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Green Growth and Air Pollution in India

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Introduction

Presence of contaminants or pollutants in the air that impact human health or welfare, or produce other detrimental environmental effects is referred to as air pollution (Vallero, 2007). In India, with the advent of industrialization and urbanization, the levels of air pollution have increased manifold, making it an important environmental issue. Outdoor air pollution is a problem in the urban areas due to presence of sources such as vehicles, industries and power plants. Rural areas also face the concerns of indoor air pollution due to usage of biomass for cooking (Watson et al. 2015). Ambient air pollution has been identified as the fifth biggest cause of mortality in India (Lim SS et. al. 2012).

Central Pollution Control Board (CPCB) categorizes air pollution under four levels viz. critical, high, moderate and low, based on an exceedence factor which depends on the ratio of observed annual mean concentration of a criteria pollutant to the annual standard for the respective pollutant. The classification is given in table 1 and percentage of cities falling in different categories for the year 2012 has been shown in figure 1.

Table 1 Pollution level classification for industrial, residential, rural and other areas

Pollution level	Annual mean concentration range (µg/m^3)		
	PM_{10}	NOx	SO_2
Low (L)	0-30	0-20	0-25
Moderate (M)	31-60	21-40	26-50
High (H)	61-90	41-60	51-75
Critical (C)	>90	>60	>75

Source: CPCB, 2012

As can be seen in figure 1, among the three pollutants, particulate matter is the major concern in outdoor air pollution. For PM_{10}, 83% of the cities violate national ambient air quality standards (NAAQS). Also, 60% of the Indian cities fall in the critical pollution level category with pollution levels ranging between 90-308 µg/m^3.

Second pollutant to be taken into consideration is NOx which basically emitted from high temperature combustion processes. For this pollutant, 3% of the cities fall in critical, 11% in high, 39 % in moderate and 47% in low pollution level category.

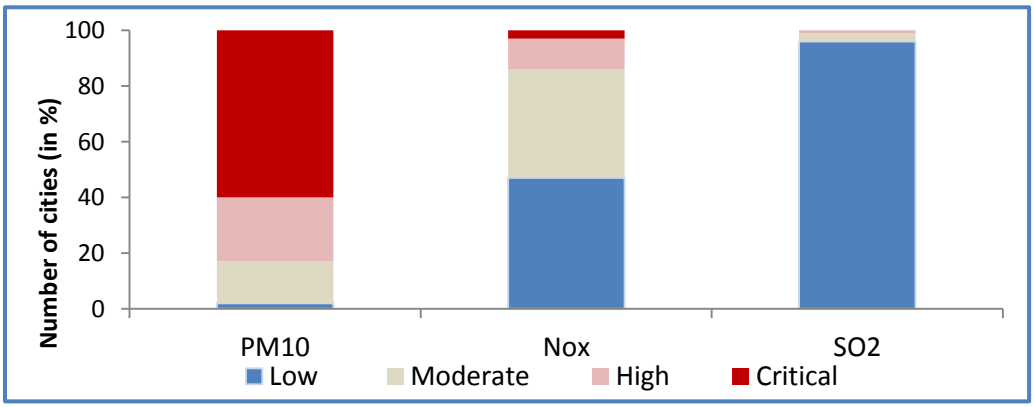

Figure 1 Percentage of cities in different pollution level categories in 2012

Source: CPCB, 2014-15

Thus particulate matter is the pollutant of concern for India as it violates the maximum permissible limits set by CPCB in almost all the cities. Following sections discuss the drivers and pressures responsible for increasing level of air pollution in the country and the status of air quality, its impacts, interventions taken to curb the air pollution levels and barriers to implement them.

Drivers and Pressures

Major sources of air pollution in India include industries, power sector, residential (domestic sector) and transport sector. The growth in urban population and extensive development activities have further added to the increased levels of air pollution in the country.

2.1 Population and economic growth

The percentage of urban population in different countries is depicted in figure 2. According to this, 53% of the world's population lives in urban areas, with the range of urban population varying from 32% in India to 85% in Brazil. In India, the proportion of urban population has increased from 25.7% in 1991 to 27.8% in 2001 and finally to 32% in 2013 (RGCC 1995, 2001; World Bank 2014-15).

Figure 3 presents an exhibit of the gross domestic product per capita income (in USD) for India over the period of 2000-2013. Simultaneously GDP per capita income in India has become almost thrice from 457.3 USD in 2000 to about 1500 in 2013.

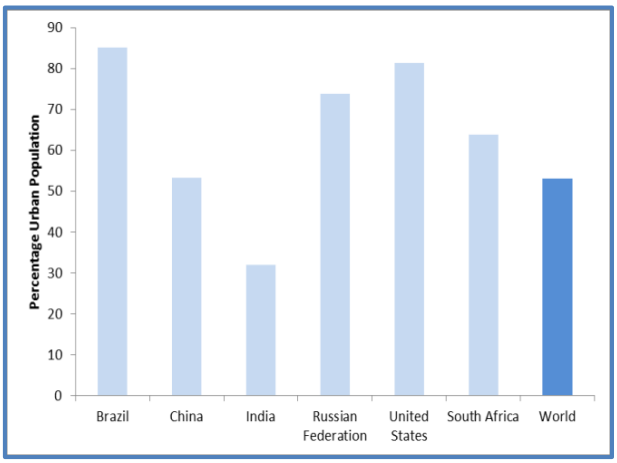

Figure 2 Urban population (millions) and their annual average growth rate for various countries for 2013

Source: World Bank (2014-15)

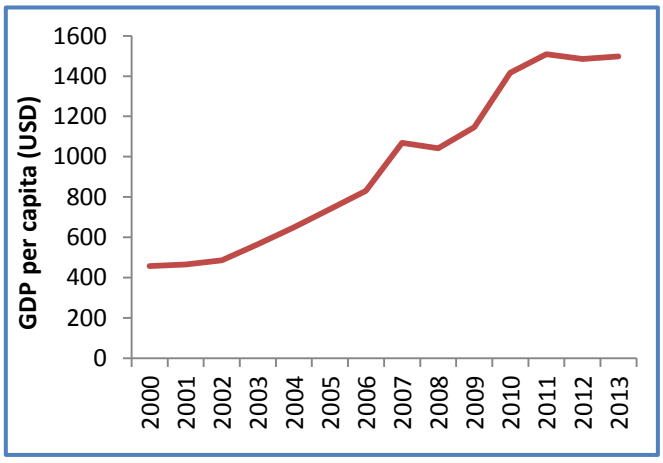

Figure 3 Gross Domestic Product (GDP) per capita income for India in US Dollars

Source: GoI (2015), Economic Survey 2014/ 15

2.2 Power

In power sector, out of the total power produced in India, coal power plants makes the 57.42 % installed capacity in India followed by hydro (18.62%), renewable energy sources (12.2%), natural gas (8.92%), nuclear plants (2.25%) and oil (0.56%) (CEA, 2013; Pryas, 2013). Electricity production from different energy sources in India in past three decades is shown in Figure 4.

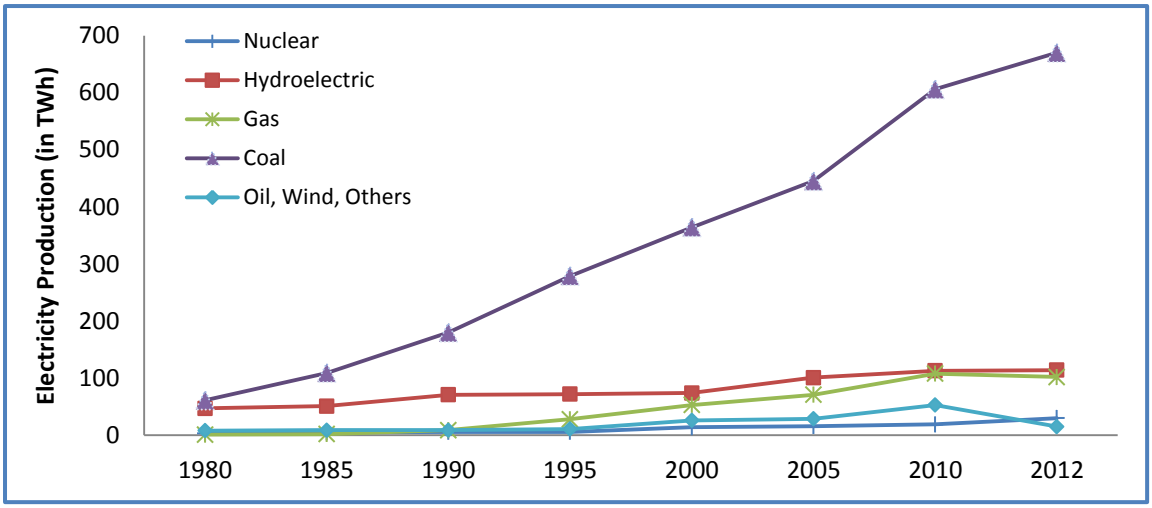

Figure 4 Electricity production (TWh) from all energy sources in India

Source: The Shift Project Data Portal

Contribution from coal shows a tremendous growth from 100TWh in 1980 to about 670 TWh in 2012. Share of natural gas and hydroelectric plants has also increased after 1990. Despite the growth of renewables and other sectors, coal is expected to be the major fuel for electricity production in India. Availability and cost effectiveness of coal has made it the prime fuel and consecutively the main cause of air pollution from power sector. Indian coal has high ash content (30-50%) and 7-20 % moisture content (Shail et al., 1994). Ash, being a non-combustible part of the coal, if present in large quantity, increases the requirement of coal to produce the same amount of electricity. Similarly, high moisture content in the coal increase the unburnt portion of the coal resulting in high content of bottom ash. Thus both these properties increase the specific coal consumption of the Indian coal. Although Electrostatic precipitators (ESPs) are installed in all the TPP, but their efficiencies and inspection and maintenance system for these units is a major topic of discussion as there is no information available for this. Also, emission standards are only available for PM10 pollutant in India for TPPs.

Thus, emissions from thermal power plants are going to increase in near future if appropriate control technologies and stringent standards have not been enforced by the government.

2.3 Industries

The industrial sector is one of the most dynamic sectors of the economy and plays an essential role in economic development. The index of industrial production (IIP) has increased from about 108 in 2005/06 to 167.8 in 2012/13. The manufacturing sector has grown at a faster rate than the mining and electricity sectors (Figure 5).

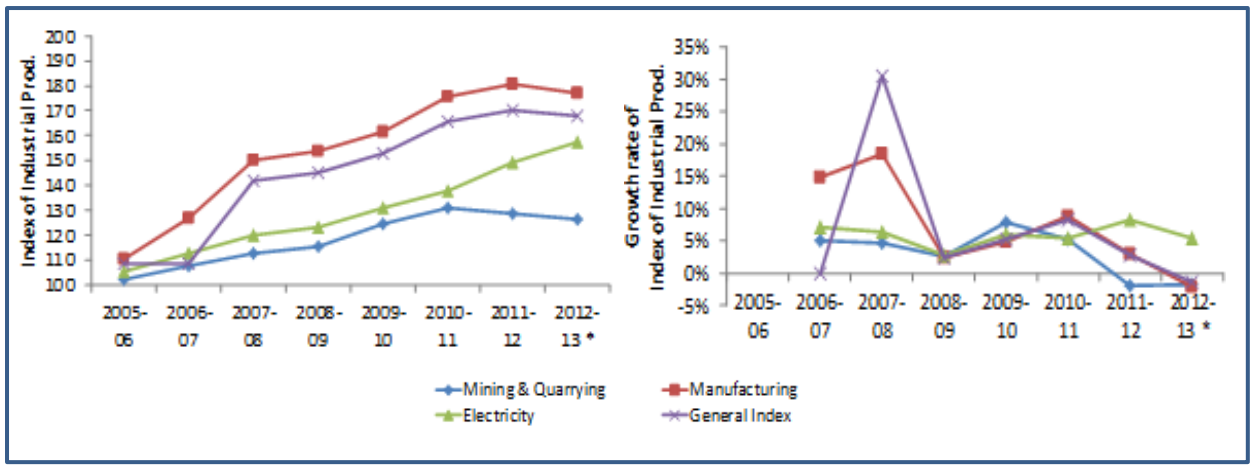

Figure 5 Index of Industrial Production and annual rates of industrial growth: 2005/ 06–2010/ 11

With the increase in industrial production, demand for fuels, water, and other natural resources has risen tremendously. If environmental concerns are not effectively addressed in the industrial sector, the implications with regards to air pollution could be severe.

2.4 Transport

India has shown phenomenal growth in certain sectors in the last two decades. With this, the mobility demands have also grown many folds. In 1951 there were 0.3 million registered vehicles in India which have grown to more than 159 million in 2012 (Figure 6). The actual number of motor vehicles used in the country could be somewhat lower considering the scrapped vehicles.

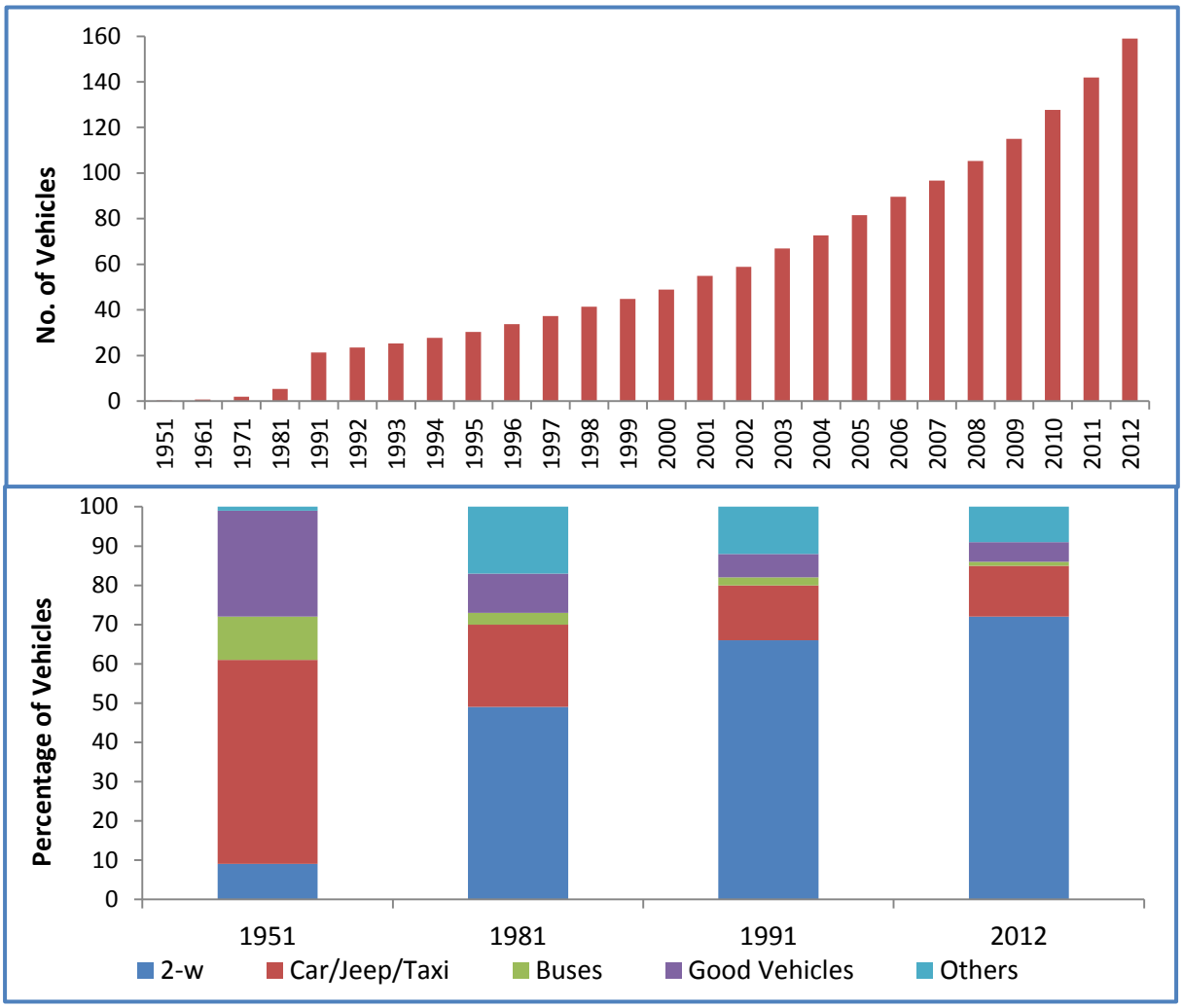

Figure 6 **(a)** Growth of vehicles in India (1951-2012) **(b)** Share of different categories of vehicles in different years in India

Source: MoPNG, 2013

*Others include tractors, trailers, three wheelers (passenger vehicles)/ LMV and other miscellaneous vehicles which are not separately classified

The growth of vehicles under various categories in India is shown in Figure 5. It is inferred that the growth has been more in case of two-wheelers and their share has increased from 9% in 1951 to 72% in 2012. However, off late, the car sales have picked up and their share has started to risen at an even higher rate. Lack of efficient public transport system in most of cities and growing travel demands has fuelled the growth of private vehicles in the country and correspondingly, increased the pollutant concentration in India.

2.5 Residential

Major sources of air pollution from residential sector in India are from use of biomass in cooking and kerosene for lighting. There is increasing number of health issues such as acute respiratory infections (ARI), chronic pulmonary diseases (COPD), asthma, heart diseases, cataract, pneumonia, low birth weight, and tuberculosis all due to indoor air pollution (IAP) (UNICEF 2013). Around 400-550 thousand premature deaths are because of indoor air

pollution only in India (Dey et al., 2012; Smith, 2000). Thus, air quality is not just an environmental issue but also a public health issue. Major sources of air pollution from residential sector are further discussed in detail in the following section.

2.5.1 Energy for cooking

Despite the introduction of cleaner fuels such as LPG and natural gas, more than 75% of the population is still dependent on traditional biomass in India (NSSO, 2012). Economic conditions, supply and delivery constraints of LPG and natural gas has played a major role in this. Figure 7 shows the percentage of households using different fuels in India.

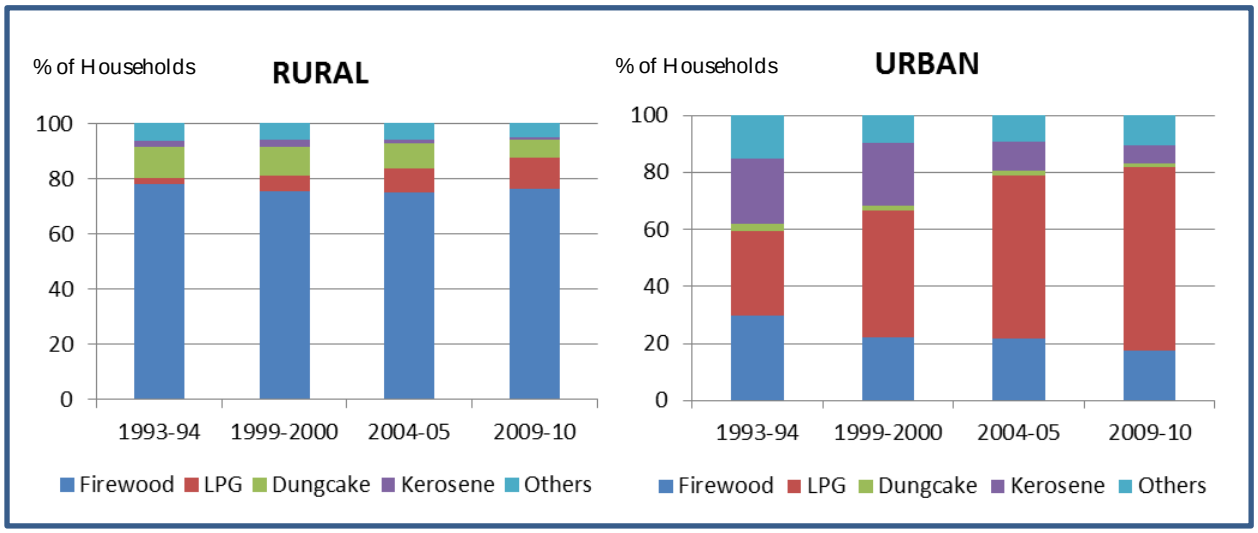

Figure 7 Percentage of households using different fuels during 1993-2010 in rural and urban areas

Source: NSS Round 66th (2012)

It is evident from the figure that number of households shifting on cleaner fuels is increasing both in urban and rural areas. But penetration is remarkably high in urban areas. In 2010, the percentage of household using LPG in rural areas is 12% in comparison to 65% in urban areas. Also, 76% of the rural population is still using firewood (NSSO, 2012).

2.5.2 Energy for lighting

Kerosene consumption for lighting purpose has severe health implications associated with it. Figure 8 shows percentage of rural households in India using kerosene and electricity in urban areas.

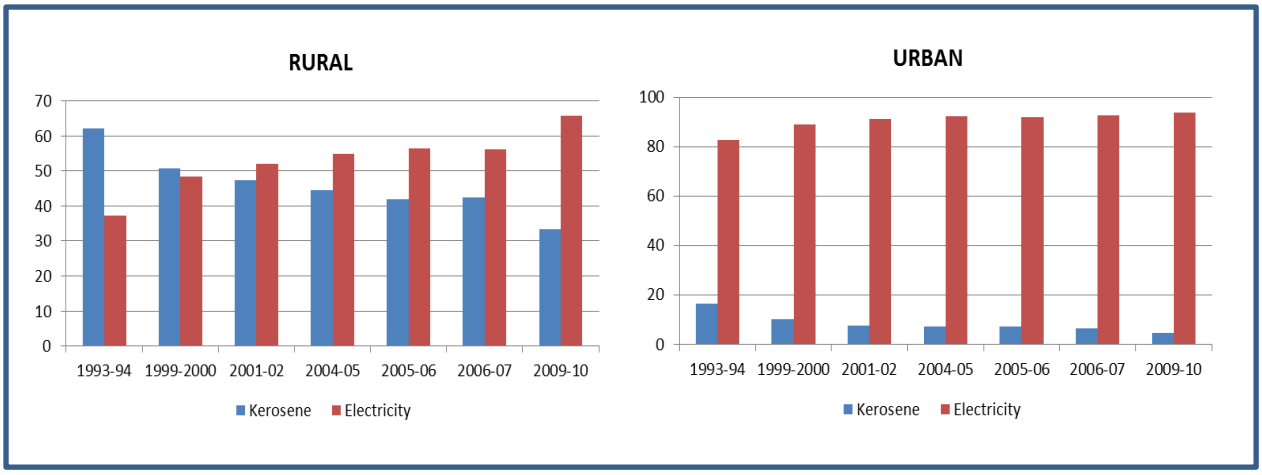

Figure 8 Percentage of households using kerosene and electricity in rural and urban areas

Source: NSS Round 66th (2012)

A declining trend can be seen for kerosene consumption in both rural and urban areas. Around 33% of rural population uses kerosene as against 5% of population in the urban areas.

Baseline Emissions

A recent emission assessment study (TERI, 2015) shows sector-wise emissions for the India (Figure 9). Industrial combustion contributes 49% of the PM_{10} emissions followed by residential sector (31%) and open burning. 31 % of NOx emissions are contributed by transport sector in the country, followed by power sector and industries.

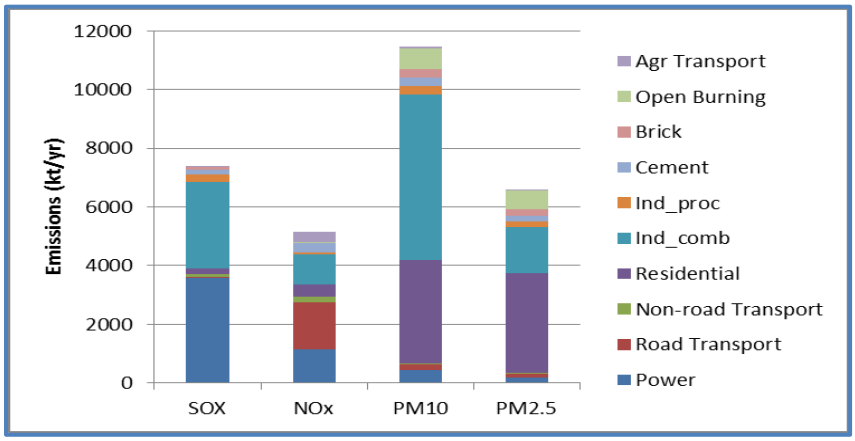

Figure 9 Sector-wise emissions (in Kt/ yr) for criteria pollutants from different sources in India in 2010

Source: TERI, 2015

State of Air Quality

In India, air quality monitoring was started in 1967 by National Environmental Engineering Research Institute (NEERI). The next initiative was from Central Pollution Control Board by starting the National Ambient air quality monitoring (NAAQM) program in the year 1984 with seven stations at Agra and Anpara. The numbers of monitoring stations kept on increasing with each year. Later the program was renamed as National Air Monitoring

Programme (NAMP). Gradually the network of air monitoring stations in India got strengthened from 28 to 456 stations during 1985 to 2011.

Under the NAMP, four air pollutants, viz., sulphur dioxide (SO_2), oxides of nitrogen as NO^2 and suspended particulate matter (SPM) and respirable suspended particulate matter (RSPM/PM_{10}), have been identified for regular monitoring at all the locations. Besides this, additional parameters such as respirable lead and other toxic trace metals, hydrogen sulphide (H2S), ammonia (NH^3) and polycyclic aromatic hydrocarbons (PAHs) are also being monitored in seven metro-cities of the country. Meteorological parameters such as wind speed and direction, relative humidity and temperature were also integrated in air quality monitoring. Further, automatic monitoring stations at few places have also been established for real time data collection. Till 1994, national ambient air quality standards were based on 8 hours averaging time but during air quality standards revision, the standards were revised for 24 hours. To determine 24 hours average for gaseous parameters, six 4-hourly observations of gaseous parameters are averaged to determine 24 hours average or daily average while three 8-hourly values are averaged to get 24 hours average value for SPM (CPCB 2010). The frequency of air quality monitoring is monitored twice a week, but due to various problems like power failure, instrumental failure, and trained manpower availability; this frequency is not adhered to. Figures 10a and 10b show the state of air quality (annual average RSPM and NO_x concentrations) in several cities of India during 2012

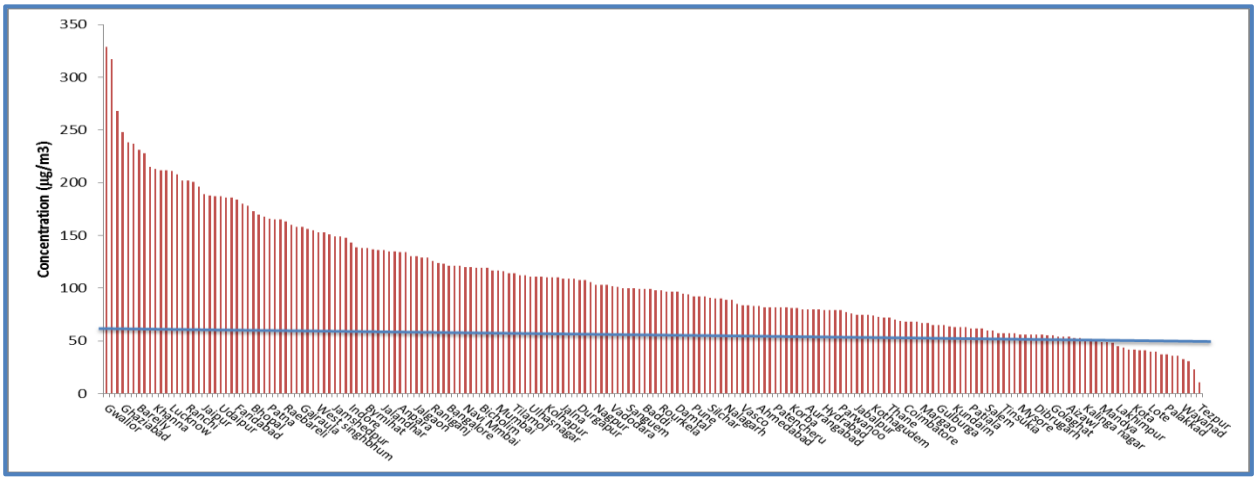

Figure 10a Annual average RSPM concentrations (µg/ m^3) in different cities of India during 2012

Source: CPCB, 2014-15

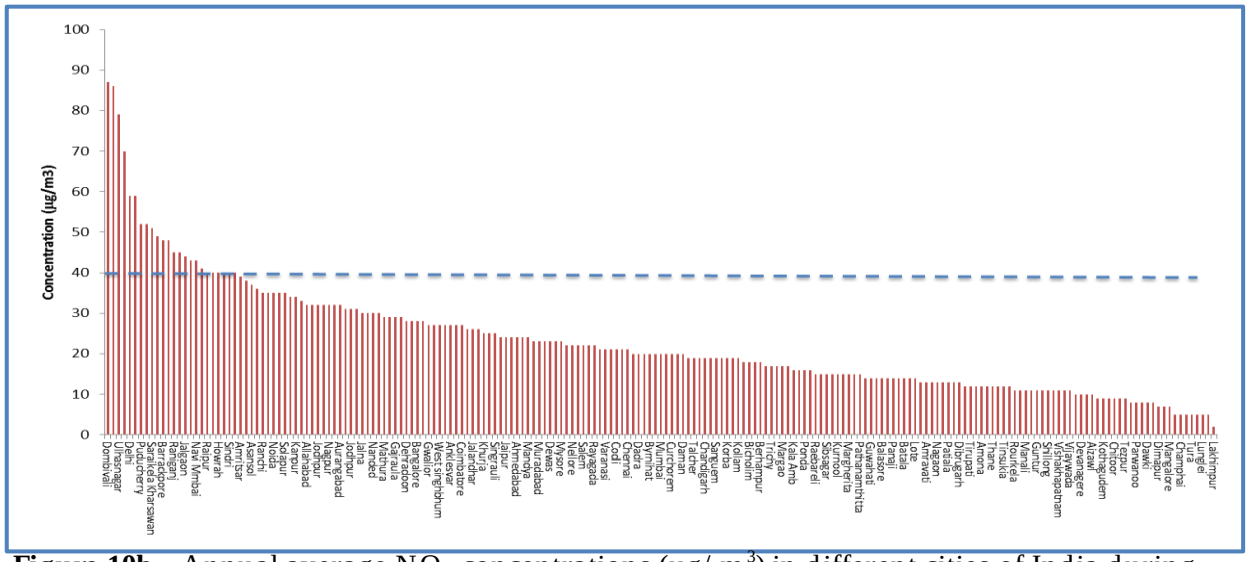

Figure 10b Annual average NO_X concentrations (µg/ m^3) in different cities of India during 2012

Source: CPCB, 2014-15

In order to get an overview of the status of change in air quality in major cities of India in nearly past one decade, status of air pollution in selected Indian cities has been shown in Figure 11.

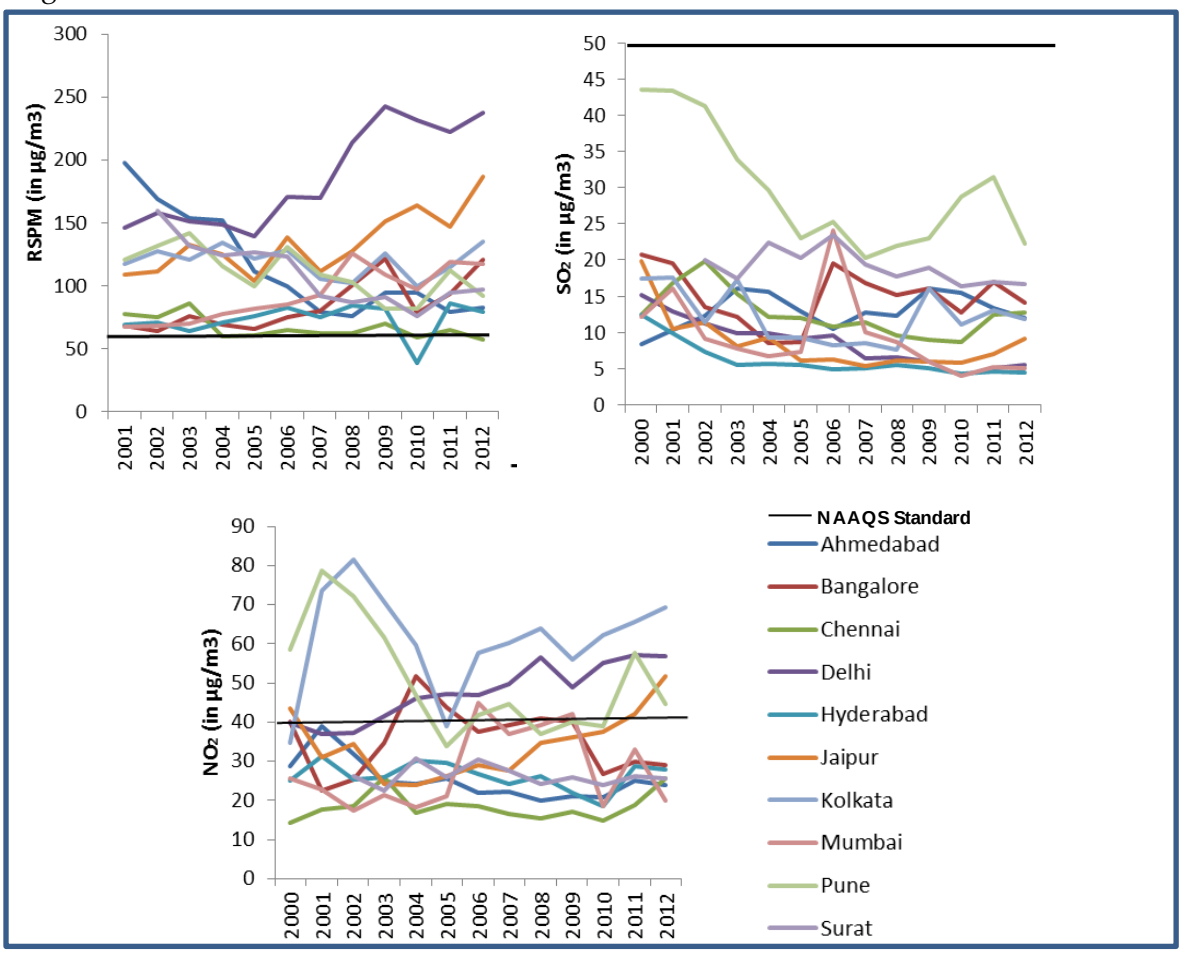

Figure 11 Air pollution for selected Indian cities (1995-2012), a) SO_2, b) NOx, c) RSPM

Source: CPCB, 2014-15

Most of the cities show mix trends for RSPM concentration, majorly lying in the range of 50 to 150 μg/m^3. However, Delhi and Jaipur shows an exceptional increase in the concentration from 150 to 220 μg/m^3 in past five years.

For SO_2, the concentration is within the required limits for all the cities (5 to 20 μg/m^3). In case of NOx, the concentration ranges between 15 to 40 μg/m^3, for most of the cities. For Kolkata and Pune, it has been decreased over the past decade. On the other hand, for Delhi, NOx concentration has been increased from 40 μg/m^3 to 60 μg/m^3.

Policy and Regulatory Framework

The role of legislation and guidelines is indispensable for curbing air pollution in Indian cities. The laws/guidelines that were introduced in India to address the problem of air pollution have been discussed in Table 2.

Table 2 Laws/ guidelines addressing air pollution in India

Year	Law/Guidelines	Key actions
1986	Environment (Protection) Act	• It was created as a response to Bhopal Gas Tragedy • Objective was to prioritize environmental protection and degradation • The act highlights the responsibility of the Indian Central government to control the sources and effects of pollution providing for both executive and legislative functions. • It provides strict punishment for any violation of the Act as per section 15 under it
1987	The Air (Prevention and Control of Pollution) Act 1981, Amendment, 1987	• GoI implied this Act to arrest the deterioration in the air quality. • It prescribes the various functions of the CPCB (Central Pollution Control Board) at the apex level and SPCB (State Pollution Control Board) at the state level.
1994	National Ambient Air Quality Standards(NAAQS)	• Issued by CPCB vide Gazette Notification of April 1994
1995	National Environmental Tribunal Act,	• The bill provides the judicial function not afforded by the Environment (Protection) Act, 1986. • It aims to set up environment courts in the country, replacing the National Environmental Appellate Authority (NEAA) in the settling of environment and public health related conflicts.
2005	WHO Air Quality Guidelines	• Objective is to offer global guidance on reducing health impacts of air pollution • The guidelines were first produced in 1987,

Year	Law/Guidelines	Key actions
		updated in 1997 • It recommends revised limits for the concentration of selected air pollutants – PM, NO_2, SO_2, ozone (O3)
2009	Revised (1994) National Ambient Air Quality Standards	• Limits for Benzene, Ozone, Benzopyrene, Arsenic, Nickel and Ammonia were included which were not covered earlier • Also, standards for residential areas have been extended to industrial areas also.

Impacts

Particulate matter has contributed significantly to the decline in health, mainly in the elderly and children. Major constituents of particulate matter i.e. elemental carbon (EC) and organic carbon (OC) are primarily responsible for harmful health effects (Hamilton & Mansfield, 1991). According to Dey *et al.* (2012), rapid increase in high aerosol loading over the last decade is a grave concern considering its impending impacts on health. Some of the major sources and health impacts associated with particular pollutants are presented in Table 3.

Table 3 Sources and health impacts of various air pollutants

Pollutants	Sources	Effects
Nitrogen dioxide (NOx)	Combustion processes (heating, power generation, and vehicles)	Bronchitis in asthmatic children. Reduced lung function growth
Particulate Matter (PM2.5, PM10)	Major sources are vehicles, industrial sources, domestic fuel burning, road dust re-suspension, construction activities	Cardiovascular and respiratory diseases, lung cancer, acute lower respiratory infections, chronic obstructive pulmonary disease.
Carbon monoxide (CO)	Incomplete fuel combustion (as in motor vehicles)	Reduces the oxygen carrying capacity of blood, causes headaches, nausea, and dizziness. Can lead to death at high levels
Sulphur dioxide (SO2)	Burning of sulfur-containing fossil fuels for domestic heating, power generation and motor vehicles.	Affects respiratory system and lung functioning. Coughing, mucus secretion, aggravation of asthma and chronic bronchitis. SO2 with water forms sulfuric acid and causes acid rain.

Intervention to address Air Pollution

Various interventions have been taken by the government to curb air pollution caused in different sectors.

7.1 Transport

Following interventions have been undertaken by the government in transport sector to address the problem of air pollution:

a) Advancement of vehicular emission standards: Advanced vehicular emission standards have been given by the Ministry of Road Transport and Highways (MoRTH). These have been discussed in table 4.

Table 4 Mass emission standards for vehicles in India

	Year	Vehicle Category	Region
BSIV	2010	All categories of new vehicles except 2-w and 3-wheelers	13 mega cities viz., Delhi (NCR), Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur, Agra, Lucknow & Sholapur
BSIII	1st Oct, 2010	All categories of new 4-w, 2-w and 3-w	All over the country
	1st Apr, 2010	All categories of 2-w and 3-wheelers	13 mega cities
	On or after 1st Apr, 2010	For diesel driven agricultural sectors (<37KW)	All over the country
	On or after 1st Apr, 2011	For diesel driven agricultural sectors (>37KW)	
	Since 1st Apr, 2011	For construction equipment vehicles	

BS – Bharat Stage

Source: CPCB, 2014

b) Advancement of fuel quality norms: In terms of fuel specifications, BS III is made available all over the country and BS IV for 13 mega cities. For petrol driven vehicles in 13 mega cities, research octane number (RON) has been boosted to 95 with lead content to 0.005 g/l and benzene content of max 1%. Content of sulphur in gasoline is also proposed to reduce to 0.005g/l in 13 cities whereas 0.015 % throughout rest of the country from 2010 (CPCB, 2014). For diesel driven vehicle, CN has been enhanced to 51 with sulphur content reduced to 0.005% in 13 mega cities whereas it is 0.035% all over the country.

c) As bio-fuels mainly ethanol and biodiesel (in B20 form), are the prospective options for India in future, many pilot studies have been initiated by CPCB.

d) Traffic management systems: To deal with increasing vehicle population many traffic management systems have been implemented. For example, BRTS (Bus Rapid Transit System) segregates the traffic in various lanes according to type of vehicles (MoEF 2014). It results in less hindrance of different speed vehicular movement as can be3 seen in Delhi and Ahemdabad. Also, interstate trucks which are not destined to the main city are not allowed to enter within the city limits.

7.2 Industry

Several measures have been taken after the establishment of emission standards under the Environment (Protection) Act, 1986 to check for air pollution (CPCB, 2014). Some of the key initiatives include the following:

a) Installment of pollution control equipment in industries units has been made mandatory for all the industries.

b) Action plans have been formulated for restoration of air quality in 24 identified critically polluted areas.

c) Annual environmental statement as an environment audit has been made compulsory for all the polluting industries.

d) District-wise zoning atlas for siting of industries based on environmental consideration is in preparation stage.

e) In brick sector, low efficient technologies in brick firing process produce high levels of product of incomplete combustion' emissions. In 1996, the government had also set emissions standards for brick kilns. Along with reduction in emissions, it has helped in fuel savings. However, the emissions from brick sector continue to be high.

7.3 Residential

Initiatives taken by government to reduce emissions from residential sector are listed as follows:

a) For cooking, National Programme on Improved Chula (1983) and National Programme on Biogas Development (NPBD) were initiated. These programs were proved to be baseline initiatives towards the issue but could not give as much results as were expected from them. The major weaknesses of the chulha program were lack of proper awareness creation on the health benefits of improved stoves and the absence of a customized need-driven approach (TERI Green India 2011). On the other hand, NPBD program was slow in initial stages and faced logistic issues, design problems and environmental instabilities such as temperature fluctuations.

b) For lighting the government had undertaken various programmes, these include Rajeev Gandhi Grameen Vidyutikaran Yojna (RGGVY) by Ministry of Power; and Village Energy Security Programme and Remote Village Electrification Programme (MNRE)

c) The government is also facilitating the access to modern and cleaner fuels like liquefied petroleum gas (LPG) by providing subsidies. Programs like Rajiv Gandhi Gramin LPG Vitaran Yojana (RGGLVY) in 2009 and Direct Benefit Transfer of LPG scheme in 2013 have been initiated by the government. RGGLVY is setting up LPG distribution agencies in order to reach remote areas.

7.4 Power

Power sector is the major contributor of SOx emissions, others being NOx and particulate emissions. To control PM emissions, electrostatic precipitators (ESPs) have been made mandatory for all the power plants in India. To control SOx emissions FGDs (Wet flue gas desulphurization) have been installed in four thermal power plants in India (Prayas, 2011; Guttikunda, 2014). Among those, three are in Maharashtra and one in Karnataka. Till 2020, only seven thermal power plants which are just 3.2 % of the total thermal power capacity in India are expected for installation of FGD units (Guttikunda, 2014).

To control fugitive emissions from coal handling in power sector, Ministry of Environment Forests & Climate Change (MoEFCC) issued a notification in June 2001. According to this, thermal power plants located beyond 1 km from pit heads and the ones located in urban and sensitive areas are required to use beneficiated coal containing ash not more than 34%. Further to control fugitive emissions from ash ponds, the ministry mandated through a notification in 2003 that brick kiln units coming in 100km radius of thermal power plants have to use 25% of bottom ash in brick kilns and any construction in the same radius will use only fly ash bricks.

7.5 Others

Some other key initiatives of selected cities targeting the air pollution have been listed below:

- **Identification of non-attainment cities on the basis of NAMP data by CPCB:** CPCB has identified list of polluted cities in which the prescribed National Ambient Air Quality Standards (NAAQS) are violated. These cities have been identified based on ambient air quality data obtained under National Air Quality Monitoring Programme (NAMP). .

- **Setting up of continuous real time air quality monitoring stations in 16 cities:** CPCB has taken-up a project for setting up of Continuous Real Time Air Quality Monitoring stations in 16 cities for which action plan is being prepared by SPCBs / state governments to control air pollution according to the orders of the Supreme Court of India.

- **Advancement of norms for the diesel engines used in the diesel generator sets:** CPCB has revised the emission norms for diesel engines set in 2002 in the year 2013. The new norms (Appendix-I) are applicable to new diesel generator sets being sold from 1st July, 2014.

- **Introduction of Environment Impact Assessment (EIA) guidelines:** Government has introduced guidelines to obtain environmental clearance of any proposed activity/project. The process helps in predicting all positive and negative impacts of activity on the environment which further helps in taking a controlled action.

Barriers

Several control measures have been introduced from time to time to combat the pollution levels, but the pace at which the emission levels have increased is very high compared to that of control measures. Barriers for this controlled pace of introduction of air pollution control equipment (APCE) are varied ranging from financial constraints to lack of awareness levels. The barriers have been discussed below:

Every investment under the umbrella of environmental protection demands for financial support by the government. While India being a developing country, the main priority is firstly the investment in development sector and provide basic amenities to the burgeoning population. Thus, allocation of funds for this sector comes as a second priority. For e.g. in transport sector, with the advent of urbanization number of on road vehicles have increased

and as a result emissions from this sector has increased tremendously. Looking at this, government has formulated an auto fuel policy which established mass emission standards. But the norms are not similar throughout the country and the timelines set for applicability of these norms is very far in the future.

In few sectors like power lack of capacity of vigilance authorities is a major reason behind control of emissions. APCEs (electrostatic precipitators) have been made compulsory for all the power plants by the government. But proper inspection and maintenance system is missing in terms of regular check on efficiencies of these APCEs.

In case of residential sector, traditional chulhas and traditional fuel are the main cause of emissions. Despite of information regarding better available technologies around the world, dissemination of the same across the entire country becomes a big challenge. RGGLVY started by the government is active since 2009. But to reach each remote village is a challenge. Since all the villages are still not electrified, villagers still rely on kerosene for lighting purpose which lead to increased emission of pollutants. Similarly, though improved cookstoves have been introduced by the government through different programs but the scale of these programs is not sufficient to cater the needs of the entire country.

Also complete awareness regarding the importance of protecting environment is still low among rural communities.

Ways Forward

Industrial combustion, transport sector, power plants and residential sector are major contributors of deteriorated air quality in India. Nearly all the cities violate the particulate matter standards as prescribed by Central Pollution Control Board. These high pollutant concentrations are posing health impacts to the public. Thus, it is imperative to control pollution levels by mitigating emissions from the respective sources.

In the base scenario, the future emissions from these sectors will grow manifold (Figure 12) if proper stringent measures are not being taken on time. It is projected that in 2030, NOx emissions from road transport sector will increase five times the current emissions. Also, particulate emissions, especially PM2.5 will increase majorly from brick, open burning and transport sector.

Further, in 2047, total emissions for all the pollutants will increase three folds.

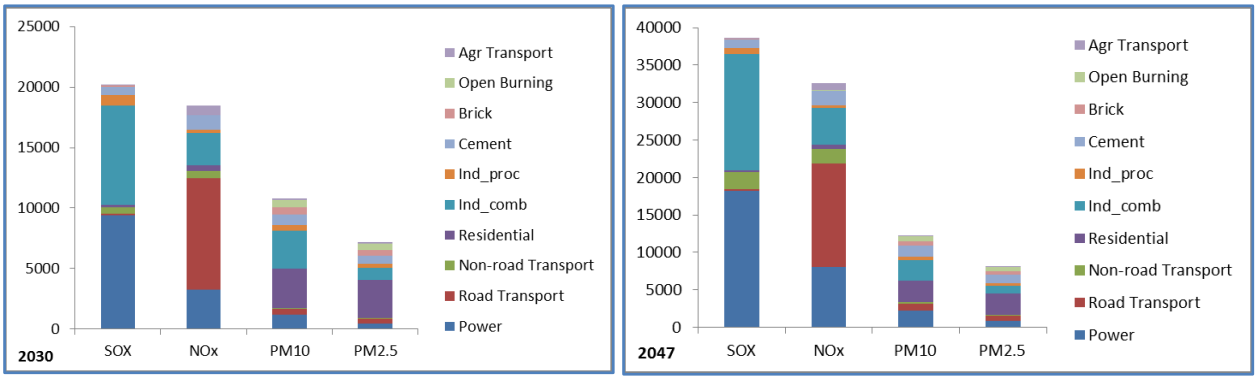

Figure 12 Sector-wise predicted emissions for criteria pollutants from different sources in India in 2030 and 2047

Source: TERI, 2015

Following recommendations are provided to curb the air pollution levels in India

9.1 Transport

- Considering the fast growth in the vehicular sector, more stringent steps should be taken. Instead of following chronological order for the norms, BS-V fuels should be considered by enabling the Indian refineries to leapfrog from BS-II to BS-V.
- An effective inspection and maintenance system should be enforced by the government in the states.
- Old vehicles should be gradually phased out with proper scrapping mechanism in place.
- A gradual shift from road to rail should be followed in Indian scenario.
- Electric mobility should be promoted.
- Government should conduct programs at community level to sensitize the public about the growing levels of the pollution due to vehicles and promote public transport systems.

9.2 Industries

- Cleaner fuels should be introduced to curb the emission levels.
- Installment of APCEs in all industrial units should be made mandatory for all the industries.
- Efficiency of installed APCE's should be checked at regular levels.
- In order to have more regular control, number of air quality monitoring stations in the country should be increased.
- Air pollution control equipment (APCE) should be enforced for each brick kiln unit and its efficiency should be monitored on regular intervals.

9.3 Power

- ESPs are installed in all the plants but inspection and maintenance systems should be enforced at regular time intervals.
- Indian emission standards for SO2 and NOx from thermal power plants in India should be developed and introduced.
- As power sector contributes the most in SO2 emissions from India, FGD's should be installed in more plants as early as possible.
- Capacity of vigilance authorities in power sector should be strengthened
- Government should provide fiscal incentives for compliance and non-compliance

9.4 Residential

- Enhanced and faster penetration of cleaner fuels like LPG
- Increased penetration of improved biomass based challahs with higher efficiencies and lower emissions
- R&D efforts to develop clean technologies

References

CPCB (Central Pollution Control Board). 2008. National Ambient Air Quality Status 2007. [NAAQMS//2008-09]. New Delhi: CPCB.

CPCB (Central Pollution Control Board). 2009. National Ambient Air Quality Status 2008. [NAAQMS//2009-10]. New Delhi: CPCB.

CPCB (Central Pollution Control Board). 2011. National Ambient Air Quality Status and Trends 2009. [NAAQMS//2010-11]. New Delhi: CPCB.

CPCB (Central Pollution Control Board). 2012. National Ambient Air Quality Status and Trends 2010. [NAAQMS//2011-12]. New Delhi: CPCB.

CPCB (Central Pollution Control Board). 2014. National Ambient Air Quality Status and Trends 2011. [NAAQMS//2013-14]. New Delhi: CPCB.

CPCB (Central Pollution Control Board). 2014. National Ambient Air Quality Status and Trends 2012. [NAAQMS//2014-15]. New Delhi: CPCB

CPCB, 2011. Air quality monitoring, emission inventory and source apportionment study for Indian cities Central Pollution Control Board , New Delhi

Dey, S., Girolamo, L Di, Donkelaar, AV., Tripathi, SN., Gupta, T., Mohan, M 2012 "Variability of outdoor fine particulate (PM2.5) concentration in the Indian subcontinent; A remote sensing approach" Remote Sensing of Environment, 127, 153-161.

Guttikunda SK., Kopakka RV., Dasari P., Gertler AW, 2012. "Receptor model-based source apportionment of particulate pollution in Hyderabad, India" Environ Monit Assess;185(7):5585-93. doi: 10.1007/s10661-012-2969-2

Guttikunda, SK & Jawahar P 2014. Atmospheric emissions and pollution from the coal-fired thermal power plants in India. Atmospheric Environment 92, 449-460.

Hamilton, R S., and Mansfield, T A 1991. "Airborne particulate elemental carbon: its sources, transport and contribution to dark smoke and soiling" Atmos. Environ. A, 25, 715–723.

Lim S S et al., 2012. A comparative Risk Assessment of Burden of Disease and Injury Attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: A Systematic Analysis for the Global Burden of Disease Study 2010, The Lancet 380: pp. 2240-2260. Available at http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(12)61766-8/abstract

MoEF (Ministry of Environment and Forest). 2014. Annual Report 2013-14.

MoPNG (Ministry of Petroleum and Natural Gas), Energy Statistics 2013.

NSSO (National Sample Survey Organization), 66th Round. 2012. Energy Sources of Indian Households for Cooking and Lighting 2009-10, MoSPI. .

Prayas, 2011. Thermal Power Plants on the Anvil: Implications and Need for Rationalization. Prayas Energy Group, Pune, India.

Shail M., Sodha S., Chandra R., Pitchumani B., Sharma J 1994. Effect of coal properties on the specific coal consumption in a typical thermal power station in India. Energy Conservation Management 35, 597-603.

Smith, K. R. 2000. National burden of disease in India from indoor air pollution. Proceedings of the National Academy of Sciences, 97(24), 13286–13293.

TERI, 2015. Understanding Energy Risks in India: Towards a Safe and Informed Energy Program, done for Atomic Energy Commission

TERI. (2009). GREEN India 2047 renewed: Looking Back to Change Track. New Delhi: TERI Press.

Vallero, D., Fundamentals of air pollution. 2007: Academic press.

Watson, J. G., Chow, J. C., 2015: Receptor models and measurements for identifying and quantifying air pollution sources, Eds. Murphy, B., Morrison, R., In Introduction to Environmental Forensics, 3rd Edition, 677-706, Elsevier: Amsterdam, The Netherlands, Published

World Bank 2014-15. Accessed on 11th June, 2015 http://data.worldbank.org/indicator/SP.POP.GROW?display=default

Appendix I: Emission Standards for Diesel Engines ≤800 kW for Generator Sets (Gazette notification of 2013, applicable from 2014)

Power category	**Emission limits**			**Smoke limit**
	NO_X + HC	CO	PM	
	(g/ kW-hr)			Light absorption coefficient, m^{-1}
Up to 19 KW	≤7.5	≤3.5	≤0.3	≤0.7
19 kW < P ≤ 75 kW	≤4.7	≤3.5	≤0.3	≤0.7
75 kW < P ≤ 800 kW	≤4.0	≤3.5	≤0.2	≤0.7

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A unique developing country institution, TERI is deeply committed to every aspect of sustainable development. From providing environment-friendly solutions to rural energy problems to helping shape the development of the Indian oil and gas sector; from tackling global climate change issues across many continents to enhancing forest conservation efforts among local communities; from advancing solutions to growing urban transport and air pollution problems to promoting energy efficiency in the Indian industry, the emphasis has always been on finding innovative solutions to make the world a better place to live in. However, while TERI's vision is global, its roots are firmly entrenched in Indian soil. All activities in TERI move from formulating local- and national-level strategies to suggesting global solutions to critical energy and environment-related issues. TERI has grown to establish a presence in not only different corners and regions of India, but is perhaps the only developing country institution to have established a presence in North America and Europe and on the Asian continent in Japan, Malaysia, and the Gulf.

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