5˚C of additional global warming in the next 25 years.

Box 5: Climate Change influenced by Air Pollution

The influence of air pollution on climate change is pervasive. Some of the key aspects that have emerged from various multilateral discussions on climate change are highlighted. In these frameworks/action plans air pollution has been flagged as one of the key contributor to climate change.

-The UN Framework Convention on Climate Change (UNFCCC), aims to prevent "dangerous" human interference in the climate system and recognizes human activities are the major contributors of climate change.

- The first COP (COP1) laid the foundation for Kyoto Protocol. It emphasised the countries to strengthen the measures to reduce greenhouse gas emissions.
- The COP3 urged countries to reduce emissions by an average of 5 percent and a carbon market called "cap and trade" was created to encourage sustainable development.
- The COP15 came up with a non-binding document which acknowledges that the global temperatures should not increase by 2^{o}C above the preindustrial levels.
- In COP16, the Green Climate Fund of USD 100 billion was established to assist developing countries in climate change mitigation and adaptation.
- The Paris agreement which is the most significant climate agreement was signed by 196 countries. Its mission is to keep global temperature rise below 2^{o}C and undertake efforts to keep it below 1.5^{o}C.
- The 6th IPCC report was released which warns that the world will reach or exceed 1.5^{o}C of warming within the next two decades, even if the countries act immediately to reduce emissions.

- The COP26 held in Glasgow, brings together the NDCs of several countries in accordance with the Paris agreement and several countries like USA, India etc. have agreed to cut the emissions with target to achieve zero-emission. Few significant plans proposed are ending fossil fuel subsidies, accelerating action to keep the target of 1.5°C, phasing out of coal, promoting carbon financing, ending of deforestation, a 45% emission cut by 2030 when compared to the 2010 levels, and build coalitions of technical know-how support including developed countries and financial institutions.

Revised stricter standards for pollutants			
WHO Standards (µg/m^3)			
Pollutant	**Average**	**2005**	**2021**
$PM_{2.5}$	Annual	10	5
	24-hour	25	15
PM_{10}	Annual	20	15
	24-hour	50	45
O_3	Peak season	-	60
	8-hour	100	100
NO_2	Annual	40	10
	24-hour	-	25
SO_2	24-hour	20	40
CO	24-hour	-	4

8. Specific policies for clean air synthesized from international learning

India is member of different multinational environmental agreements which include Paris Agreement on Climate Change, United Nations Framework Convention on Climate Change (UNFCCC), Climate and Clean air coalition. These agreements complement each other underscoring the broad aim of adopting leaner energy sustainable

production, translation towards environment friendly transport, agriculture, waste management, etc.

These treaties and policies on climate change and clean air mainly focussed on the measures to preserve environment, improve air quality, health and socio-economic development. India is the third largest country emitting greenhouse gases after China and USA. The energy intensity from coal power plants, which is the most intensive energy-carrier and agriculture burning has resulted in high emission levels, with an increase of CO_2 emissions to 335.33% since 1990 (World Energy Outlook, 2018). India's NDC has a strong focus on climate change adaptability. The adaptation strategies aim at providing potential alternatives to reduce air pollutants and improve air quality, even with climate change.

Box 6: Methane – A potent short-lived climate forcer

India is the third largest country of methane emissions. The high concentration of methane in the atmosphere is due to human emissions and it leads to the second-most radiative forcing effect after CO_2. As per the Global methane budget 2020 (Saunois et al., 2020), methane is 28 times as that of CO_2 in causing global warming. Since, methane is a short-lived climate pollutant, methane emission reduction results in short-term climate benefits. Hence, setting up a separate target for methane emissions reduction is important within the NDCs of countries. Several cost-effective control technologies and daily practices can be utilized to reduce methane emissions to certain extent. For instance, methane emissions can be effectively controlled by reducing the food waste and producing greenhouse gas intensive foods. The UNEP suggested that proper management of livestock manure, solid waste and waste-water may lead to considerable reduction in methane emissions. In the global methane challenge program, in Indian context, IIT Delhi has set up Biogas Development and Training Centre in 2008 in support from the Ministry of New and

Renewable Energy. This centre supports R&D in biomethanation, and developed efficient methane emission reduction technologies. In the same year, India has also established Coalbed methane (CBM) clearing house to contribute to the commercial development of CBM. As India relying upon the livestock and plants for dietary sources, reducing the methane emissions from livestock and agricultural wastes, by transforming these wastes into fuel will provide scope to reduce methane emissions.

Box 7: UNECE Convention

- Since air quality and climate change have direct impact on each other, the climate change treaties and conventions have also integrated air pollution abatement measures; the first international treaty of this kind was the United Nations Economic Commission for Europe (UNECE) convention.
- Cross-border environmental issues between different countries have been a challenge to resolve combat both air pollution and climate change relevant to such issues, UNECE Convention on Long-Range Trans boundary, Air-pollution (LRTAP) was proposed in 1979 (E. Moses. et al., 2020)
- The convention was signed by 51 countries including 32 European countries, USA and Canada. Though, the convention is less emphasized, it has played a significant role leading to cleaner air and conservation of forests and lakes in North America.
- The convention also aided in preventing over 600,000 annual premature deaths in Europe; case studies in Europe and North America reveal that the convention reduced the particulate matter and sulphur emissions by 30 – 80% and 30 – 40% in Europe and North America, respectively, since 1990.

- The treaty incorporates both urban and non-urban sources as effective contributors to air pollution and provides relevant scientific tools, models, data and best international practices to address air pollution even at local level. In contrast to other convention on climate change and air pollution, the LRTAP engages both scientists and policy makers on the same board to involve in decision making.

The war on air pollution calls for countries to collaborate and learn from each other. A close-reading of various policy measures of different countries draw attention to some useful approaches to tackle air pollution. These policy measures can be revisited in the Indian context to see whether they can be implemented. The important initiates of different countries are highlighted below.

- As early as 1970, USA created a comprehensive federal law 'The Clean Air Act (CAA)' which is implemented by its Environmental protection Agency (EPA). This law has given statutory authorisation to EPA for establishing National Ambient Air Quality Standards (NAAQS), among others. CAA has been suitably modified over the years to address new challenges due to air pollution. Achieving real and measurable air emission reductions is one of the major goals of the EPA (EPA, USA). Greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs) and hydrofluorocarbons (HFCs) are currently declared as priority air pollutants. Some novel initiates have been undertaken by the USA in recent years. Among them is the implementation of 'Clean Air Technology Center' by the EPA. This acts as a resource base for prevention and control of air pollution, control technologies available, provides access to public access

to these resources, the use, effectiveness and cost of pollution prevention control technologies, provides support to government agencies technical and economic feasibility, operation and maintenance of control technologies.

- South African government, manufacturers involved in the production processes of these gases should submit pollution prevention plans to the Government and undertake regular monitoring and evaluation of such plans (National Environmental Management: Air Quality Act 39 , 2004.)
- Beijing which was the most polluted city in 2013 and in 2017, has been able to reduce particle pollution by 33%. This reduction was achieved by the rigorous action of Chinese government which imposed ban on coal heating and usage of natural gas was promoted countrywide (The World Bank, China, 2020).
- The promotion of clean technology has already been implemented in Brazil by providing land charge discounts for water recycling, waste reduction and renewable energy use. This exponent of international green building standards by the Brazilian government has attained considerable success in urban areas of Brazil (Andrade et al. 2017). As an efficient process of waste management, in 2018, the Brazil Government has shut down its mega dump outside Brasilia covering more than 300 acres of waste.
- Indoor air pollution in developing countries has become a major threat to environment and health. (Bruce et al. 2000). To reduce the air pollution to a considerable extent in household and work environments, the government should provide access to sustainable energy resources to the public. These may include the use of electric energy instead of gasoline-powered generators, usage of biogas for cooking and heating purposes,

removal of waste from households on a daily basis and their proper disposal etc. Such environmentally friendly procedure has already been practiced in the largest African country Nigeria to reduce indoor air pollution (Dopheide, 2019).

- All vehicles and engines must abide by emission standards for specific pollutants, including smog, soot and greenhouse gases. This will thereby improve fuel efficiency and reduce emissions in newer vehicles. Installing air filtration systems in areas with high levels of pollution may assist in reducing exposure to toxic air. However, installing such systems is cost effective and requires funding from the government, industries and also individuals. The currently followed pollution check for vehicles should be restricted more. If this pollution check is properly done, then there is a great chance of reducing the pollution to some extent. The pollution check should be renewed for every six months and each vehicle should be monitored to follow this rule. Public should be given the responsibility to report to the government if they find any vehicle emitting smoke. In order to reduce the emissions and the age of the vehicle fleet and to improve air quality, the Government of Peru reduced the maximum age for the import of the vehicles from five to two years and created scrap bond programme to provide incentives for citizens to scrap old vehicles that are causing pollution. This program is estimated to result in recycling of around 10,250 vehicles between 2021 and 2030.
- Unlike other pollutants, tropospheric ozone is a secondary pollutant which is difficult to control via normal regulations. A strategic approach is highly required to control ozone pollution. European, USA and Chinese governments set a threshold of 60 parts per billion (ppb), 70 ppb and 75 ppb.

- Reducing the effects of acid deposition caused by acid rain which leads to stratospheric ozone depletion should be given considerable importance. The sulphur compounds resulting from the acid rain do travel long distances in the atmosphere and the air quality is affected not only within the country but also across the borders. The Scandinavian countries have proposed major projects on preventing the trans boundary transport of air pollution that needs collaboration across international borders (Grennfelt et al., 2020).

9. Disaster Management Plan

In India, Air pollution is fast emerging problem resulting in a significant number of fatalities. An estimate by The Lancet commission on pollution and health in 2015, highlighted that globally nearly 9 million premature deaths were caused due to air pollution. In these, India had the most in any single country, more than 2.5 million of these deaths. Cities have long been the engines of economic growth across the world, as they are the "crucibles of new ideas and innovation". This leading economic role comes at a toll of rising air pollution and perhaps require new technologies and solutions which employ the same level of innovation and inventiveness to address urban air pollution in an urgent manner (Bhatt, 2018).

The air pollution in India, should be considered as a disaster as the risk to the health of the residents in cities is continuously rising. In the traditional sense, any cataclysmic event which happens suddenly leading to an immediate loss of life and property is considered as a Disasters. Certain disasters, however, are more insidious, but have the same sort of impact. In this respect, Air pollution leads to a slow but widespread loss and the damages caused by it extend over a long period of time. As a result, even

with abysmally low quality of air (see figure 1), citizens have to live and work in such polluted environment putting their lives at risk every day. There is an urgent need to explore the possibilities for considering air pollution as a disaster in India. It is hypothesised that if the situation is to improve, National Disaster Management Authority (NDMA) has to start taking up sustained vigilance of this fast-spreading hazard across Indian cities and employ mitigating measures.

As an action learning programme with officials and NGOs, the National Disaster Management Institute (NIDM) has qualified teams to tackle this rising risk in India not only by defining poor air quality as a disaster, but also by designing action learning programmes with them. As Mami Mizutori of the United Nations Office for Disaster Risk Reduction (UNISDR) noted at AMCDRR 2018[5] at Ulaanbaatar in Mongolia, we need more data on losses and damages resulting from disasters as well as losses and damages avoided due to risk reduction in Asia. This need for data is even more urgent with respect to the risks related to air quality in India. The need to share data on the stakeholder level is urgent and requires innovative interventions for enabling air quality improvement. One such intervention is being done by the Natural Resources Defense Council (NRDC) of the USA, which has started its initiatives in Ahmedabad and other cities in an effort to reduce the impact of air pollution on daily lives of the individuals[6].

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[5] Asia Regional Plan for Implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030, Asian Ministerial Conference on Disaster Risk Reduction, (2018), Ulaanbaatar, Mongolia

[6] Blog entitled "Highlighting City Actions to Reduce Air Pollution in India", by Anjali Jaiswal, Kim Knowlton & Vijay Limaye

So far, Action plans, policies, schemes, and even penalties have not succeeded in reducing pollution levels in India. Do we have no other option but to use face and surgical masks in the near future? It is important that more sustainable and prudent steps are taken. Some such steps include effective policy implementation to promote cleaner energy generation options, a greater use of public transport, stringent workplace regulations to reduce the individual carbon footprint, etc. (Upmanyu, 2018).

10. Recommendations and Policy Suggestions

In spite of several initiatives by the government, and other stakeholder's still air pollution is showing alarming trends. As highlighted, 22 cities out of 30 world most polluted cities are in India (WHO, 2020). There is need of more effective implementation of S&T interventions, strategies and policies to tackle the air pollution problem. Though the national standards for emission and air quality are already existing, mechanisms and procedure to comply with the ambient air quality standards must be made publicly available. Such mechanisms may include determining the priority pollutants and their main sources, developing quickest means of control strategies by involving common public and measurable air emission reductions. Nitrous oxide (N_2O), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) are extremely potent and persistent greenhouse gases which are widely used in many applications and should be declared as priority air pollutants. Aside from the policies, the first thing is the responsibility of the individuals to contribute to the mitigation of air pollution through various ways such as reduction of energy consumption in transportation, households etc. Citizen groups can

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(2019).https://www.nrdc.org/experts/vijay-limaye/highlighting-city-actions-reduce-air-pollution-india

play an important role in this regard. More specifically we draw attention to the issues we have raised in this discussion paper which we argue can provide a more constructive and viable approach for making our Air clean.

- Air pollution has to be recognised as a disaster and should be in the ambit of National Disaster Management authority whenever the limits cross dangerous levels.
- Regular monitoring of air quality in Indian cities is required. Though the national standards for emission and air quality are already existing, mechanisms and procedure to comply with the ambient air quality standards must be made publicly available. Such mechanisms may include determining the priority pollutants and their main sources, developing quickest means of control strategies by involving common public and measurable air emission reductions. This procedure should aid in real and measurable air emission reduction.
- Many solutions for clean air are not technology solutions as such. They need to be interfaced with socio-economic aspects and involve citizen/citizen groups. Straw burning for example needs a more holistic approach that can lead to a permanent solution. Thus, it is important that bodies like CPCB develop stronger interfaces with institutions that work on socio-economic aspects and look at solutions that are only technology solutions.
- A revision in NAAQs is necessary as the current standards which were last revised in 2009 did not result in effective air pollution control. The current standard for PM2.5 is eight and four-fold higher than the WHO standards for 24 hour and annual exposures, respectively. Stringent NAAQs should be introduced.

- The current mechanism of air quality monitoring should be expanded to rural areas as well. In both urban and rural regions, regular monitoring of air quality should be done. The areas where the AQI exceeds should be declared as pollution hotspots and immediate action plan to control air pollution should be followed. The action plan should prioritise the measures that specifically targets improvement in the air quality in the particular hotspots. The air quality monitoring stations should be located on congested areas in order to provide reliable local data.
- Aside from standardisation techniques to monitor air pollution, implementation of air pollution prevention techniques should be envisaged to improve the air quality. For this, regional air pollution prevention and control programs should be developed by providing technical and financial support to the State governments.
- The current monitoring and assessment of air quality should be improved by incorporating the information of deposition of pollutants and the indicators used. This information should be made available to the public.
- Establishing "Clean Air Technology Center" in regions of high pollution may serve as a good initiative to reduce air pollution to some extent. Such centers may aid as resource centres to control air pollution prevention technologies like implementation and efficiency. To start with, controlling in smaller means can be implemented. For instance, a combustion and gasification systems can be installed in the centres to generate clean gas without significant investment in gas cleaning. In particular, municipal solid waste can be converted to clean gas by these systems. Likewise, many other basic technologies should be installed in clean air technology centers.

Such centers have already been installed by EPA in USA and have proved to result in good outcome. The legislation for supporting clean and green technologies to preserve air quality should be enforced and incentives should be provided to the emerging clean technology industries.

- Mapping of city-wise major sources of Air pollution. The highly polluted areas should be declared as air pollution management areas and preference should be given to control the emission sources in such areas.
- Emphasis should be laid to reduce the ozone threshold level to at least 80 ppb. One of the key strategies is to establish regional monitoring networks in many stations and making use of skilled manpower to maintain the equipment. Technological innovations in each sector to reduce ozone pollution should be largely encouraged.
- Impose emission limit values for SO_2, NO_x and CO emitted from large combustion plants and incinerators and also emission limit values should be provided for technologies used as well.
- The government should enforce a legislation to prohibit the use of coal at least in some industrial and household applications. The financing for clean energy through innovative financing may be provided by the government to increase energy efficiency and expand clean energy.
- All vehicles and engines must abide by emission standards for specific pollutants, including smog, soot and greenhouse gases. This will thereby improve fuel efficiency and reduce emissions in newer vehicles. Installing air filtration systems in areas with high levels of pollution may assist in reducing exposure to toxic air. However, installing such systems is cost effective and requires funding from the government, industries and also

individuals. The currently followed pollution check for vehicles should be restricted more. If this pollution check is properly done, then there is a great chance of reducing the pollution to some extent. The pollution check should be renewed for every six months and each vehicle should be monitored to follow this rule. Public should be given the responsibility to report to the government if they find any vehicle emitting smoke.

- Unlike other pollutants, tropospheric ozone is a secondary pollutant which is difficult to control via normal regulations. A strategic approach is highly required to control ozone pollution. European, USA and Chinese governments set a threshold of 60 ppb, 70 ppb and 75 ppb, whereas in India the ozone threshold level is 100 ppb. Emphasis should be laid to reduce the ozone threshold level to at least 80 ppb. One of the key strategies is to establish regional monitoring networks in many stations and making use of skilled man power to maintain the equipment. Technological innovations in each sector to reduce ozone pollution should be largely encouraged.
- Review of Air quality management options from national to regional scale.
- Need of Effective Collaboration between inter-state and inter-ministerial for formulation of policies and implementation
- More Scientific studies on impacts of air pollution on health of human, environment and the ecosystems and need greater public awareness of the problems and action to be taken.
- India needs actionable, implementable polices that are based on good assessment of pollution levels and sources. There should not be one all policy but should be decentralised from national to state level, district level and even town level.
- Need to secure greater public awareness of the problems and commitment to action at civic, commercial, and political levels.

- To ensure that action to tackle air pollution is seen in the context of wider social and economic development policies.
- Investing in green-belt development so that more and more trees are planted at the road side as well as building more green buffer zones. Promote green infrastructure in urban areas and rely on nature-based solutions. This can be achieved by planting trees which emit Volatile Organic Compounds (VOC) and pollens in fewer amounts and preventing the source as well as formation of chemical species that are sensitive to air pollution.
- Improving the public transit system (accessibility, frequency and quality) and implementing clean energy efficient transportation (electric vehicles, clean fuel policy etc.) Upgrading or replacing or scrapping of the old polluting vehicles. Expand the usage of zero emission vehicles in mega-cities.
- Projects on trans-boundary air pollution should be initiated in India and more funding for emission inventories, acid deposition accompanied by modelling studies for the assessment of transport should be provided.
- Better enforcement of law and stricter monitoring of industries by strengthening pollution control boards.
- There is need to take campaign like 'War Against Pollution' for fight with air pollution.
- Increase transparency in government reporting of air quality statistics. Built a nationwide network of air pollution monitors and makes the data publicly available.
- Prohibit new coal-fired plants in the target regions and create measures and support system so that existing coal plants can reduce emissions.

- Increase renewable energy generation and use and furthermore increase energy efficiency and access to cleaner, affordable and reliable fossil fuel technology. The government should invest on providing access to renewable energy sources for daily needs. Further, the public should be advised to limit the use of aerosol spray products, paints and solvents that contribute to smog and as suggested by WHO, water-based products should be used rather than oil-based products.
- Sustainable practices towards achieving circular economy, where the materials produced can be reused, recycled or recovered should be promoted among the manufacturers as well as consumers to reduce waste generation and specially to prevent greenhouse gas emissions. Audit mechanism can be created in this regard with industries also evaluated to what extent they include these mechanisms in practice.
- Indian government has taken a bold initiative of Smart City project. IoT is embedded as the driver in transformation of cities to smart city. Smart city underscores air pollution control, mitigation and overall move towards clean air as one of its underlying objectives. CPCB and other stakeholders involved in air pollution measurement, control, mitigation need to adopt the new technologies like IoT more vigorously and link more strongly with smart city projects.

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CSIR-National Institute of Science Communication and Policy Research (CSIR-NIScPR)

CSIR-NIScPR is a constituent laboratory of Council of Scientific & Industrial Research, under the aegis of Ministry of Science & Technology, Government of India. The new Institute was formally announced on 14 January 2021 by then Hon'ble Minister for Science & Technology and Earth Sciences Dr Harsh Vardhan by merging the two very well recognized institutes namely CSIR-National Institute of Science Communication and Information Resources (CSIR-NISCAIR) and CSIR-National Institute of Science Technology and Development Studies (CSIR-NISTADS). Prof. Ranjana Aggarwal is the founder Director of this new institute.

The institute is guided by the following vision and mission:

Vision: To become a globally respected think-tank and resource center for undertaking Science, Technology & Innovation Policy Research and Science Communication.

Mission: to promote STI policy studies and science communication among diverse stakeholders and act as a bridge at the interface of science, technology, industry and society which is essential to a robust S&T ecosystem in the country.

NIScPR mandate/activities will be covered under the following broad domains:

- Provide evidence based policy advocacy on Techno-Socio-Economic issues identified by CSIR/Government and other stakeholders
- Identify ST&I needs for National missions and create road maps for Sustainable Development
- To establish a repository of data, information, road-maps and policy documents related to science, technology and innovation activities in India as well as the world and create a digital Resource Centre for the Nation
- To provide linkages of communication among the scientific community in the form of research journals in different areas of ST&I
- To disseminate ST&I information to Society
- To harness information technology for science communication and publication
- To act as a facilitator in furthering the economic, social, industrial, scientific and commercial development by providing timely access to relevant and accurate information
- To collaborate with national and international Institutions and organizations having objectives and goals similar to those of CSIR-NIScPR