Country Synthesis Report on Urban Air Quality Management

India

Discussion Draft, December 2006

Country Synthesis Report on Urban Air Quality Management

India

Discussion Draft, December 2006

Printed in the Philippines.

ADB facilitated this study through its Regional Technical Assistance 6291: Rolling Out Air Quality Management in Asia.

The Study was led by the CAI-Asia Secretariat and the information contained in this report was developed by the CAI-Asia Secretariat with inputs by a range of organizations and air quality experts from across Asia and elsewhere.

Table of Contents

Tables, Figures, and Boxes

Tables

Figures

Boxes

Abbreviations

ADB	Asian Development Bank
APA	Air Pollution Act
AQM	air quality management
BenMAP	Benefits Mapping and Analysis Program
CAAQM	continuous ambient air quality monitoring
CAI	Clean Air Initiative (for Asia)
CNG	compressed natural gas
CO	Carbon monoxide
CPCB	Central Pollution Control Board
CSE	Centre for Science and Environment
EBD	Environmental Data Bank
EIA	Environmental Impact Assessment
EPA	Environment Protection Act
EPCA	Environment Pollution (Prevention and Control) Authority
GDP	gross domestic product
HC	hydrocarbon
HSD	high-sulfur diesel
I&M	inspection and maintenance
KMA	Kolkata Metropolitan Area
LPG	liquefied petroleum gas
MoEF	Ministry of Environment and Forest
MRTS	mass rapid transport system
NAAQS	national ambient air quality standard
NAAQSR	national ambient air quality status report
NAMP	national air quality monitoring network
NCR	National Capital Region
NCT	National Capital Territory
NEERI	National Environmental Engineering Research Institute
NGV	natural gas vehicle
NO_2	Nitrogen dioxide
NOx	Nitrogen oxide
NUTP	National Urban Transport Policy
O_3	ozone
PCC	Pollution Control Committee
PM	particulate matter
PM_{10}	particulate matter with diameter less than 10 micrograms
$PM_{2.5}$	particulate matter with diameter less than 2.5 micrograms
PRC	People's Republic of China
PUC	pollution under check
RPM	respirable particulate matter
Rs	rupee (Indian)
RSPM	respirable suspended particulate matter
SASEC	South Asian Subregional Economic Cooperation
SC	Supreme Court
SO_2	Sulfur dioxide
SPM	suspended particulate matter
SPCB	State Pollution Control Board
ug/m^3	microgram per cubic meter
UNEP	United Nations Environment Programme
URBAIR	Urban Air Quality Management Strategy
US EPA	United States Environmental Protection Agency
UT	Union Territory
WHO	World Health Organization

Note: "$" means "US dollar" in this publication.

Acknowledgments

This series of country reports is the first time that a comprehensive overview of urban air quality management (AQM) at the country level has been prepared in Asia. Research compilation for this country synthesis report (CSR) on Urban Air Quality Management was led by the Clean Air Initiative for Asian Cities (CAI-Asia) Secretariat with inputs by a range of organizations and air quality experts from across Asia and elsewhere and facilitated by the Asian Development Bank (ADB) through its Regional Technical Assistance No. 6291: Rolling Out Air Quality Management in Asia. The primary authors of the reports are Ms. Aurora Fe Ables, Ms. May Ajero, Mr. Herbert Fabian, and Ms. Ninette Ramirez, all from CAI-Asia with the supervision of Mr. Cornie Huizenga, Head of Secretariat, CAI-Asia.

The CSRs were prepared with assistance from volunteer authors from the different countries and facilitated by CAI-Asia local networks in Nepal (Clean Air Network-Nepal), Pakistan (Pakistan Clean Air Network), Philippines (Partnership for Clean Air [PCA]), the People's Republic of China (PRC) (CAI-Asia Project Office), Sri Lanka (Clean Air Sri Lanka), and Viet Nam (Viet Nam Clean Air Partnership). CAI-Asia local networks have also organized in the respective countries a development partners meeting on clean air where initial drafts of the CSRs were presented to local AQM stakeholders.

For the India CSR, CAI-Asia extends special thanks to Naresh Badhwar of the Central Pollution Control Board for providing various reports and all air quality data and for the comments to the report.

CAI-Asia would like to thank ADB for facilitating the research and Mr. Masami Tsuji, Senior Environment Specialist, Dr. David McCauley, Senior Environmental Economist, and Mr. Nessim Ahmad, Director—all from the Environment and Social Safeguard Division, Regional and Sustainable Development Department—for providing guidance. Ms. Glynda Bathan, Mr. Michael Co, Ms. Agatha Diaz, and Ms. Gianina Panopio of CAI-Asia are also acknowledged for their logistical and technical support for the CSR team.

CAI-Asia and the respective country Ministries of Environments reviewed the volume—with technical review inputs from Prof. Frank Murray of Murdoch University—which Ms. Agnes Adre and Ms. Theresa Castillo copyedited. Mr. Segundo dela Cruz, Jr. handled the graphic design and layout.

» Part One

General Information

Geography and Climate

India is the seventh largest country in the world, covering an area of 3.28 million square kilometers (km^2). It is bordered by Nepal, the People's Republic of China (PRC), and Bhutan to the north, Bangladesh and Myanmar to the east, and Pakistan to the northwest. India consists of diverse physio-geographical features that may be classified into (a) the Great Mountain Wall (the Himalayan range in the north), (b) the Northern Plains, (c) the Great Peninsular Plateau, (d) the Coastal Plains, and (e) the Islands. India is a "sovereign, socialist, secular, democratic republic." It has a federal form of government with 29 states and six union territories (UTs). The largest cities are Bombay (Mumbai), Calcutta (Kolkata), Bangalore, Madras (Chennai), Ahmedabad, Hyderabad, and Kanpur.

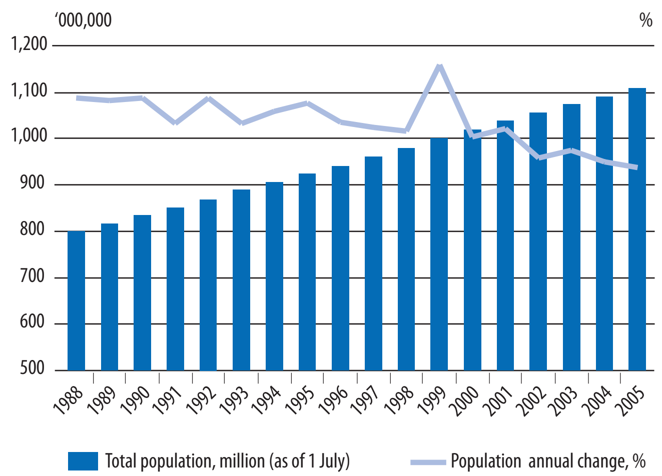
Its climate varies significantly from the Himalayas in the north to the tropical south; thereby, also affecting the quality of air in the different regions. Some areas have four seasons—relatively dry, cool winter (December to February); dry, hot summer (March to May); southwest monsoon (June to September) when predominating southwest maritime winds bring rains to most of the country; and northeast, or retreating, monsoon (October and November).

Urbanization and Population

India is the second most populous country in the world next to the PRC. Population for 2006 is estimated at 1.09 billion, with a corresponding growth rate of 1.4% (World Bank 2005). While global population has increased threefold from 2 billion to 6 billion during this century, the population of India has increased nearly five times from 238 million to 1 billion in the same period. Although the total population continues to increase over the years, annual growth rate has been decreasing because of the implementation of National Population Policy 2000 (Figure 1.1) (Asian Development Bank [ADB] 2006a). Nevertheless, with such a large population base, the absolute increase in population is still substantial (Ministry of Environment and Forest [MoEF] 2004).

FIGURE 1.1

India's Population and Population Growth Rate, 2000–2005



Source: ADB, 2006. Source: ADB, 2006.

India also has the most populous cities in the world. With a population of 15.3 million, the capital city Delhi is the world's sixth most populous city (2005 estimate). Delhi's metropolitan area, informally known as the National Capital Region (NCR), comprise Delhi and the neighboring satellite towns of Faridabad and Gurgaon in Haryana, and Noida and Ghaziabad in Uttar Pradesh—making it the sixth most populous agglomeration in the world, with an estimated population of 19.7 million.

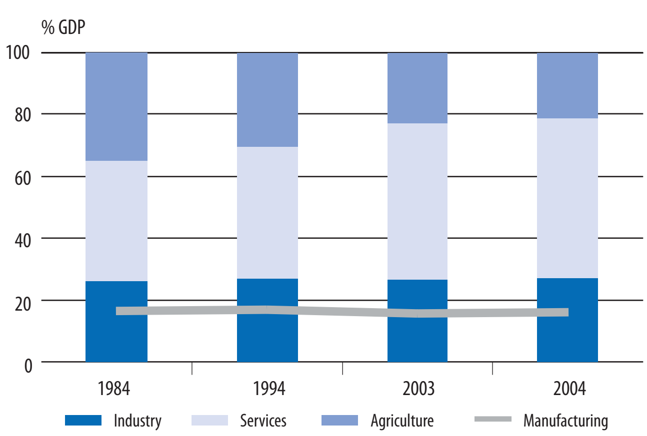
Compared with other developing countries in the region, the share of urbanization in India is relatively low at only 30%. However, its urban population is projected to grow to about 473 million in 2021 and 820 million by 2051, as against only 285 million in 2001. The unplanned urban development and uncontrolled increase of urban population has resulted in changed consumption patterns and increased demands for transport, energy, and other infrastructure that, in turn, have resulted in high levels of emissions (Office of the Register General, India 2001).

Economy and Industry

India is the fourth largest economy after the United States of America, PRC, and Japan. India's economy grew by 8.1% in fiscal year (FY) 2005 with a forecasted growth rate of 7.6% in FY2006. The annual average growth rate from 2006 to 2010 is unlikely to exceed 8–8.5% (ADB 2006b). Such future growth will largely be stimulated by the secondary and tertiary sectors of the economy (National Urban Transport Policy [NUTP] 2006). Industrial development—fueled in part by economic liberalization—has contributed significantly to the economic growth. Industry contribution to the gross domestic product (GDP) has increased from 22% in 1970–1971 to 30% in 1996–1997, and currently, 27% of GDP (Figure 1.2). This strong performance was driven by manufacturing, which accounts for about 20% of industrial output. Manufacturing (specifically, textile, basic metals and alloys, and transport equipment) were the fastest-growing product categories. India is the world's largest motorcycle manufacturer, the second largest two-wheeler and tractor manufacturer, and the fifth largest commercial vehicle manufacturer and the fourth largest car market in Asia—one million plus vehicles in 2004–2005 (India in Business 2006).

FIGURE 1.2

Sectoral and Manufacturing Industry Contribution to GDP



Source: ADB, 2006.

Lists of large polluting industries are categorized and maintained by each State Pollution Control Board (SPCB) in the country across the state and across regions, as defined by SPCBs.

Energy

Coal and oil constitute the main sources of energy sources in the country. The share of various energy sources in the commercial consumption of energy is shown in Figure 1.3. Apart from commercial energy, a large amount of traditional energy sources in the form of fuel wood, agricultural waste, and animal residue are also used in the country.

India ranks third among the largest coal producers in the world and is rich in coal reserves, which can last over 200 years. The reserves, however, are of poor quality with high ash content (40–50%) and low calorific value making this a source of high air pollutant emissions. Aside from coal, India is also rich in oil and natural gas reserves which have not been well-explored. Despite significant growth in the production of crude oil, natural gas, and petroleum products, domestic production has not matched the demand. India is increasingly dependent on imported crude oil and petroleum products, accounting for 20–25% of total imports in the last few years (ADB 2000).

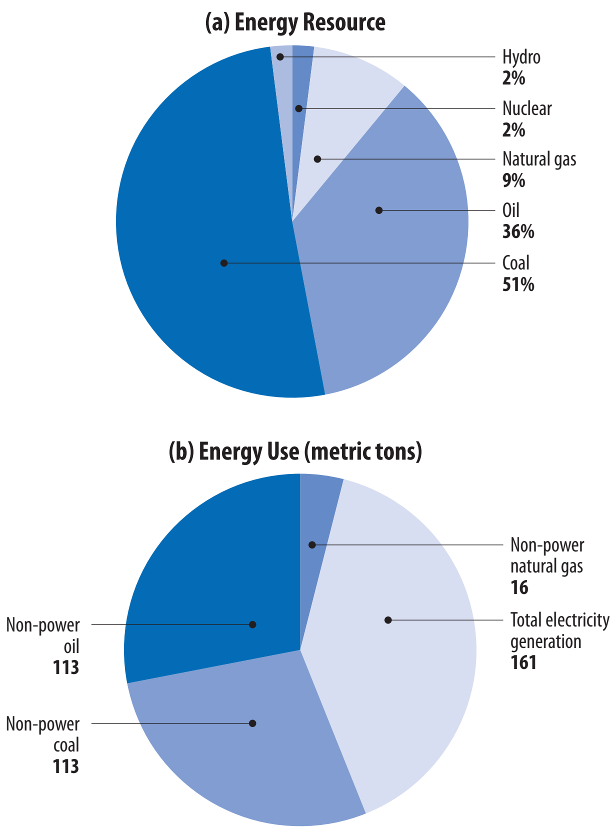
India also has substantial reserves of nuclear fuel—having the world's largest deposits of thorium (about 363 thousand tons) and about 34 thousand tons of uranium ore. However, only 44% of these resources is economically exploitable. The potential for renewable energy (solar, wind, biomass, and small hydro) is also high at an estimated 100,000 megawatts.

The industrial sector is the largest consumer of energy; consuming about 50% of the total commercial energy produced in the country. Of the commercial sources of energy used in the industrial sector, coal and lignite contribute about 57%, oil and gas around 33%, hydroelectric power 3%, and nuclear power 0.2%. Among the most energy-intensive industries (which together account for nearly 80% of the total industrial energy consumption) are fertilizer, aluminum, textile, cement, iron and steel, pulp and paper, and chlor-alkali. (South Asian Subregional Economic Cooperation [SASEC] 2005)

The transport sector is the main consumer of petroleum products—mainly in the form of high sulfur diesel (HSD) and gasoline—and accounts for nearly 50% of the total consumption. The total transport sector (including road, rail, aviation, and water navigation) energy consumption in India was 31.14 million tons of oil equivalent in 2003–2004 with share of petroleum fuel at 98% and electricity at 2% (Ministry of Petroleum and Natural Gas 2005). Of the total petroleum products consumed, share of HSD was the highest at 71%; gasoline at 27%; and all other fuel at less than 1%.

FIGURE 1.3

India's Primary Energy Resources and Energy Use, 2006



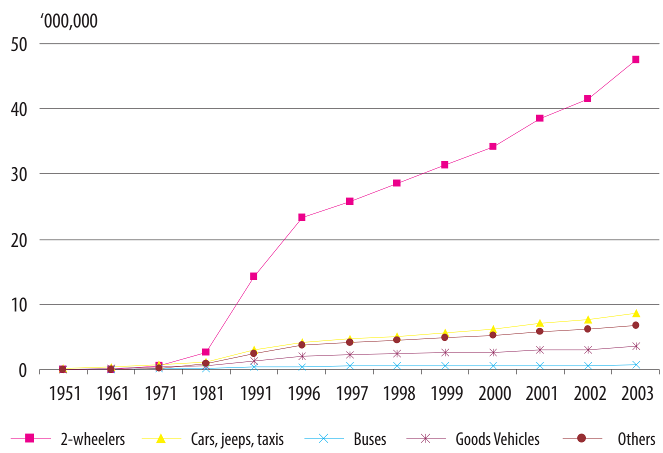
Source: India Energy Outlook, 2006.

Motorization

As a leading manufacturer in the region, India has also seen a rapid rise in motorization— especially in motorcycles over the years—particularly in its major urban areas. The total number of registered motor vehicles in India has increased from 1.86 million in 1971 to 67 million in 2003 (Figure 1.4). Motorized two-wheelers (motorcycles, scooters, and mopeds) account for over 70% of the total registered fleet that will clearly impact on Carbon monoxide (CO) and hydrocarbon (HC) emissions. The absence of an effective mass rapid transport system (MRTS) and intra-city railway networks have resulted in people using their own vehicles to commute to work. The proportion of buses to the total registered fleet has fallen from 5% in 1971 to 1.1% in 2003. Correspondingly, the proportion of private vehicles (two-wheelers and cars) to the total number of registered vehicles in India has increased from 65% in 1971, to 84% in 2003.

FIGURE 1.4

Vehicular Growth in India



Source: Data from the Department of Road Transport and Highways and graph by Clean Air Initiative for Asian Cities (CAI-Asia).

The power generating capacity in India comprises a mix of hydro, coal-based thermal, oil-fired thermal, gas, and nuclear. About 72% of power generation is thermal-based, using predominantly coal. While the share of gas-based thermal generating capacity has also gone up, the nuclear-based generating capacity has declined in spite of a high degree of self-reliance in nuclear technology. Despite a substantial increase in electricity generation, energy shortages affect all sectors of the Indian economy (Planning Commission GoI 1999).

In 2003, 23 out of 35 metropolitan cities accounted for about ⅓ of the total 67 million vehicles registered in the country. About 45% of the total cars in India are confined to these metropolitan cities. The corresponding figures for other vehicular modes are shown in Figure 1.5a. In the five major metropolitan cities (Mumbai, Kolkata, Delhi, Chennai, and Bangalore), the growth in registered motor vehicles has outpaced population growth. While the population in these cities has doubled during 1981–2001, the number of vehicle has gone up by six-and-a-half fold. Figure 1.5b represents

FIGURE 1.5A

Vehicle Composition in Indian Cities, 2003

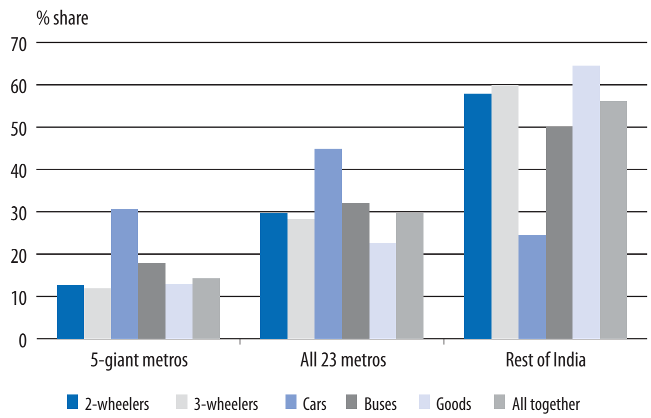
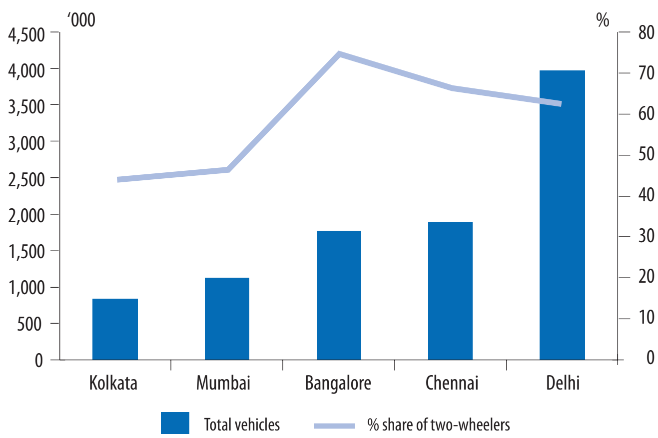


FIGURE 1.5B

Share of Two-wheelers in Total City Motor Vehicle Fleet, 2003



the share of two-wheelers in each of these five cities. Two-wheelers are the dominant mode of transport in these cities, accounting for more than 40% of the total vehicle population, with Bangalore registering the highest percentage share at almost 75% (Bose 2006).

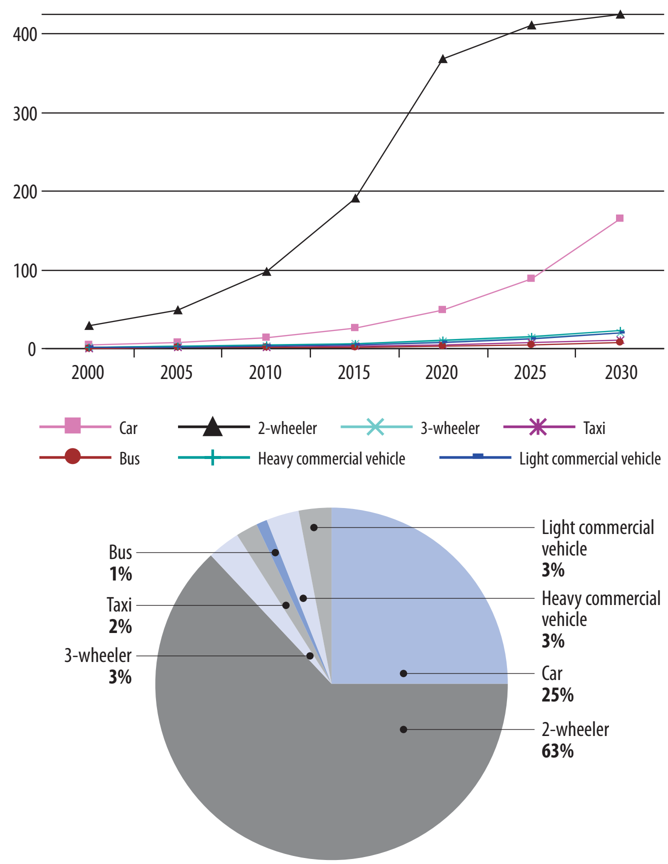
Estimating the number of vehicles on the road and its composition proves to be a major challenge because of the deficiencies and inconsistencies in the available data, and several past studies were based upon highly questionable estimates (Bose 2006). While records of new vehicle registrations are kept to reasonable accuracy, there is no data on vehicle retirements or vehicles actually on the road. These personal vehicles are registered only once as new vehicles for a 15-year period. However, all other categories of commercial vehicles (namely, three-wheelers, taxis, buses, light commercial vehicles, and heavy commercial vehicles, are registered every year as long as they are considerably roadworthy. Any commercial vehicle, which is unable to produce an annual roadworthiness certificate, does not get a registration certificate and is automatically deregistered in the registration data. Nonmotorized modes of transport such as bicycles are typically observed only in semi-rural and small towns and without any dedicated bicycle lanes.

Figure 1.6 shows the number of in-use motor vehicles in India and the projected figures, using the assumed 8% GDP growth[1] per year from 2004 to 2030. The total number of vehicles is estimated to rise at 10% per annum, reaching 672 million in 2030. Two-wheelers have the highest growth rate at 14% annually and this figure will reach 425 million by 2030. The share of buses is estimated to fall further for the same period.

[1] The Asian Development Bank (ADB) projected 8–-8.5% GDP growth rate until 2010. Ranjan Bose's paper therefore assumed that in the high-growth scenario, 8% growth rate of GDP could be sustained until 2030.

FIGURE 1.6

Projected Number and Percentage Distribution per Type of Vehicle by 2030



Source: Bose, 2006 and graphs by CAI-Asia.

The bus and rail network in Mumbai is by far the best public transportation infrastructure in the country in terms of coverage, carrying capacity, and utilization. Moreover, Mumbai is implementing an MRTS. An MRTS is also under implementation in Chennai. A pilot bus rapid transport system is under implementation in Pune.

In 2005, NUTP was formulated to allow the cities to evolve into an urban form that is best suited (or the unique geography of their locations) and best placed to support the main social and economic activities that take place in the city. NUTP clearly prioritizes efforts to initiate a shift from personal to public transportation by strengthening the mass transport infrastructure. NUTP also emphasizes clean technologies and better fuel quality to reduce air emissions.

» Part Two

Sources of Air Pollution

Emission Inventory

Preparation of urban, state, and national air emission inventories is not mandated by law. Emission inventories have been mainly carried out for metros and large cities in India. Unfortunately, there is no programmatic approach to update emission inventories. A void in leadership (i.e., who should conduct the inventory), problems in institutional coordination (e.g., between road traffic office, SPCBs, Civic Administration, etc), data gaps (especially on-site or case-specific emission factors) have been some important barriers in the conduct of emission inventories. Some of the key emission inventory studies carried out in India are summarized in Table 2.1.

The Central Pollution Control Board (CPCB) carried out the first government-led emissions inventory and modeling exercise for Delhi in 1994 for four source categories (industrial point source, small industry, traffic, and domestic coal consumption). In 1995, the National Environmental Engineering Research Institute (NEERI) conducted "Air Accounts for NCT-Delhi Study" that identified relative contributions of different sources to the ambient air. Both emissions estimates show that the industrial sector accounts for most of the particulate matter (PM) and Sulfur dioxide (SO_2) problem in Delhi, while Nitrogen oxides (NO_x) and CO are mostly attributed to the transportation sector. (Mashelkar, R.A. et al..2002).

Several organizations and academic institutions have conducted different studies to identify sources and their emissions. A comprehensive emission inventory was conducted in 1997 for Mumbai as part of the Urban Air Quality Management Strategy (URBAIR). It was found in the study that the total suspended particulates exposure was primarily due to resuspension from roads caused by vehicles (40%), emission from diesel and gasoline vehicles (14%), domestic wood and refuse burning (31%), and others (15%) (World Bank 1997). The aspect of resuspension formed one of the important areas of investigation in the later emission inventory-related studies.

In 2002, the United States Environmental Protection Agency (US EPA) and the United States Agency for International Development (USAID) New Delhi Mission initiated the Integrated Environmental Strategies (IES) program in India to help Indian policymakers identify, evaluate, and eventually implement a variety of mitigation opportunities with local and global co-benefits. A project aimed to develop analytical tools and an analytical framework for quantifying greenhouse gas and particulate matter with diameter less than 10 micrograms (PM_{10}) emissions and assess the associated public health benefits from reducing local pollutant concentrations through integrated clean energy strategies,was initiated at Hyderabad. In addition to generating a first-ever emissions inventory of all reported combustion sources in Hyderabad Urban Development Area, the emissions reductions due to several clean-fuel mitigation programs was also quantified. Results of the study show that most air pollution in Hyderabad is due to emissions from the transportation sector; industry is the second largest contributor to air emissions; and the major pollutants in the city are PM, CO, HC and NO_x. Reports on this study can be accessed from www.epa.gov/ies/indiadocs.htm.

Notwithstanding numerous emission inventories conducted over time, the SASEC final report for India identified the following gaps in the emission inventory studies:

- The above studies are merely indicative and mostly based on secondary data where more assumptions have been taken into consideration.
- Inventory of only few categories of pollutants has been studied.
- A good database for different types of polluting sources is not available.

TABLE 2.1

Compilation of Results of Various Studies for Mumbai and Delhi

Organization	Project	Year of Study	Pollutants	Transport (%)	Industrial[a] (%)	Domestic (%)
TERI	Environmental implications of energy use in Delhi	1988/1989	CO	76	13	11
			HC	–	–	–
			NO_x	66	33	1
			SO_2	12	84	4
			PM	3	95	2
UNEP/WHO	Estimated and projected anthropogenic emissions by source for 2000 in Mumbai	1992	CO	92	8	–
			HC	–	–	–
			NO_x	60	40	–
			SO_2	2	98	–
			PM	4	96	–
UNEP/WHO	Estimated and projected anthropogenic emissions by source for 2000	1992	CO	90	–	10
			HC	–	–	–
			NO_x	72	13	1
			SO_2	8	92	–
			PM	4	96	–
BARC/CESE/IIT	Source apportionment of SPM in Mumbai	1992	PM	15–18	from vehicular exhaust	
				33–41	from road dust	
				15	from marine aerosols	
				6–11	from coal combustion	
				6–8	from metal industries	
				15–17	from unexplained sources	
CPCB	Modeling and surveillance of dispersion and movement of pollutants in Delhi	1994	NO_x	74	25	2
			SO_2	10	86	4
			PM	22	74	4
NEERI	Air Accounts for NCT- Delhi	1995	CO	80	3	16.3
			HC	95	5	–
			NOx	69	29	1.6
			SO_2	5	95	–
			PM	7	91	Domestic and others =2

Ref. www.petroleumbazaar.com/Library/auto%20fuel%20policy/ch_4.pdf.

BARC = Bhabha Atomic Research Centre; CESE = Centre for Environmental Science and Engineering; CO = Carbon monoxide; CPCB = Central Pollution Control Board; CSE = Centre for Science and Environment; HC = hydrocarbons; IIT = Indian Institute of Technology; NCT = National Capital Territory; NEERI = National Environmental Engineering Research Institute; NO_x = Nitrogen oxide; PM = particulate matter; SO_2 = Sulfur dioxide; SPM = suspended particulate matter; TERI = The Energy and Resources Institute; UNEP = United Nations Environment Programme; WHO = World Health Organization; and % = percent

Note: PM referred above are all SPM except for the World Bank study where PM is PM_{10}.

[a] Industrial includes power plants also.

Source: CPCB based on the following references:

Kumar, A.Vinod, et.al. 2001. Source apportionment of suspended particulate matter at two traffic junctions in Mumbai, India. *Atmospheric Environment*-35; 4245–4251.
Bose, Ranjan. 1990. Environmental Implications of energy use in the city of Delhi. *Encology;* 5(6), 1–9.
World Bank. 1997. Technical Paper No. 381 on Urban air quality management strategy in Asia. *Greater Mumbai Report.*
WHO-UNEP. 1992. Report on Urban air quality in mega-cities of the world.
CPCB Report. 1994. Modeling and surveillance of Dispersion and Movement of Pollutants in Delhi.
———. 2000. Transport Fuel Quality for year 2005.
CSE Report. 2000. Working Model of Vehicular Pollution of Delhi for 1999–2015.
NEERI. 1998. Carrying capacity based air quality management in NCT-Delhi. Paper presented in workshop on Integrated Approach to Vehicular Pollution Control in Delhi. 16–18 April.

- Emission factor has not been developed for different categories of polluting sources. Most of the studies used the World Health Organization (WHO) emission factor.
- For vehicle emission inventory, data on actual vehicles plying on road, vehicle usage data, and fuel usage data are not available or well-documented.
- The method used for estimating emission inventory is not uniform.

Source Apportionment

CPCB has prepared Conceptual Guidelines for Common Methodology on Air Quality Monitoring, Inventory and Source Apportionment Studies for Indian Cities (CPCB 2006a). The document is available at the CPCB website. A study on source apportionment has been initiated in six Indian cities: Delhi, Mumbai, Chennai, Kolkata, Bangalore, Pune. The details are as follows:

Source apportionment studies so far carried out in India are restricted to PM. The periods of study are for less number of days and most do not cover all seasons. Training for such type of studies is also not adequate and professionals are not familiar with the different types of models required for source apportionment study. A compilation of several studies on source apportionment carried out so far in India has been included in the SASEC program final report (SASEC Final Report 2005).

In 2005, an exercise was conducted under the ADB technical assistance (3423 IND Component E) program to identify and apportion respirable particulate matter (RPM) emission sources within the Kolkata Metropolitan Area (KMA). The principal tasks completed during the project included a video survey and traffic counts of on-the-road vehicles;[1] survey of small-scale industrial sources combined with existing information on emissions from power plants and brick kilns operations; and quantification of paved road dust RPM emissions based on 39 locations within KMA. Emissions data related to cooking in slum areas, open burning, asphalt hot mix operations, and diesel trains operations were compiled also in an attempt to develop a full and complete RPM emission inventory. Results were then compared to an independent aerosol apportionment study based on the chemical analysis of aerosol samples collected in Kolkata in 2001. The apportionment studies showed that RPM emissions within KMA are about 75,140 tons per year. The studies also revealed that RPM emissions from vehicles, road dust, other area sources, and industry would grow to 136,796 tons per year at the projected growth rates if significant efforts were not made to reduce emissions and improve air quality. Implementation of the proposed emission reductions are expected to improve RPM air quality in Kolkata and have important public health benefits, thus, preventing an estimated 36,000 RPM-related premature deaths over the next decade.

[1] This data was used as the basis for calculating vehicle fleet emissions for all major pollutants under current conditions.

Box 2.1

Auto Fuel Policy

The Auto Fuel Policy document submitted to the Government of India by Dr. Mashelkar's committee has identified knowledge gaps in the area of air pollution source apportionment. With this background, air pollution source apportionment studies have been initiated in six major cities with the participation of oil companies, leading research institutes, CPCB, SPCBs, and MoEF. The focus of this study is the characterization and apportionment of PM10 with limited exercises on PM2.5 to have a better understanding and correlation between these two fractions at source and receptor. The specific objectives of the study are:

- To profile baseline ground level concentration of air pollutants in different parts including source specific "hot spots" viz. kerbsides, industrial zones, etc.
- To develop emission factors for different categories of pertinent sources with due consideration to local variance in fuel quality, technology, size and vintage of sources, control systems, etc. The emission factors shall cover both fugitive as well as tail pipe emissions.
- To conduct inventory of pollution loads from various sources for their spatial and temporal distribution in the cities covered under this project.
- To profile the source emission characteristics of different potential sources.
- To conduct source apportionment studies and prioritize the source categories for evolving mitigation strategies.
- To assess the impact of sources on ambient air quality under different management/interventions/control options and draw a roadmap of short- and long-term measures as considered appropriate and cost effective to ensure cleaner air in urban areas.

Upon completion of the data collection, validation, interpretation of information, a detailed road map will be drawn considering all possible measures for air quality improvement. These measures will be classified into short and long-term measures with priority to be given to low-cost measures that give maximum benefits.

Source: Auto Fuel Policy, 2005.

» Part Three

Status of Air Quality

Air Quality Monitoring

CPCB, in collaboration with, SPCBs has established a national ambient air quality monitoring network or NAMP, comprising 310 operating stations covering 115 cities/towns in 25 states, and 4 UTs of the country. The areas monitored have been categorized as industrial, residential, and sensitive.

The network was established under the 1981 Air (Prevention and Control) of Pollution Act (APA) to collect compile and disseminate information on air quality. NAMP, being a nationwide network, has several agencies involved in the activities. AQM is monitored by CPCB, SPCBs, Pollution Control Committees (PCCs), and NEERI. These are:

1. CPCB in the city of Delhi;
2. SPCBs in the respective states;
3. PCCs in the respective UTs; and
4. NEERI, Nagpur in six metro cities of the country;

Under this network, SO_2, NOx, suspended particulate matter (SPM), and respirable suspended particulate matter (RSPM)/ PM_{10} have been identified for regular monitoring in all locations. The monitoring of meteorological parameters such as wind speed and direction, relative humidity, and temperature is also integrated with the monitoring of air quality. In addition to these conventional parameters, NEERI monitors special parameters like NH_3, H_2S, RSPM, polyaromatic hydrocarbons (PAHs), and heavy metals. CPCB has initiated monitoring of particulate lead, PAH, heavy metals, ozone (O_3), and CO at some of its monitoring stations in Delhi. The monitoring of pollutants is carried out twice a week for 24 hours (4-hourly sampling for gaseous pollutants and 8-hourly sampling for particulate matter) to have 104 observations in a year.

CPCB provides funds for operation and maintenance cost as well as capital cost to all agencies. It also coordinates with these agencies to ensure the uniformity, consistency, and compatibility of air quality data. CPCB has provided guidelines and methods to all these agencies and the same methods/ instruments are used by all monitoring agencies. This data is then reported to CPCB for publication.

Apart from the above monitoring network, some of the large industries maintain their own monitoring stations. As of 2004, an estimated 200 industries have automatic ambient air quality monitoring stations (CPCB 2004). Data from these agencies are submitted to the respective SPCBs. Some SPCBs maintain their own monitoring station apart from the network station.

Quality Assurance/ Quality Control

CPCB has been conducting the quality assurance program for SPCBs and inter-laboratory comparison since 1999. The frequency of calibration varies between agencies. CPCB carries out calibration regularly at all the monitoring stations in Delhi. The frequency of calibration reported by NEERI is once in 2 to 3 months. Calibration is conducted using top loading calibrator and the recording of calibration data is not uniform across the different agencies.

Since important decisions are being taken based on the results obtained by CPCB through its air quality monitoring programme on various pollution control activities, it is important that the data being generated is of acceptable quality. To ensure the quality of data, CPCB is carrying out various exercises as follows:

1. Regular visits of monitoring stations and laboratories to ensure proper methodology for sampling and analysis.
2. Conducting review meetings with monitoring agencies to discuss various problems related to monitoring activities and sort remedial measures.

3. Training of people involved in air quality monitoring including sampling and analysis. CPCB carries out training program on ambient air quality monitoring with an objective to improve quality of data generated under NAMP. Training is provided to field and laboratory staff involved in NAMP. The training is provided on measurement methods of air pollutants—i.e., SO_2, Nitrogen dioxide (NO_2), RSPM, and SPM.
4. Conducting regular analytical quality control exercises using ring test facility to evaluate the performance of different laboratories.
5. Developing a guideline for evaluation of laboratories and their performance for recognition under the Environment Protection Act (EPA).
6. Based on the data obtained, judiciaries, the Government, and other agencies take important decisions (costing enormous resources to the country). Thus, the quality of data is critically important. To ensure the quality of data, regular calibration, servicing, and repair of the field device is a must. Realizing this fact, CPCB has initiated the project entitled "Calibration and Evaluation of Ambient Air Quality Monitoring Stations in India." In this project, the consultant evaluates all monitoring stations as per CPCB guidelines and carries out servicing, repair, calibration of high-volume samplers, respirable dust samplers, and balance (CPCB 2006b). A similar exercise was carried out earlier in 1996 also.
7. CPCB compiled a report entitled "Guidelines for Ambient Air Quality Monitoring," which includes monitoring methods, guidelines for locating stations, and quality control and quality assurance in air quality monitoring (SASEC 2005). This report has been provided to all monitoring agencies and an official of CPCB inspects the stations to ensure a uniform methodology is being carried out.

Air Quality Reporting

Monitoring data is submitted to CPCB by agencies responsible for the operation of NAMP stations every month. The agencies enter data in an environmental data bank software, where data is checked and displayed on the CPCB website; thereby, reducing delay in its dissemination. Raw data is collated, compiled, interpreted, and analyzed in CPCB. Annual air quality data, as collected at the stations under NAMP, are provided on CPCB's website. The analyzed data is compiled in the form of a report on Ambient Air Quality Status and Statistics and published every year. Air pollution status of various pollutants are reported in terms of low, moderate, high, and critical in relation to the notified ambient air standards. The most recent, issued in 2004, has included air quality trends in 17 polluted cities as identified by the Supreme Court. (National Ambient Air Quality Status Report [NAAQSR] 2004)

Following are the initiatives taken by CPCB for faster dissemination of data.

Environmental Data Bank. CPCB has developed a web-based software known as Environmental Data Bank (EDB). The various monitoring agencies enter data in EDB on internet and data is received instantaneously on CPCB server from where it is checked and displayed on CPCB website on a daily basis. Data of 287 monitoring stations under NAMP is being entered in EDB. The data in EDB software is available to public currently on CPCB website.

On-line Data Transmission from Continuous Ambient Air Quality Monitoring (CAAQM) Stations of Delhi. To provide data to the public on a real-time basis, the networking of CAAQM stations of the Delhi project has been initiated with four air quality monitoring stations composed of three fixed monitoring stations and one mobile van. All stations are capable of monitoring SO_2, NO_x, CO, RSPM, SPM, benzene, toluene, xylene, and O_3. The three fixed stations are located at Bahadurshah Zafar Marg, Delhi College of Engineering, and Sirifort. CAAQM stations data is available on the CPCB website.

Many SPCBs—notably Maharashtra, Andhra Pradesh, Karnataka, West Bengal, and Gujarat—publish air quality data on their respective websites. Air quality data is also published in city environmental status reports that are submitted by class A urban local bodies to the Ministry of Urban Development. While the air pollution index is not formally practiced in India, several newspapers and leading news channels report air quality data from metros in the country on a daily basis. Typically, data on SO_2, NO_x, and SPM is reported in terms of daily maximum or averages. In Pune, the local language newspaper, *Sakaal*, publishes data on maximum air pollutant concentration daily. Air quality data is displayed on electronic signboards in various locations in cities like Delhi, Pune, and Hyderabad.

Ambient Air Quality

PM is the main pollutant of concern in Indian cities. As industrial countries shifted their monitoring efforts to PM_{10}—and more recently to $PM_{2.5}$—on account of overwhelming evidence pointing to adverse health impacts from finer fractions of SPM, CPCB started publishing RSPM data for select cities in 1999. However, monitoring of RSPM by NEERI was started on behalf of CPCB as early as 1993 under the auspices of the NAMP. It still continues to date (World Bank 2005).

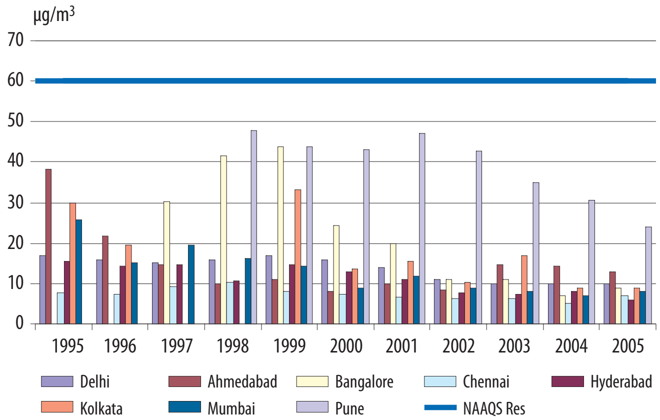
CPCB has established the following criteria for averaging data for ambient air quality: (a) outliers from data are removed; (b) data monitored for 16 hours or more are considered for calculating 24-hour average. Days on which monitoring is carried out for less than 16 hours are not considered; and (c) annual average is calculated only if data is available for 50 or more days in a year.

In the 2004 NAAQR published by CPCB, ambient air quality monitoring was carried out at 224 monitoring stations. Adequate data[1] for annual average concentration for SO_2 was received for 203 stations (91%), 204 stations (91%) for NO_2, 196 stations (87.5%) for RSPM, and 188 stations (84%) for SPM.

Sulfur dioxide (SO_2). Figure 3.1 shows the annual SO_2 trends in residential areas in the eight major Indian cities, while SO_2 trends in industrial areas are in Figure 3.2. Both residential and industrial areas' annual SO_2 levels are below the national ambient air quality standard (NAAQS) values of 60 ug/m^3 (residential) and 80 ug/m^3 (industrial). A decreasing trend has been observed in SO_2 levels in residential and industrial areas, which may be due to various measures taken (e.g., reduction of sulfur in diesel etc. and the use of liquefied petroleum gas (LPG) instead of coal as domestic fuel). In addition, conversion of diesel vehicles to compressed natural gas (CNG) may have resulted in the decreasing trend of SO_2 levels.

FIGURE 3.1

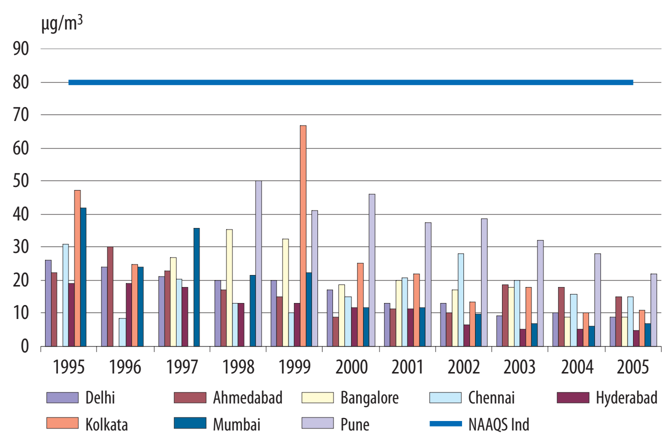
Annual SO_2 Levels in Residential and Other Areas of Eight Major Indian Cities



CPCB = Central Pollution Control Board; NAAQS Res = national ambient air quality standard for residential areas; SO_2 = Sulfur dioxide; and ug/m^3 = microgram per cubic meter
Source: CPCB, 2006.

FIGURE 3.2

Annual SO_2 Levels in Industrial Areas of Eight Major Indian Cities



CPCB = Central Pollution Control Board; NAAQS Res = national ambient air quality standard for industrial areas; SO_2 = Sulfur dioxide; and ug/m^3 = microgram per cubic meter
Source: CPCB, 2006.

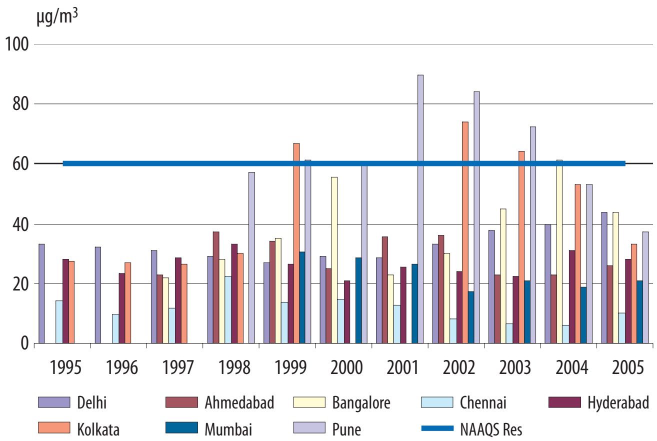
Nitrogen dioxide (NO_2). Figure 3.3 shows the annual NO_2 trends in residential areas in the eight major Indian cities, while NO_2 trends in industrial areas are in Figure 3.4. Both residential and industrial areas' annual NO_2 levels have decreased to levels below NAAQS values of 60 ug/m^3 (residential) and 80 ug/m^3 (industrial). A decreasing trend has also been observed in NO_2 levels in both residential and industrial areas in the last few years for cities with the highest concentrations, although levels in other cities appear to be relatively unchanged. The decreasing trend in NO_2 levels may be due to various measures taken for vehicular pollution control such as stricter vehicular emission norms[2], etc. Vehicles are one of the major sources of NO_2 in the country.

[1] For annual monitoring, 50 or more monitoring days are required.

[2] Norm – terminology used in India for "standard."

FIGURE 3.3

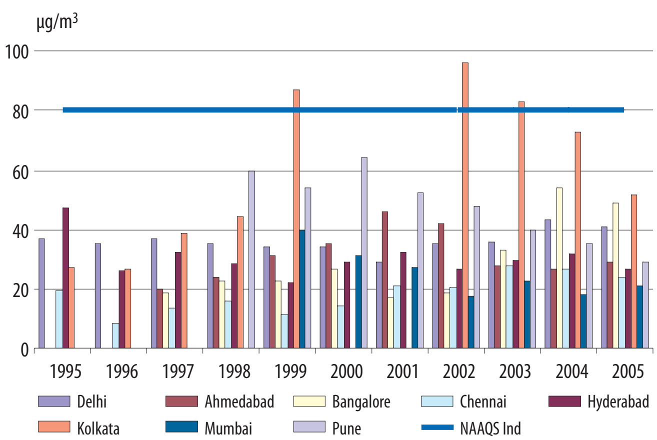
Annual NO_2 Levels in Residential and Other Areas of Eight Major Indian Cities



NO_2 = Nitrogen dioxide; NAAQS Res = national ambient air quality standard for residential areas; ug/m³ = microgram per cubic meter
Source: CPCB, 2006.

FIGURE 3.4

Annual NO_2 Levels in Industrial Areas of Eight Major Indian Cities

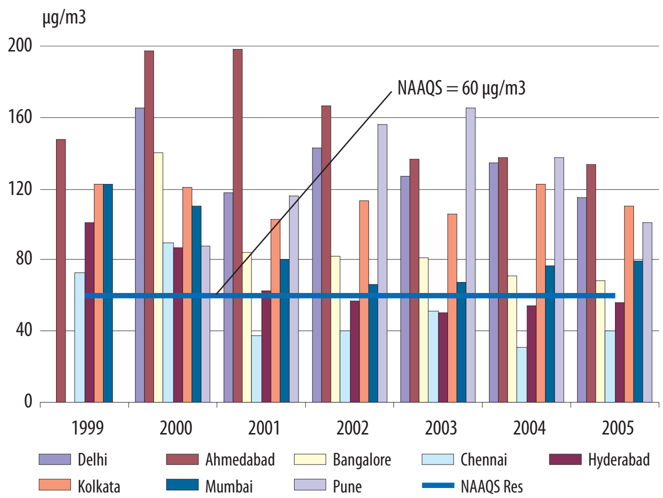


CPCB = Central Pollution Control Board; NAAQS Res = national ambient air quality standard for residential areas; NO_2 = Nitrogen dioxide; and ug/m³ = microgram per cubic meter
Source: CPCB, 2006.

Respirable Suspended Particulate Matter (RSPM). Air quality trends in RSPM in residential and industrial areas in the eight major Indian cities are depicted in Figures 3.5 and 3.6. Data shows almost all residential areas exceeded NAAQS of 60 ug/m3, while industrial areas in Delhi, Ahmedabad, and Kolkata exceeded NAAQS of 120 ug/m3. It is also noted that the trends in annual average SPM concentrations are fluctuating in many cities. However, a decreasing trend has been observed in residential areas of cities including Ahmedabad. RSPM shows a slowly declining trend recently in Chennai, Hyderabad, and Kolkata, and a steady decline since 1997 in Mumbai. Decreasing trend in RSPM levels may be due to various measures taken such as reduction of sulfur in diesel, stringent standard of particulate matter in diesel vehicles, etc.

FIGURE 3.5

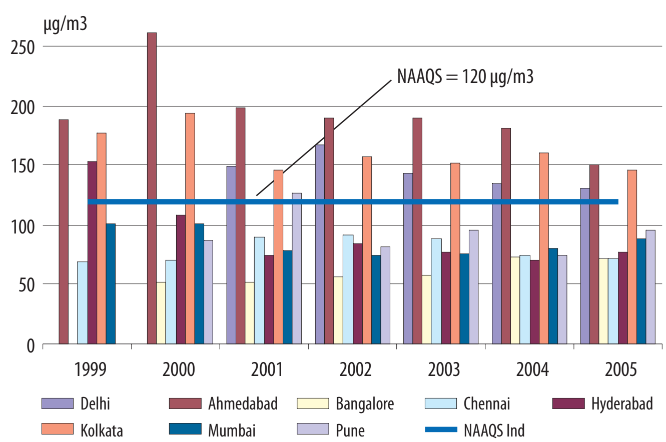
Annual RSPM Levels in Residential and Other Areas of Eight Major Indian Cities



CPCB = Central Pollution Control Board; NAAQS Res = national ambient air quality standard for residential areas; RSPM = respirable suspended particulate matter; and ug/m³ = microgram per cubic meter
Source: CPCB, 2006.

FIGURE 3.6

Annual RSPM Levels in Industrial Areas of Eight Major Indian Cities

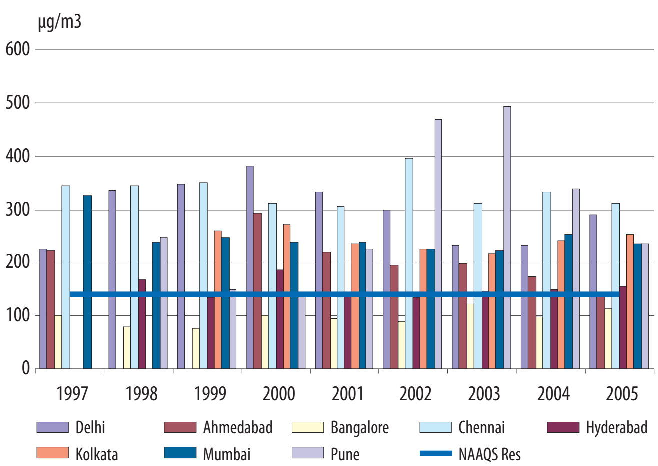


CPCB = Central Pollution Control Board; NAAQS Res = national ambient air quality standard for industrial areas; RSPM = respirable suspended particulate matter; ug/m³ = microgram per cubic meter
Source: CPCB, 2006.

Suspended Particulate Matter (SPM). Trends in annual average concentration of SPM for residential and industrial areas are shown in Figures 3.7 and 3.8 respectively. Similar to RSPM, SPM trends are fluctuating in many cities. A decreasing trend has been observed in some cities including Ahmedabad, but concentrations in other cities appear to remain relatively unchanged. Data show that Delhi has the highest ambient concentrations of SPM, followed by Kolkata, and then by Mumbai. Chennai and Bangalore have the lowest ambient concentrations among the eight cities. A decreasing trend in SPM levels in some cities but not in others may be due to various measures taken for vehicular and industrial pollution control. Vehicular pollution control measures include stringent vehicular emission norms, reduction of sulfur in diesel, stringent standard of particulate matter in diesel vehicles, etc.

FIGURE 3.7

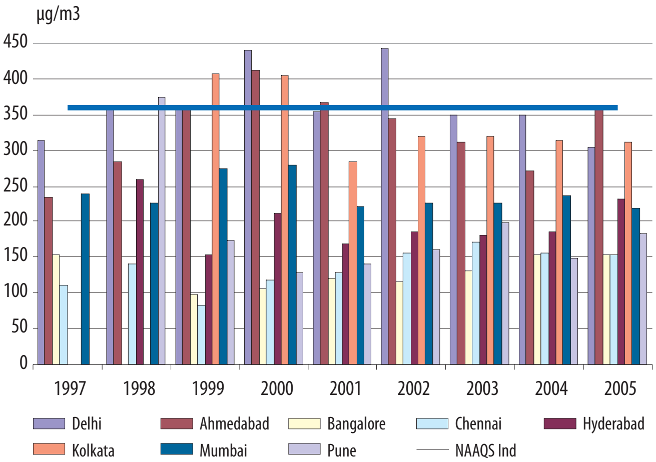
Annual SPM Levels in Residential and Other Areas of Eight Major Indian Cities



CPCB = Central Pollution Control Board; NAAQS Res = national ambient air quality standards for residential area; SPM = suspended particulate matter; and ug/m^3 = micrograms per cubic meter
Source: CPCB, 2006.

FIGURE 3.8

Annual SPM Levels in Industrial Areas of Eight Major Indian Cities



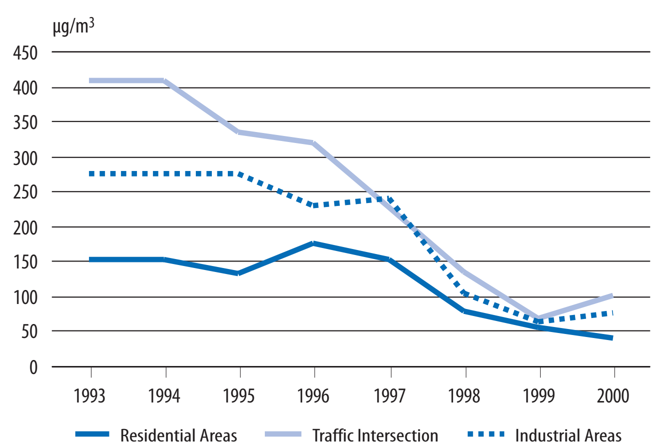
CPCB = Central Pollution Control Board; NAAQS Res = national ambient air quality standards for industrial areas; SPM = suspended particulate matter; and ug/m^3 = micrograms per cubic meter
Source: CPCB, 2006.

Lead. A substantial decrease in the ambient levels of lead was observed since introducing low leaded gasoline in the city. Lead in gasoline has been decreased from 0.56g/l in 1994 to 0.15g/l in 1997 and completely phased out in 1998 (SASEC 2005). The decrease in the ambient levels of lead can be observed in Figure 3.9.

Ozone (O_3). Ambient ozone concentrations in Delhi have been within WHO (2006 update) limits of 100µg/m^3 with some occasional peaks above the guideline values. The values ranged from 32–104µg/m^3 in 1998, 26–82µg/m^3 in 1999, 10–77µg/m^3 in 2000, 10–130µg/m^3 in 2001, and 10–65µg/m^3 in 2002.

FIGURE 3.9

Annual Ambient Lead Concentrations in Delhi



ng/m^3 = nanograms per cubic meter
Source: Sengupta, 2004.

» Part Four

Impacts of Air Pollution

Health Impact

Numerous epidemiologic studies of air quality and health have been conducted in India (Health Effects Institute 2005). Most studies have been published in the past 10 years and collectively, the studies examined the association of PM and gaseous pollutants with mortality, hospital admissions, respiratory symptoms, pulmonary function, and adverse reproductive outcomes. Most were conducted in the northwestern areas of the country, including Delhi, Mumbai, and Ahmedabad. They evaluated respiratory-related symptoms and diseases using cross-sectional study designs. Half of the studies estimated the effects of exposure to both PM and gaseous pollutants. The other half estimated the effects of exposure based on residential proximity to air pollution sources and haze (Public Health and Air Pollution in Asia—Science Access on the Net [PAPA-SAN] 2006). The complete table of Indian studies as of June 2005 is available at www.healtheffects.org/Asia/PAPA-Table4.pdf.

Health-related studies with respect to air pollution have been carried out in Delhi, Mumbai, Hyderabad, Bangalore, Kolkata, Ahmedabad, Chennai, and Cochin by various organizations. Several organizations are involved in health-related studies and the description and results of the studies can be found in the SASEC Final Report (www.cleanairnet.org/caiasia/1412/articles-70581_v45b.pdf).

CPCB, with support from SPCBs, has been regularly sponsoring epidemiological studies. Details of two recent studies (CPCB 2006b), which are being finalized, is as follows:

TABLE 4.1

Epidemiological Studies

Title of Study	Description	Objectives	Scope of Work
Epidemiological to find the Effect of Air Pollutants in Delhi	A study is being carried out on epidemiological effects of air pollutants (specifically, RSPM and other carcinogens on human health in Delhi). The study is being carried out by Chittaranjan National Cancer Institute (CNCI), Kolkata and is sponsored by CPCB.	To prepare a database on air pollution-related respiratory symptoms among the residents of Delhi. To assess the degree of lung function impairment in persons chronically exposed to the city's air. To explore the underlying mechanism of air pollution-related pulmonary dysfunction at the cellular and subcellular level.	The scope of work involves health assessment including evaluation of respiratory symptoms through questionnaire survey and clinical examination, assessment of lung function, assessment of cellular lung response to air pollution, assessment of systemic effects of Delhi's air pollution, assessment of hematological profile, changes in liver and kidney function, assessment of genotoxic effects, and correlation between health effect and air quality.
A Study on Ambient Air Quality, Respiratory Symptoms and Lung Function of Children in Delhi	The study is being carried out by Chittaranjan National Cancer Institute (CNCI), Kolkata.	Assessment of the respiratory health status of schoolchildren chronically exposed to ambient air pollution of Delhi; and Establishment of a database relating to pollution related respiratory problems among children of the city.	Prevalence, duration, and severity of respiratory symptoms will be determined from questionnaire responses and actual tests on various physiological parameters like lung function tests.

Source: CPCB, 2006a.

BOX 4.1

Mumbai Benefits Mapping and Analysis Program (BenMAP)

A study of air quality trends and health impacts in Mumbai was carried out in January 2006. The environmental BenMAP was primarily intended as a tool for estimating the health impacts and associated economic values associated with changes in ambient air pollution. BenMAP combines health impact functions, which relate a change in the concentration of a pollutant with a change in the incidence of a health endpoint, with estimates of air quality. BenMAP also calculates the economic value of health impacts.

BenMAP also serves as a geographic information system, allowing users to create, utilize, and visualize maps of air pollution, population, incidence rates, incidence rate changes, economic valuations, and other types of data.

Source: Environmental Benefits Mapping and Analysis Program, Case Study. Mumbai. 2006. Prepared by – Abt Associates Inc. January.

The following summarizes some gaps in health impact studies conducted in India (SASEC 2005). There is a need to:

1. Centralize systems for the collection of health-related data relevant to air pollution.
2. Establish or strengthen national and local epidemiological monitoring programs that record morbidity and mortality cases associated with air pollution on a regular basis and use environment and health indicators following regional guidelines where they exist.
3. Regularly collect hospital data on health outcomes relevant to air pollution including respiratory, cardio cerebrovascular, congestive heart failure, emergency room visits for respiratory illness, new cases of chronic bronchitis, deaths from cardiovascular, cardiopulmonary, lung cancer, respiratory illnesses, etc.
4. Conduct studies to estimate public exposure to potential health impacts from air pollution in a broader range of cities.
5. Consider health-related data in cities before deciding on relevant policies.
6. Conduct studies in India on dose-response functions that relate ambient levels of pollutants to impacts on specific assets or certain aspects of health, marginal physical impact per unit of pollution, monetary values per unit of physical impact, and monetary value of benefits/damage due to changes in air pollution.

Public Perception

The World Bank conducted a public perception survey in 2004. One purpose of the survey was to compare the perceptions of stakeholders to the findings of the recent analyses of air quality trends and sources of particulate air pollution in Indian cities. The survey was not designed to yield statistically significant results. It was rather a modest attempt to get a broad picture of the perceptions and understandings of informed observers of urban air pollution in India. Nearly half of the respondents said that air quality in their cities was deteriorating. Transport was considered the most important cause of air pollution. Delhi residents were more optimistic about AQM than those in other cities. Asked about barriers to effective,AQM, respondents cited a lack of political will as the greatest obstacle, followed by lack of information and knowledge at the decision-making level. Consistent with these answers, sharing knowledge and lessons from international experience and assisting sectors that influence air quality were seen to be the most important support international agencies could provide.

» Part Five

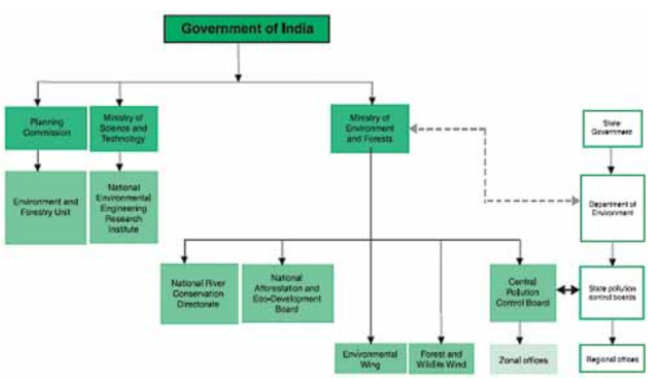
Air Quality Management

Legislation

MoEF, constituted in 1985, is the nodal agency in the administrative structure of the Central Government responsible for AQM. Different ministries, boards, and organizations responsible for AQM are shown in Figure 20. MoEF, CPCB, and SPCBs form the regulatory and administrative core, while other ministries and bodies are also involved through various functions, policies, and schemes to promote AQM. In addition, there is a network of government and nongovernmental institutions, organizations and laboratories involved in monitoring, reporting, and conduct of AQM studies.

FIGURE 5.1

Air Quality Management Structure in India



Source: CPCB, 2006.

The Government of India enacted the APA in 1981 to arrest the deterioration in air quality. The act prescribes various functions for CPCB at the apex level and SPCB at the state level. The main functions of CPCB are as follows:

- To advise the Central Government on any matter concerning the improvement of air quality and the prevention, control, and abatement of air pollution.
- To plan and cause to be executed a nationwide program for the prevention, control, and abatement of air pollution.
- To provide technical assistance and guidance to SPCB.
- To carry out and sponsor investigations and research related to air pollution prevention, control, and abatement of air pollution.
- To collect, compile, and publish technical and statistical data related to air pollution; and
- To lay down standards for the quality of air and emission quantities.

The main functions of SPCB are as follows:

- To plan a comprehensive program for prevention, control, or abatement of air pollution and to secure the execution thereof.
- To advise the state Government on any matter concerning prevention, control, and abatement of air pollution.
- To collect and disseminate information related to air pollution.
- To collaborate with CPCB in program related to prevention, control, and abatement of air pollution.
- To inspect air pollution control areas, assess quality of air, and to take steps for prevention, control, and abatement of air pollution in such areas.

MoEF constituted the Environment Pollution (Prevention and Control) Authority (EPCA) for the NCR in 1998. EPCA was given sweeping powers; it was enabled to take the necessary steps to ensure compliance with directions of different agencies. EPCA could take up matters on its own or receive complaints. It was also given extensive powers of search, entry, inspection, and seizure (CSE 2005). CPCB laid down national standards on ambient air quality and source specific emission standards for implementation at the local levels through the concerned officials of SPCBs.

In recent years, the judiciary has been playing an important role in promoting AQM initiatives through judicial interventions on public grievances voided in public interest litigations (PILs)/writ petitions on air pollution. A number of judgments relating to stringent vehicle emission norms, fuel quality, introduction of cleaner fuels, phasing out of older vehicles, and shifting of hazardous industries have provided a great deal of momentum to the efforts for improvement of air quality.

BOX 5.1

Supreme Court Directive on Developing Air Quality Action Plans in Indian Cities

The Supreme Court (SC) of India passed in April 2002 an order considering the formulation and implementation of action plans for the control of pollution in selected cities that do not meet the ambient air quality standards. Initially, nine cities were listed in the April 2002 order and four cities were added in May 2002 with three additional cities in August 2003. Based on air quality data from 1995 to 2001, CPCB and MoEF identified 53 non-attainment cities and towns. Concerned SPCBs were requested to identify air polluting sources, assess pollution load, prepare a city-wise action plan for AQM, and set up inter-agency task force for formulation and implementation of action plan. The State governments and EPCA have agreed upon a common minimum program for all Indian cities for Delhi NCR. Some key issues addressed in this program include emission norms and automotive fuel quality, alternative fuels, public transport system and transportation plan, in-use vehicles, vehicle inspection, adulteration of automotive fuels, control of emissions from industrial and commercial sources, and air quality monitoring network.

Summary of action plans for 16 cities submitted by the state government/state boards are annexed to the SASEC report. The Centre for Science and Environment's (CSE)'s "The Leapfrog Factor" cited ministry officials as saying that 53 cities have already submitted their action plans.

This SC-led process has pushed cities toward a composite framework for addressing different pollution sources and developing proper AQM tools, which has caused both the union and state governments to address common key strategies that cut across all cities, to curb vehicular pollution. These include tightening of the emissions standards, developing a public transport policy, controlling travel demand, expanding the clean fuel programs, and formulating an effective policy for in-use vehicle inspection programs. All state governments concerned have constituted a task force under the authority of either SPCBs or the chief secretary. This has helped overcome the problem of lack of coordination among implementing agencies. The SC initiative has also moved MoEF to begin an executive process to coordinate city action plans. State-level coordination committees have been formed to supervise the action plans.

The overriding concern of EPCA during the early stages of the action plan preparation has been the tendency to propose minimum norms and use of national laws and provisions as the basis of most actions. However, recognizing limited management capacities at city levels, EPCA accepted the city plans as the common minimum but focused on ensuring and tightening implementation.

Source: CSE 2005.

Ambient Air Quality Standards

CPCB is responsible for setting NAAQS. The NAAQSR published by CPCB in 2004 stated that ambient air quality objectives/standards are prerequisite to develop a management program for the effective management of ambient air quality and to reduce the damaging effects of air pollution. The objectives of air quality standards are:

- To indicate the levels of air quality necessary with an adequate margin of safety to protect public health, vegetation, and property;
- To assist in establishing priorities for abatement and control of pollutant level;
- To provide a uniform yardstick for assessing air quality at national level; and
- To indicate the need and extent of monitoring program.

NAAQS are presented in Table 5.1. These standards are based on land use and other factors of the area. The guidelines for declaring sensitive areas are as follows:

Sensitive areas may include the following:

1. 10 kms around the periphery of health resorts as notified by SPCBs and in consultation with the Department of Public Health of the concerned state;
2. 10 kms around the periphery of biosphere reserves, sanctuaries, and national parks, so notified by MoEF or concerned states;
3. 5 kms around the periphery of an archeological monument declared to be of national importance or otherwise, so notified in consultation with SPCBs;
4. Areas where some delicate or sensitive to air pollution crops/important to the agriculture/horticulture of that area are grown, so notified by SPCBs and in consultation with the Department of Agriculture/Horticulture of the concerned state; and
5. 5 kms around the periphery of centers of tourism and/or pilgrimage due to their religious, historical, scenic, or other attractions, so notified by the Department of Tourism of the concerned state with SPCBs.

TABLE 5.1

Comparison of India's NAAQS with WHO and US EPA

Air Pollutant	Time-weighted Average	India (μg/m³)[a,b]			WHO[c] (μg/m³)	US EPA July 1997 (μg/m³)
		Industrial	Residential	Sensitive		
NO_2	Annual	80.00	60.00	15.00	40.00	100.00
	24 hours	120.00	80.00	30.00		
SO_2	Annual	80.00	60.00	15.00	50.00	80.00
	24 hours	120.00	80.00	30.00	20.00	365.00
CO	8 hours	5,000.00	2,000.00	1,000.00	10,000.00 (d)	10,000.00
	1 hour	10,000.00	4,000.00	2,000.00	30,000.00 (d)	40,000.00
Pb	Annual	1.00	0.75	0.50	0.50 (d)	1.50
	24 hours	1.50	1.00	0.75		
PM_{10}	Annual	120.00	60.00	50.00	20.00	
	24 hours	150.00	100.00	75.00	50.00	150.00
SPM	Annual	360.00	140.00	70.00		
	24 hours	500.00	200.00	100.00		
NH_3	Annual		100.00			
			400.00			

CO = Carbon monoxide; NAAQS = national ambient air quality standard; NH_3 = ammonia; NO_2 = Nitrogen dioxide; Pb = lead; PM_{10} = particulate matter with diameter less than 10 micrograms; SO_2 = Sulfur dioxide; SPM = suspended particulate matter; US EPA = United States Environmental Protection Agency; WHO = World Health Organization; and ug/m³ = micrograms per cubic meter

[a] Annual average of minimum of 104 measurements in a year, taken twice a week, 24-hourly uniform intervals.

[b] 4-hourly/8-hourly values should be met 98% of the time in a year, it could exceed 2% of the time but not on 2 consecutive days.

[c] WHO 2006.

[d] WHO 2000.

Source: WHO (2006), WHO (2000), US EPA.

CPCB Annual Action Plan, 2005–2006

As per CPCB's action plan for 2006 to 2007 (available on the CPCB website), the total allocated funds of CPCB under NAMP is 250 Indian rupees (Rs) lacs[1] ($0.556 million). CPCB contributes 50% of the operation and maintenance cost and the remaining 50% is contributed by SPCBs. Thus, this figure represents approximately 50% of the total expenditure on air quality monitoring under NAMP. However, SPCBs/PCCs that do not have enough resources of their own; CPCB contributes 100% of operation and maintenance cost. The expenditure on laboratory management and research and development is Rs238.5 lacs ($0.533 million).

NAMP, which also includes the monitoring of toxic and critical pollutants in urban areas, has been allocated funds worth Rs15 million ($335.6 thousand). Establishment of air laboratories under The Laboratory Management and Research and Development project has been allocated Rs5.95 million ($133 thousand).

This project includes:

- Operation and maintenance of continuous air quality monitoring stations in Delhi;
- Quality assurance in air quality measurements;
- Poly-nuclear aromatic HC sampling and analysis in Delhi;
- Standardization of methodology of sampling and analysis of benzene;
- Monitoring of benzene in Delhi and Kanpur/Lucknow (passive sampling method);
- Inspection of Authorized pollution checking centers in Delhi;
- Air quality assessment in different areas including traffic intersections in Delhi;

[1] 1 lac = 100,000

- Studies on spatial and temporal distribution of ambient O_3 in Delhi;
- Development and strengthening of monitoring of ambient $PM_{2.5}$ at Delhi;
- Manual monitoring of ambient air quality in five zonal offices and for reporting on television;
- Fabrication of a new mobile van with facilities for the measurement of SO_2, CO, O_3, PM_{10}, and nitrogen oxide (NO)-NO_2-NO_x, including meteorology parameters;
- Characterization of PM and source identification; and
- Standardization of method for measurement of HC in source emission.

The CAAQM Program is planned for networking at selected locations/cities. CPCB has allocated Rs141 million ($3.15 million) for its implementation activities for 2006. The activities include:

- Setting up continuous ambient air quality monitoring stations in major cities;
- Setting up 16 continuous ambient air quality monitoring stations in 16 cities as per directions of the SC;
- Networking of CAAQM stations in 10 cities;
- Networking of CAAQM stations maintained by industries; and
- Japanese Debt Relief Grant Assistance Project for the import of equipment required for toxic pollutants monitoring.

Management of Mobile Sources

To reduce vehicular emissions, a program schedule has been prepared for mandating emission and reducing concentrations of specified components including benzene, lead, and sulfur in vehicular fuel (Sengupta 2004).

The measures taken by the Government to mitigate emissions from the transport sector are as follows:

Stringent emission norms. In 1991, the first stage emission norms came into force for petrol vehicles and in 1992, for diesel vehicles. From April 1995, new laws were in effect mandating the use of catalytic converters in new petrol passenger cars sold in the four metros of Delhi, Calcutta, Mumbai, and Chennai, along with the supply of unleaded petrol. Availability of unleaded petrol was further extended to 42 major cities later, and now, Euro II grade unleaded fuel is available throughout the country. Emission standards were further raised in 2000 when passenger cars and commercial vehicles had to meet the Euro I equivalent, India 2000 norms, while two-wheeled vehicles were also similarly made to meet tighter emission norms. At present, the emission norms stipulated for two-wheeled vehicles in India are among the most stringent in the world. Euro II (Bharat Stage-II) emission norms for all categories of four-wheeled vehicles are applicable all over India from 1 April 2005. Bharat Stage-III will be made applicable throughout India starting April 2010. However, Bharat Stage-III was introduced in 11 cities[2] in April 2005 and Bharat Stage-IV is planned to be introduced in April 2010 (SASEC 2005).

Emission norms in certain areas. In the case of the NCR, only private vehicles conforming to Euro-II equivalent—i.e., Bharat Stage-II norms—were allowed to register. In Mumbai, Euro-II standards for private vehicles (four-wheelers) have been applicable from 2001. In Kolkata, India,2000 norms (Euro-I) have been applicable from November 1999. Bharat Stage-II norms for new four-wheeler private noncommercial vehicles were introduced in Mumbai from January 2001; Kolkata, in July 2001; and Chennai, in October 2004. Starting 2003, only Bharat Stage-II emissions norms-compliant all new vehicles (except two- and three-wheelers) were registered in Hyderabad, Secunderabad, Bangalore, Ahmedabadm Kanpur, Agra, and Surat. Only those taxis that meet Bharat Stage-II norms are being registered in Delhi (SASEC 2005).

Cleaner fuel quality. Fuel quality specifications have been laid down by the Bureau of Indian Standards for gasoline and diesel for the period 2000–2005 and beyond 2005 for the country. Given the increased usage of diesel in India, it becomes necessary to reduce its sulfur content. In a recent directive by the Supreme Court, the Ministry of Petroleum and Natural Gas is to supply diesel with 0.05% m/m sulphur to NCT by 31 December 2000 and the entire NCR from 30 June 2001. For gasoline, lead was phased out in the entire country from 1 February 2000. Similarly, the benzene content was reduced; and by 2001, gasoline with 1% benzene was supplied to the whole of NCR (CSE 2000).

Inspection and maintenance (I&M). The first and most important step toward emission control for the large in-use fleet of vehicles is the formulation of an I&M system. It is possible to reduce 30–40% emission loads generated

[2] 11cities that had been identified are the four metros—Mumbai, Kolkata, Chennai, New Delhi—and the mini-metros—Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur, and Agra.

by vehicles through proper periodical inspections and maintenance of vehicles. In India, the existing mechanism of I&M, the pollution under check (PUC) system is not fully effective. Regional transport offices authorized PUC testing and certification centers in most petrol pumps (gas stations). With the help of regional transport offices, mobile PUC vans have been created in some areas. These vehicles are rotated and stationed at parking areas, and entry points into cities for the convenience of vehicle owners.

Alternative fuels. All government vehicles were required to fit CNG kits or catalytic converters in December 1996. Customs duty on CNG kit has been exempted for promotion of CNG vehicles. India has about 248,000 natural gas vehicles (including 207,000 classified as cars and light-duty vehicles) and 10,146 buses. It is also estimated that 127,000 vehicles are natural gas three-wheelers and most probably included in the light-duty vehicle classification. The country has 198 natural gas refueling stations. Emission norms for CNG/LPG vehicles and for diesel vehicles fitted with LPG engines were made effective from May 2003.

Tax measures. In addition to various taxes related to motor vehicle procurement and operations, the Government of Tamil Nadu introduced an additional Green Tax (Hindu Business Line 2003) on all classes of old motor vehicles to discourage the use of old vehicles from March 2003. The tax payments are levied for motorcycles (Rs500 for 5 years), other motor vehicle types (Rs1,000 for 5 years), and for motor vehicles with longer than 7 years of registration (Rs500 per annum).

Other measures. Other measures include bans on commercial vehicles more than 15 years old, a ban on the registration of new auto-rickshaws with front engine, replacement of all pre-1990 autos and taxis with new vehicles using clean fuel; and all buses in Delhi to switch to CNG instead of diesel by March 2001 (SASEC 2005).

Traffic management. Restrictions have been imposed on goods vehicles during daytime in Delhi. Left lane has been made exclusive to buses and other heavy motor vehicles in Delhi. Traffic signal clocks have been installed in important red lights in cities including Delhi, Mumbai, Pune, and Hyderabad to enable drivers to switch off their engines depending on the time left in the clocks. Several major cities are also constructing several flyovers and subways and closing T-junctions for better traffic flow.

Public transport system. The number of buses has been increased to discourage the use of private vehicles. Metro Rail Project for Shahdara-Rithala Section in Delhi has been completed and commissioned from December 2003. Several cities in India—including Pune, Delhi, and Ahmedabad—are considering bus rapid transits to complement their existing public transportation system, while other cities (including Chennai, Mumbai, and Delhi) have plans to establish light-rail transport systems.

BOX 5.2

Compressed Natural Gas (CNG) in Delhi

The SC ruling in 1998 mandated CNG as the fuel for public transport in Delhi to control air pollution. In 2002, a further ruling directed the Union government to prioritize the transport sector for CNG and a further four cities have implemented programs for urban transport.[1] The status of action on the issues arising out of the SC's directions in July 1998 and June 2006 are given in Table 9. In Mumbai, the Bombay High Court order stated that all the 137 D diesel engine premier model taxis in Mumbai are either phased out or converted to CNG.

In the mid-1990s, Sunita Narain, director of the New Delhi-based CSE, filed a lawsuit to force Delhi's buses, taxis, and rickshaws to convert to cleaner burning CNG. In July 1998, the SC ordered a ban on leaded fuel, conversion of all diesel-powered buses to CNG, and the scrapping of old diesel taxis and rickshaws. By December 2002, the last diesel bus had left Delhi and 10,000 taxis, 12,000 buses, and 80,000 rickshaws were powered by CNG.

Source: www.zeenews.com, March 27, 2006.

Phase-out of old vehicles. India has number of very old and polluting vehicles. In Delhi, commercial vehicles that are more than 15 years old have been phased out effective December 1998. Buses that are 8 years or more have also been phased out. The replacement of pre-1990 and conversion of post-1990 auto-rickshaws and taxis to clean fuels is in progress in the capital. In Delhi, the contribution of two-wheelers and three-wheelers to all the air pollutants is very high. A study in Delhi found that SPM exposure of commuters depended upon their mode of travel. People traveling in three-wheelers were exposed to the highest levels of SPM with an average of 782 ug/m^3 as against those traveling by buses (354 ug/m^3 of SPM) and cars (398 ug/m^3 of SPM).

BOX 5.3

Air Pollution Down in Delhi, But Better Public Transport Needed, CSE 2005[a]

Although the air in Delhi has improved over the past 10 years, the growing number of private cars on the road continues to worry planners and environmentalists (CSE 2005). Although air pollution levels in New Delhi have gone down by 26% in the past 10 years, the growing number of cars in the city remains an issue for planners and administrators. Likewise, Delhi is still among the 57 most critically polluted cities in the country and the rising levels of NO_x are causing serious concern. CPCB also stated that while levels of PM have dropped significantly, they are still far higher than the desired level.

Delhi would have been suffering a pollution load of 38% more particulate matter had the Supreme Court not intervened to introduce cleaner fuel and emissions technology in the city (CSE 2005). The study points out that despite the dip in particulate matter, Delhi reported a 21.3% increase in lung disease cases, more than 20% increase in asthma attacks, and 25% rise in the number of heart patients. Over 7% of males in the city suffer some form of respiratory disease due to air pollution. Decrease in the pollution level has been reported in a World Bank study in Delhi, Mumbai, Kolkata, Ahmedabad, and Hyderabad and has seen about 13,000 less premature deaths due to air pollution-related diseases. The Delhi chief minister has said that her government is working on an integrated public transport system that will be in place by 2010.

[a] These are Ahmedabad, Lucknow, Kanpur, and Hyderabad. If the national gas grid is implemented, 22 cities will be enabled.
Source: CSE 2005.

Management of Stationary Sources

CPCB has laid down the maximum permissible limits for different pollutants for many categories of industries that contribute to air pollution. The standards have been notified by MoEF under the EPA of 1986. Submission of an environmental statement by polluting units to the concerned SPCBs s has been made mandatory under the Act.

Industries are encouraged to use cleaner and low-waste or no-waste technologies to reduce waste generation and the emission of pollutants (CPCB 2000). There is an opportunity for the demonstration and replication of cleaner technologies in clusters of small-scale industries.

Use of beneficiated coal. MoEF has made it mandatory for thermal power plants located more than 1,000 km from the coal pit-head, or in urban, ecologically-sensitive or critically-polluted areas, to use beneficiated/blended coal containing ash no more than 34%, with effect from June 2002. The power plants using fluidized bed combustion and an integrated gasification combined cycle combustion technologies are, however, exempted from using beneficiated coal irrespective of their locations.

Pollution control in critical areas. Various strategies for control of air pollution in non-attainment cities and problem areas have been adopted. Action plans are being prepared and implemented for the 24 critically-polluted areas. MoEF has initiated environmental epidemiological studies in seven critically-polluted areas viz. Vapi (Gujarat), Angul-Talcher (Orissa), Chembur (Mumbai), Cochin (Kerala), Kanpur (UP), Mandi-Govindgarh (Punjab), Najafgarh drain basin Delhi, and in Pune. Compliance with respective air standards is continuously assessed in 17 categories of highly polluting medium- and large-scale industries as their emissions are regularly monitored. Emission standards have been notified for a large number of industries while several others are being finalized. Minimal national standards have been prepared for highly polluting industries under APA and EPA.

Role of the judiciary. EPCA in NCR has been monitoring the implementation of action points outlined in the White paper on Pollution in Delhi with an action plan and priority measures approved by the Supreme Court.

Guidelines for siting of industries. Guidelines for siting industries are prescribed so that the possible adverse effects on the environment and quality of life can be minimized. Considering some natural life-sustaining systems and specific land-uses are more sensitive, minimum distances for siting a given industry has been prescribed in such cases. In Delhi, the courts ordered that the polluting industries and industries operating in non-conforming areas be either closed or shifted to other areas. CPCB through its Spatial Environmental Planning Cell (SEPC) has been supporting Zoning Atlas project that is targeted to provide siting related advice at district level to the departments of industries in the States through SPCBs. Under this project, tools like a geographic information system are used and air pollution potential is considered as one of the decision variables in recommending siting of industries (MoEF 2000).

Environmental impact assessment (EIA). EIA is an important instrument directed by the EPA of 1986. MoEF has recently introduced thresholds for 32 types of development projects for screening and categorization, emphasized scoping and public consultation, and decentralized the decision-making process. The procedure for examining the impact of different activities includes the preparation of an EIA report, holding a public hearing, and examination by duly constituted appraisal committees at the state and center levels (MoEF 2006). MoEF has also taken up carrying capacity-based regional planning studies in certain selected areas of the country including the NCR. To facilitate conduct of EIA studies, MoEF has piloted Environmental Information Centre on the model of public-private partnership.

Management of Area Sources

Efforts are being made to target non-point sources of air pollution. The open incineration/combustion of dry leaves, old tires, plastics, and garbage is prohibited in Delhi. There is also an encouraging trend toward use of cleaner fuel. For example, LPG is becoming more popular as a domestic cooking fuel. As a control measure to reduce air pollution, massive afforestation and greenery program, and development of green barriers and green buffers are being promoted.

Public Participation

Public awareness and participation are key to bringing about policy change. Widespread environmental education promotes the understanding of linkages between pollution and health and encourages public involvement. Private sector participation through innovative schemes like accepting delivery only from trucks that meet government emission standards, adopt-a-street campaigns, and air quality monitoring displays should be encouraged. Media can also participate in raising awareness by disseminating air pollution related data. Here, *Down to Earth* publication from Centre for Science and Environment, New Delhi has played an important role. Its website www.cseindia.org/apc-index.htm is dedicated to the theme of air pollution and provides updated information on air pollution.

City specific awareness and skills-building programs on air pollution have an important role to catalyze scientific debates, identify and manage collaborative projects, and promote advocacy. In Pune, a series of urban AQM and awareness-raising seminars implemented by the Environmental Monitoring Centre of Pune and organized in partnership with the Air Quality Management Cell of Pune Municipal Corporation has led to the establishment of Clean Air Pune, a network of experts, and representatives of nongovernment organizations and government in Pune. Clean Air Pune is now one of the pro-active networks in India promoting AQM.

» Part Six

Conclusions

The major metropolitan cities in India are facing severe air pollution problems. Critical levels of PM_{10} and SPM exist in many cities. SO_2, NO_x, and lead levels in ambient air are decreasing in most cities due to the measures taken such as reduction of sulfur in fuel and introduction of unleaded petrol. However, continuing severe levels of air pollution are leading to high incidence of respiratory diseases, cancer, and heart diseases. Major economic costs are associated with the health impacts of poor air quality.

Vehicles have been identified as the major source of air pollutants in the largest cities. The reasons for high rates of vehicle emissions include poor fuel quality, high vehicular density, the large number of old vehicles, inadequate I&M system, poor vehicle design, fuel adulteration, improper traffic management, and inadequate mass transport systems. Clearly, control of vehicle emissions in the large cities needs to be highly prioritized. India has identified many issues and is working toward addressing most aspects, although ensuring effective implementation is always a challenge. Strategies that need to be effectively implemented include the promotion of public transport and MRTS together with traffic planning and management. In addition, taxes on fuels and vehicles, stringent emission norms and fuel quality specifications, promotion of cleaner fuels such as CNG, replacement of 2-stroke engines, and a strengthening of the I&M system, are needed.

Industrial sources, both large- and small-scale units, also need to be targeted to reduce air pollution. These include promotion of cleaner technologies, strengthening and effectively implementing emission standards, and introducing economic incentives to reduce or avoid emissions. Emphasis should be given to waste minimization and utilization. In addition, non-point sources of pollution also need to be addressed adequately. A comprehensive urban AQM strategy should be formulated using information related to urban planning, ambient air quality, emission inventory, and air quality dispersion models. Strengthening the monitoring network and institutional capabilities would facilitate an improvement in the enforcement mechanism.

With the enactment of the central legislation for prevention and control of air pollution in 1981, air quality issues received countrywide attention. However, it took several years to build up the monitoring facilities and to create a database on air quality status and trends. NAMP initiated by CPCB in collaboration with NEERI and SPCBs led to a beginning of air quality monitoring network in 1984. Over the years, monitoring stations have increased in numbers and the capabilities for monitoring have improved. Dissemination of air quality data through the media has helped in raising awareness of air quality issues. With the increasing awareness, the public demand for air pollution control increased and it was reflected in the representations and public interest litigations and petitions. Judicial interventions in response to the litigations and petitions also helped enforce air pollution control measures, tighten emission standards, switch to cleaner fuels, and the relocation of polluting industries.

Notwithstanding various developments, there is a need for the establishment of a well-conceived network for a common understanding among the stakeholders representing diverse sections of society. The existing networks are mostly intermittent in nature with the involvement of particular interest groups which may not serve the long-term needs for integrated AQM.

Health risk studies are major factors driving actions to address air pollution. Health regulatory and research agencies in India must build capacities to undertake epidemiological studies on the health impact of air pollution.

The SC's intervention demonstrated the need for a more structured national-level system of AQM. The city-specific model of management, compliance, and enforcement is still very weak. To achieve its goal in achieving clean air, India must establish a legal framework to ensure the enforcement of agreed measures. Although considerable progress has been made in recent years, much of this progress has been based on a series of individual actions, often in individual cities with varying effectiveness of implementation. A systematic approach required—national in vision, with senior-level commitment—a broad, transparent plan including targets and dates to be achieved, with a clear allocation of responsibilities and resources for implementation, public reporting,— and accountability for achievement of targets, and publicly reported review and improvement.

References

ABT Associates, Inc. 2006. Environmental Benefits Mapping and Analysis Program. Case Study: Mumbai. Prepared by - Abt Associates Inc. January.

Asian Development Bank (ADB). 2006a. Key Indicators. Available online at www.adb.org.

———. 2006b. Outlook 2006: India. Available at: www.adb.org/Documents/Books/ADO/2006/documents/ind.pdf.

Auto Fuel Policy. 2005. Available at: www.petroleumbazaar.com/Library/auto%20fuel%20policy/ch_4.pdf.

Bose, Ranjan. 1990. Environmental Implications of energy use in the city of Delhi.

Bose, Ranjan. 2006. Energy Efficiency and Climate Change Considerations for On-road Transport in Asia. Available at: www.cleanairnet.org/caiasia/1412/articles-70656_draft2.pdf.

Bose, Ranjan. 2006. Bose's paper which was included in the Draft Policy Paper on (Energy Efficiency and Climate Change Considerations for On-road Transport in Asia) as Appendix III.

Brandon, Carter, et al. 1995. The cost of inaction: valuing the economic-wide cost of environmental degradation in India. World Bank: Washington DC, USA. P. 6.

Central Pollution Control Board (CPCB). 2004a. Integrated Air Quality Management in India. Presented during BAQ 2004 by CPCB. Available at: www.cleanairnet.org/baq2004/1527/article-59087.html.

———. 2004b. National Ambient Air Quality Status Report.

———. 2006a. Personal correspondence of Naresh Badhwar with N. Ramirez. 31 October.

———. 2006b. Personal correspondence of Naresh Badhwar with N. Ramirez. 08 November.

CSE 2005. The Leapfrog Factor: Clearing the Air in Asian Cities. Available at: www.cseindia.org/campaign/apc/leapfrog_factor.htm.

———. 2000. Working Model of Vehicular Pollution of Delhi for 1999–2015.

Department of Road Transport and Highways. 2006. Total Number of Registered Motor Vehicles in India 1951– 2003. Available at: http://morth.nic.in/motorstat/Table%20No11.htm. Accessed on July 2006.

Health Effects Institute (HEI). 2004. Special Report #15. Available at: http://pubs.healtheffects.org/view.php?id=3.

India Energy Outlook. 2006. Health Effects of Outdoor Air Pollution in Developing Countries of Asia: A Literature Review. Available at: www.in.kpmg.com/pdf/India_Energy_Outlook_2006.pdf.

India in Business. 2006. Available at: http://india.gov.in/outerwin.htm?id=http://indiainbusiness.nic.in. Accessed on September 2006.

Ministry of Environment and Forestry (MoEF). 2000. Report of the Committee on Environment and Health. May.

National Ambient Air Quality Status. 2004. Available at: www.cpcb.nic.in.

Public Health and Air Pollution in Asia—*Science Access on the Net* (PAPA-SAN). 2006. April. Available at: www.healtheffects.org/Asia/papasan-resultsbycountry.htm#india. Accessed on September 2006.

Sengupta, B. 2004. Air Quality Management In India—Gaps And Limitations. Paper Presented at Workshop organized by the World Bank / MoEF / CPCB on Urban Air Quality Management : Progress and Future Challenges. New Delhi. 18–19 October. Available at: http://lnweb18.worldbank.org/SAR/sa.nsf/Attachments/PresSengupta/$File/Dr+Sengupta+-+CPCB.ppt.

South Asian Subregional Economic Cooperation (SASEC). 2005. Countries For Regional Air Quality Management. Asian Development Bank. December. Available at: www.cleanairnet.org/caiasia/1412/article-70581.html.

The Hindu Business Line, 2003. Motor vehicles tax hiked — Green Tax introduced in TN. Available at: www.thehindubusinessline.com/2003/03/22/stories/2003032201881700.htm.

United States Environment Protection Agency (US EPA). 2006. National Ambient Air Quality Standards. Available at: http://epa.gov/air/criteria.html.

Urban Air Quality Management Strategy in Asia (URBAIR). Available at: www.aespl.co.in/URBAIR.pdf.

World Bank. 2004. Urban Air Pollution in India: Perceptions of Stakeholders. South Asia Urban Air Quality Management Briefing Note No. 15. Available at: http://lnweb18.worldbank.org/sar/sa.nsf/Attachments/Briefing15/$File/Briefing_Note_No_15.pdf.

World Health Organization (WHO). 2000. Guidelines for Air Quality. Geneva: WHO. Available at: http://whqlibdoc.who.int/hq/2000/WHO_SDE_OEH_00.02_pp1–104.pdf.

———. 2006. WHO Air Quality guidelines for particulate matter, ozone, Nitrogen dioxide, and Sulfur dioxide. Global Update 2005. Summary of Risk Assessment. Available at: www.who.int/phe/air/aqg2006execsum.pdf.