3

Managing air quality

The rate at which urban air pollution has grown across India is alarming. A vast majority of cities are caught inextricably in the toxic web as air quality fails to meet health-based standards. Almost all cities are reeling under severe particulate pollution while newer pollutants like oxides of nitrogen and air toxics have begun to add to the public health challenge.

India's capacity to monitor and assess the problem of air pollution remains abysmally weak, which impedes nationwide planning and action. The data generated allows only a fragmented, though scary picture of the status of air quality in our cities. On a nationwide scale, very few pollutants are monitored on a regular basis, making risk assessment difficult. The planners do not have a complete understanding of the whole range of local situations to assess the exposure levels. Many Western countries with severe air pollution problems have begun monitoring almost half a dozen pollutants regularly, if not more, and study their health implications, to take remedial measures. Apart from creating a health advisory, monitoring also helps assess the impact of pollution control decisions on air quality.

In India, despite advances in the scale and scope of urban air quality monitoring in recent years, major hurdles persist in getting comprehensive and reliable data, which can pass the muster of rigorous quality control criteria. Therefore, poor data quality, weak institutional capacity to assess pollution sources and the absence of an effective legal framework for air quality management are the reasons for ad hoc and fragmented planning.

In the absence of a strong scientific framework, a few rapid and ad hoc pollution inventory studies undertaken by different agencies are becoming increasingly vulnerable to biased interpretation, keeping policy action lenient. It is not always clear from existing studies as to which pollution sources are important in terms of maximum toxic exposure to the population. As a result, policy-makers are often not clear on interpreting and using the results of these studies for their decisions. For instance, contribution of vehicles to finer particulate pollution load in India is often played down to stave off hard decisions. It is clear that state regulatory authorities will have to develop the capacity for autonomous air quality planning, free from industry bias.

It is important to improve air quality monitoring in cities to assess the risk of air pollution, to formulate appropriate policies to control it and to create awareness and sensitise people to prepare them for hard policy decisions.

Right to
CLEAN AIR

- Particulate pollution is a scourge in Asia. Since 1990, there has been a consistent increase in pollution levels of particulate matter of size less than 10 micron (PM_{10}) across the Asian region

- In more than half the cities monitored in India, PM_{10} has reached critical levels. An obscure and small city like Raipur tops the list and is ranked as more polluted than even big metros

- While particulates remain a killer, nitrogen dioxide has emerged as a new threat. Cities with high vehicular traffic are in its pincer grip

- Air quality data do not meet the quality benchmark in India. Data from a large number of monitoring stations are rejected as they fail to fulfill the minimum criteria

- Weak science leads to weak action. Pollution inventory studies in themselves are not sacrosanct. Unless these are used along with other criteria, including toxicity and exposure assessments, misleading policy conclusions can be drawn

- The Supreme Court in India has shown that it is possible to act based on the existing knowledge — achieve balance between composite and priority action for effective impact

- Air quality planning framework is ineffective in India because ambient air quality standards are not legally enforceable

3.1 State of urban air in Asia

Urban air is a cocktail of particulates and gaseous pollutants, including nitrogen oxides (NO_X), sulphur dioxide (SO_2), carbon monoxide (CO), benzene, ozone (O_3), a range of polycyclic aromatic hydrocarbons (PAH) and a variety of volatile organic compounds (VOCs).

Some of the worst cases of outdoor air pollution are found in Asian, particularly Indian cities. Even medium and small-sized cities are witnessing a phenomenal spurt in pollution as severe as any megacity. Within a span of only a few years, there has been an explosion in information from various cities in Asia, signalling a severe crisis. There is now a desperation in the region to assess the problem and shop for a menu of actions to curtail this menace.

The overriding concern is the very high levels of particulate matter (PM) of different size fraction, coming from various sources, these show very high concentration in several Asian cities. The most commonly reported parameter is the total suspended particulate matter (TSPM). Not many cities in Asia separately monitor the smaller size fractions such as PM_{10} and $PM_{2.5}$ (PM less than 10 and 2.5 micron size). Data for PM_{10} is available only for a few. A joint report of World Health Organization's (WHO), United Nations Environment Programme (UNEP) among others called *Air Pollution in Megacities of Asia, 2002*, shows that since 1990, there has been a consistent increase in PM_{10} levels across the region, which shows a distinct regional pattern. The Boston-based Health Effects Institute (HEI) reports that annual mean PM_{10} levels tend to be higher in middle-income east Asian — mainly Chinese — cities, and in lower-income south Asian — mainly Indian — cities compared to middle or high-income Asian cities, including Bangkok, Busan, Hong Kong and Seoul. One of the cleanest in Asia is Singapore.[1] Beijing, Shanghai, Hanoi, Kathmandu and Jakarta are reeling under severe PM_{10} load. Particularly, in south Asian countries like Pakistan, Bangladesh, Sri Lanka and Nepal, fine particulate pollution has acquired worrisome proportions.

A World Bank, Washington, DC, study released in March 2004, which looked into fine particulate pollution in south Asian cities, shows typically high levels of PM_{10} and $PM_{2.5}$ in the region. Several large Indian cities and also south Asian ones like Dhaka, Colombo, Lahore and Kathmandu have an alarmingly high concentration of particulates.[2] Lahore records average PM_{10} levels of 900 microgramme per cubic metre, which is extremely high by any standard. The study cautions that in Lahore, if $PM_{2.5}$ is taken as one-half, or less, of the PM_{10} level, then even that would be very high in relation to any ambient air quality standard worldwide.[3] In comparison, levels of nitrogen dioxide (NO_2), SO_2, CO and O_3 have been relatively low, not exceeding WHO's health-based guidelines though NO_2 has been increasing in these cities.[4]

Action has begun — though not uniformly aggressive — to lower particulate pollution. Its impact has also begun to show. A combined study by the World Bank and the Clean Air Initiative for Asian cities (CAI-Asia), released in December 2004, analysed the air pollution levels in 20 cities. The study compared the air quality trend for two time slabs — 1990-1999 and 2000-2003 — to assess the impact of actions begun in many of these cities. But it showed that even after a substantial improvement in its air quality, Delhi — one of the most polluted during the 1990s — was still at the top.[5]

The comparison further showed that PM_{10} levels had begun declining in all cities except Taiwan, whereas the levels were more or less constant in Busan and Colombo. The SO_2 levels had declined in almost all except Colombo and Hong Kong, where they showed a slight increase. Also, some Chinese cities like Chongqing were able to curb SO_2 by changing the energy matrix and moving away from sulphur-rich coal. In many Chinese cities, coal is still the main power source and, therefore, a major source of SO_2 emissions.[6]

NO_2 levels, on the other hand, recorded a rise in many Asian cities, including Bangkok, Chongqing, Busan, Kolkata, Hong Kong, Osaka, Pune, Seoul and Tokyo.[7] Vehicular traffic was largely held responsible for this trend. Its levels exceeded WHO guidelines in some cities. An HEI study of 2004 points out, "Some cities like Shanghai and Seoul, where vehicular traffic has been increasing over the past decade, are experiencing especially elevated and increasing levels of NO_2. Maintaining NO_2 even at current levels will be difficult in the face of rapid increases in total energy consumption, vehicle numbers and vehicle miles travelled."[8] The same study warns that increasing NO_X concentration combined with hydrocarbon (HC) from vehicular exhaust, in the presence of abundant sunlight, is the right recipe for hurtling towards an O_3 disaster (see Graph 3.1: *The Asian challenge*).

The NO_2 dilemma further indicates that the mitigation strategy would require to be more holistic to target key pollutants together, to avoid trade off with particulate pollution. For instance, Hong Kong's experience shows that while it has succeeded in taking many aggressive measures to control particulate pollution, it finds that apart from particulates, which are still high near the roadside, roadside NO_X, and O_3 have also begun recording high levels.[9] This truly represents the real scenario of the current Asian air pollution challenge.

AMIT SHANKER / CSE

MEAN STREETS: Some of the worst cases of air pollution are found in Asian cities where the air is laden with several pollutants

Graph 3.1: **THE ASIAN CHALLENGE**

Levels of most pollutants exceed standards in New Delhi, Hanoi, Beijing and Jakarta

Notes: PM_{10} levels are exceeding standards in New Delhi, Beijing, Dhaka and Kathmandu; NO_2 levels are exceeding the World Health Organization guidelines in Beijing, Seoul, Kolkata and Tokyo; SO_x levels are exceeding the World Health Organization guidelines in Hanoi and Beijing; µg/m^3 — microgramme per cubic metre

Timeline of air quality data: Busan (2000-2002); Dhaka (2002-2003); Hanoi (2000-2002); Jakarta (2000-2001); Kathmandu (2003); Manila — PM_{10} (2002-2003); Mumbai (2000-2001); New Delhi (2000-2002); Osaka (2000-2001); Seoul (2000-2002), SPM (2000-2001); Tokyo (2000-2001).

Source: Cornelius Huizenga *et al* 2004, *AQM capability in Asian cities,* paper presented at '13th world clean air and environmental protection congress and exhibition', London, England, August 22-27, p 3

3.2 Air quality status in India

Worldwide, the most widely monitored air pollutants are PM, NO_2, SO_2 CO and O_3. They are also called criteria pollutants as they are the most common indicators of air quality and are regulated. With the exception of O_3 and CO, they are monitored at all stations on a regular basis in India. In the PM category, while TSPM is monitored in all stations, PM_{10} monitoring has also expanded considerably. But chronological data is available for a longer time-frame, (since the late 1980s) and for a larger geographical coverage since the 1990s, only for TSPM, NO_2, and SO_2. It is, therefore, easy to determine their long-term trend across the country.

The latest nationwide data released by the Central Pollution Control Board (CPCB), New Delhi, on its website for 2004 present a very scary picture. The data shows that in more than 60 Indian cities being monitored under the National Air Quality Monitoring Programme (NAMP), at least one criteria pollutant exceeds either the annual average or the 24-hourly ambient air quality standards (see Graph 3.2: *Under the scanner*).

The CPCB defines cities as critically polluted if the levels of criteria pollutants are more than 1.5 times the standards. Levels up to 1.5 times the standard are labelled high; levels dipping till 50 per cent of the standards are considered moderate. Below this they are low.

Besides criteria pollutants there is a range of air toxics. These are extremely lethal even in very small trace amounts. These are largely VOCs, including benzene, xylene, toulene and also a group of PAHs. The WHO does not consider any threshold level as safe for air toxics. Most of these are carcinogens and dangerous even at very low concentration. India's capacity to monitor them is still very weak.

Particulate matter

TSPM shows very strong persistence and very high levels in most cities and a declining trend in some. The CPCB's data for 2004 reveals that while more than two-thirds of the cities monitored have TSPM levels above the standards, exactly half of all monitoring stations have recorded critical levels. Since TSPM includes all possible dust particles, there is considerable contribution from top soil, dust storms in arid zones and wind blown dust from the northwestern deserts of India. Finer particles come largely from combustion sources. TSPM hotspots are, therefore, concentrated in the northern and western regions where the impact of natural dust is higher (see Table 3.1: *TSPM hotspots*).

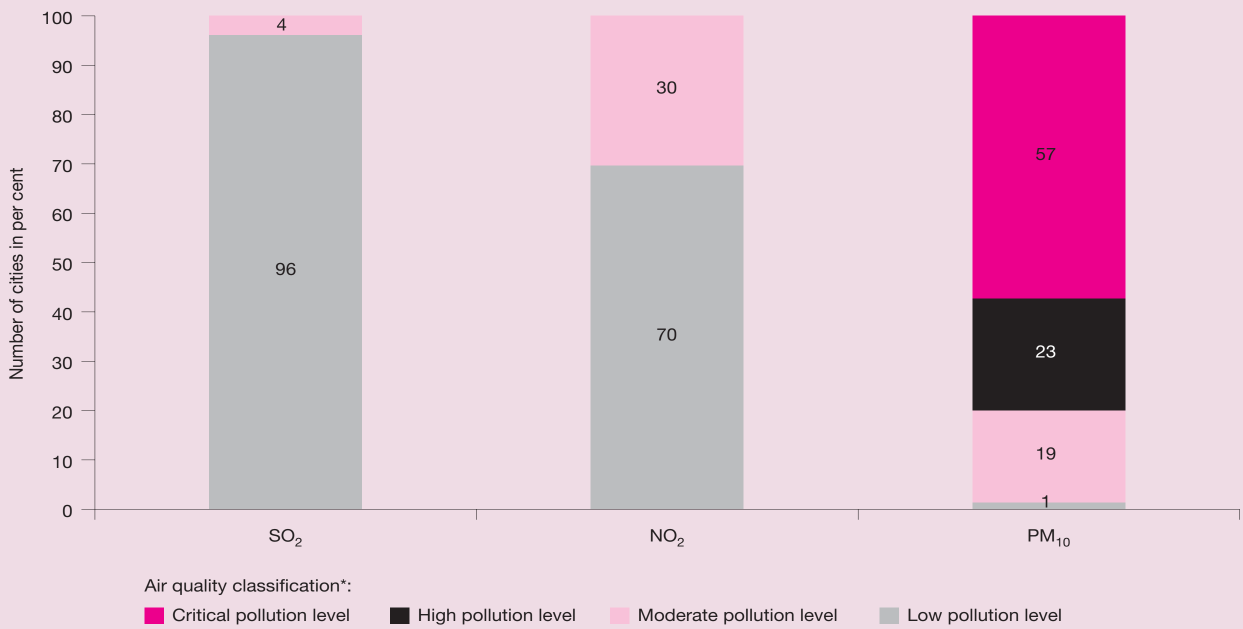
Bigger dust particles from natural sources, however, pose little danger. Therefore, TSPM monitoring has almost been stopped in developed countries of Europe and the US as it is not an adequate indicator of health hazards. The health effect of particles depends on the chemical characteristics and the size of particulates. This requires separate monitoring of smaller size fraction of PM_{10} and $PM_{2.5}$.

SMALL PARTICLES: PM_{10}

Building a long-term trendline for PM_{10} levels in Indian cities is not possible as separate monitoring of PM_{10} began in 1999 and that too

Graph 3.2: UNDER THE SCANNER

During 2004, nearly 57 per cent of the cities monitored recorded critical levels of PM_{10}. About 30 per cent had moderate levels of NO_2 and four per cent had moderate SO_2 levels



Notes: PM_{10} — particulate matter size 10 micron; NO_2 — nitrogen oxide; SO_2 — sulphur oxide

*Air quality classification computed on the basis of standard for residential areas of 60 microgramme per cubic metre (µg/m^3) for three pollutants, SO_2, NO_2 and PM_{10}. Pollution levels in cities: 1. Cities with annual average level more than 50 per cent of the standard is termed as 'critical pollution level', i.e. annual average levels more than 90 µg/m^3. 2. Up to 50 per cent above the standard is termed 'high pollution level', i.e. from 60-90 µg/m^3. 3. From 50 per cent of the standard to the standard limit is termed 'moderate pollution level', i.e. from 30-60 µg/m^3 4. Below 50 per cent is termed 'low pollution level', i.e. from 0-30 µg/m^3.

Source: Anon 2005, *Ambient air quality data year 2004,* Central Pollution Control Board, New Delhi

Table 3.1: TSPM HOTSPOTS

North Indian cities top the chart as TSPM hotspots

Locations	Annual average* 2003	Locations	Annual average* 2004
Nal Stop (R), Pune	521	Town Hall (R), Delhi	508
Nunhai (I), Agra	479	Mayapuri Industrial Area (I), Delhi	484
Town Hall (R), Delhi	478	Fazalganj (I), Kanpur	438
Swargate (R), Pune	465	Golmuri vehicle testing centre (I), Jamshedpur	434
Regional office, (R), Agra	440	Nunhai (I), Agra	431
Fazalganj (I), Kanpur	439	Deputy ka parao (R), Kanpur	428
Gee Pee Electroplating and Eng. Works (I), Noida	431	M/s Woolworth (I) Ltd (I), Raipur	416
Mayapuri Industrial Area (I), Delhi	425	Kidwai Nagar (R), Kanpur	413
Talkatora (I), Lucknow	423	Talkatora (I), Lucknow	408
Kidwai Nagar (R), Kanpur	410	Bistupur vehicle testing centre (I), Jamshedpur	405

Notes: Standard for residential areas 140 microgramme per cubic metre

* — in microgramme per cubic metre, I — industrial area, R — residential area

Sources:

- Anon 2004, *National ambient air quality status 2003*, Central Pollution Control Board, New Delhi
- Anon 2005, *Ambient air quality data year 2004,* Central Pollution Control Board, New Delhi

only in 13 cities. This was gradually extended to 80 cities under NAMP in 2004. Prior to 1999, the Nagpur-based National Environmental Engineering Research Institute (NEERI) had conducted limited monitoring in a few cities. The limited time series data for PM_{10} in most cities do not permit a trend analysis.

Expanding PM_{10} monitoring facilities allowed instant detection of areas reeling under severe respirable particulate pollution. In 2004, PM_{10} levels in 57 per cent of the cities monitored were labelled critical, which meant that the PM_{10} levels were at least one and a half times above the permissible limit for residential areas — 60 microgramme per cubic metre (see Table 3.2: *PM_{10} hotspots*).

What is alarming is that the number of monitoring stations recording exceedance of the 24-hourly standards is higher than those reporting exceedance of the annual standards. In 2003, for instance, as many as 133 monitoring stations had exceeded the 24-hourly standards. In contrast, about 105 stations had violated annual average standards. This means on a daily basis people are exposed to high dose of pollution.

There are, however, specific features of the regional trends. The PM_{10} levels remain persistently high in the northern region. Notoriously high levels of PM_{10} have been recorded in Delhi, Faridabad, Ludhiana, Anpara, Dehradun and Kanpur. In western and eastern India, there is usually a mixed trend. Ahmedabad, Alwar, Jaipur, Rajkot, Solapur and Satna show very high levels of PM_{10}. Similarly, in the east, the key metro and industrial cities show high levels of $PM_{10.}$ These include Kolkata, Korba, Raipur and Jamshedpur.

In southern India, though the cities generally have lower PM_{10}

Table 3.2: PM_{10} HOTSPOTS

Even lesser known cities are now ranked along with the most polluted ones

Locations	Annual average* 2003	Locations	Annual average* 2004
Rita Sewing Machines (I), Ludhiana	295	M/s Woolworth (I) Ltd (I), Raipur	292
Focal Point (I), Jalandhar	291	New HIG - 9, Hirapur (R), Raipur	275
Sardhara Industrial Corporation (I), Rajkot	275	Sardhara Industrial Corporation (I), Rajkot	220
M/s Wool Worth India Pvt Ltd (I), Raipur	246	Mayapuri industrial area (I), Delhi	213
Regional office (R), Jalandhar	245	Sub-divisional office (I), Satna	209
M/s Modi Oil and General Mills (I), Mandi Gobindgarh	241	Fazalganj (I), Kanpur	196
New HIG-9, Hirapur (R), Raipur	240	Deputy ka parao (R), Kanpur	189
M/s Hargobind Steel Industries (I), Mandi Gobindgarh	236	Cadilla Bridge, Narol (R), Ahmedabad	187
CETP Nandeswari (I), Vadodara	233	Talkatora (I), Lucknow	185
Regional office, Punjab SPCB (R), Ludhiana	218	CETP Nandeswari (I), Vadodara	184

Notes: Standard for residential areas is 60 microgramme per cum; *in microgramme per cubic metre; I — industrial area; R — residential area

Sources:

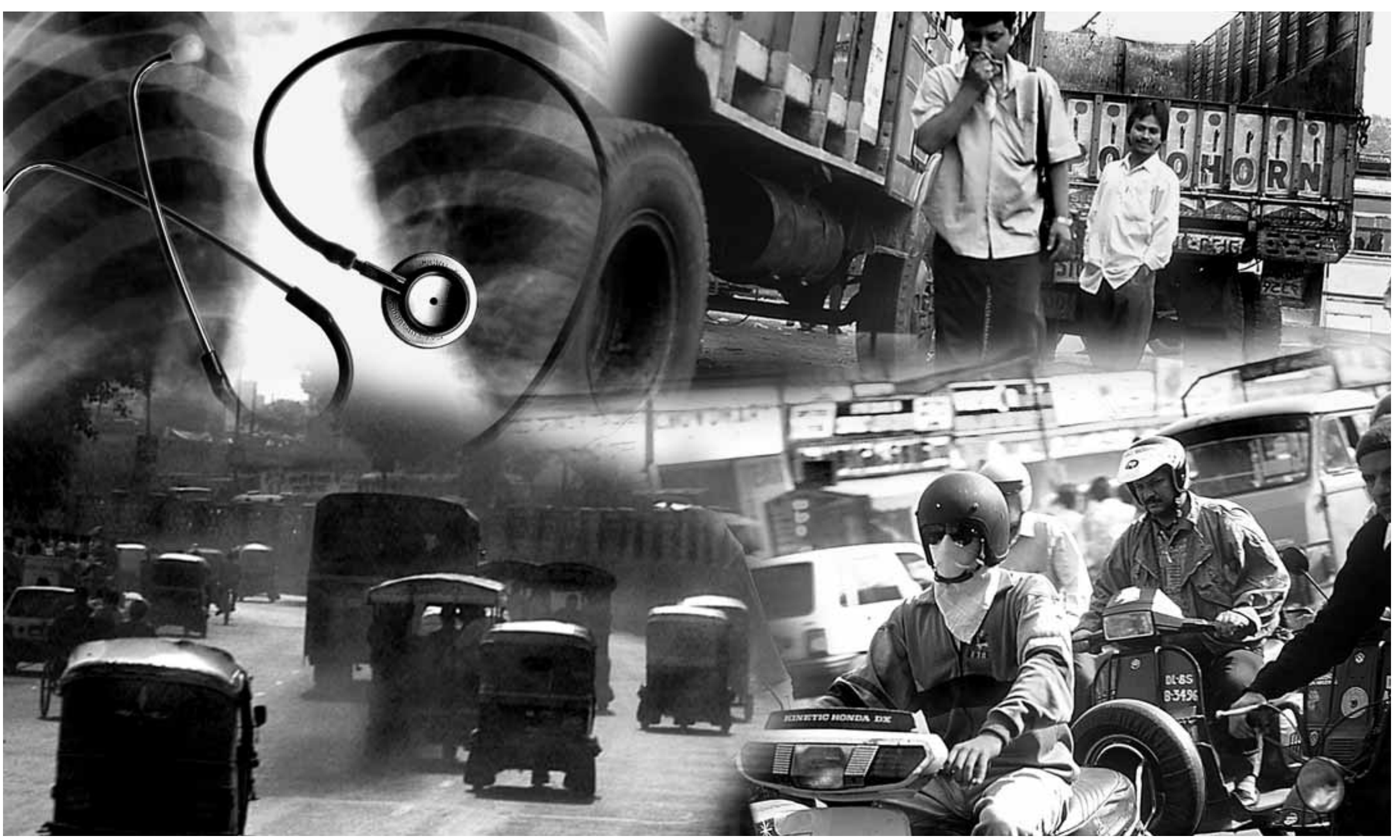
- Anon 2004, *National ambient alr quality status 2003,* Central Pollution Control Board, New Delhi
- Anon 2005, *Ambient air quality data year 2004,* Central Pollution Control Board, New Delhi

levels compared to the northern ones, some including Madurai, Coimbatore and Visakhapatnam show an increase in PM_{10} levels over the years. Most surprising trend has been noted in Chennai. It has recorded nearly a 60 per cent drop in residential areas in one year — from 75 microgramme per cubic metre in 2003 to 31 microgramme per cubic metre in 2004. Though specific meteorological conditions can have significant impact, drastic swings have also raised doubts about data quality. This aspect will be discussed in the subsequent sections (see Graph 3.3 A-D: *PM_{10} trend in selected cities in India*).

Fine particles: $PM_{2.5}$

The finer particles of size less than 2.5 micron ($PM_{2.5}$) have become the focus of air quality monitoring worldwide because of their extremely adverse health impacts. Discussions towards this end have begun in India, though institutional capacities have not been created to monitor $PM_{2.5}$ on a nationwide basis. Monitoring only on a pilot-scale has been conducted in Kolkata and Delhi.

The short-term monitoring data of these cities show that 24-hourly levels have already exceeded the US Environmental Protection Agency (USEPA) standard of 65 microgramme per



CSE

SMALL IS DEADLY: The finer particles ($PM_{2.5}$) are the focus of air quality monitoring worldwide because of their adverse health impacts

Graphs 3.3 A-D: PM_{10} trend in selected cities in India

Notes: City annual average concentrations are computed as weighted averages for 2000-2004; Standard for residential areas = 60 microgramme per cubic metre

Sources:

- Anon, *National ambient alr quality status*, Series of reports from 2000 to 2003, Central Pollution Control Board, New Delhi
- Anon 2005, *Ambient air quality data year 2004*, Central Pollution Control Board, New Delhi

DISSECTING POLLUTANTS IN KOLKATA

Special studies carried out on the levels of $PM_{2.5}$ and other toxics bear out the public health challenge in Kolkata

Kolkata is caught in a double whammy. Its ambient air is laden with high levels of both particulate matter less than 10 micron (PM_{10}) and nitrogen oxide (NO_X). The West Bengal Pollution Control Board (WBPCB) had conducted special studies on $PM_{2.5}$ in 2003. They had classified PM_{10} particles into different size fractions and also in terms of their constituents.

There are 17 monitoring stations in the city, including two which are online. These provide data not only for the criteria pollutants but also for O_3, hydrocarbons (HC) and carbon monoxide. The stations also monitor benzene, toluene, xylene (BTX), sulphates and polycyclic aromatic hydrocarbon (PAH) composition of small particles.

However, the study on $PM_{2.5}$ — conducted in six stations during the winter of 2003 — drew considerable attention. All stations reported similar trends. The average $PM_{2.5}$ fraction was about 73 per cent of the total PM_{10} and the range varied between 67 and 78 per cent. The benzene soluble organic fraction (BSOF) of the particulates, relevant in terms of toxicity, was a significant part of PM_{10} and $PM_{2.5}$. The BSOF was about 10 to 18 per cent of the PM_{10} mass. The same BSOF in $PM_{2.5}$ was a little higher. The weighted percentage mean was 16.16 per cent and the range varied between 11.3 and 21.43 per cent.

The study suggests that $PM_{2.5}$ provides greater surface area for absorption of toxic organic pollutants. $PM_{2.5}$ absorbs more BSOF per unit of mass than PM_{10}. Therefore, from the public health perspective, it is more important to monitor size fractions smaller than 3.5 micron. Besides, monitoring should also be done near heavy traffic areas.

The study was also conducted in several prestigious schools. Its objective was to create awareness among the parents. The monitoring reports showed a very high deposition of smaller fractions of particulates. The highest deposition observed was in the range of 0.2 to 0.4 micron, a size that can enter deep into the lungs.

Similar studies were conducted at seven other locations. The results showed that tiny particles smaller than 3.3 micron comprised 74 per cent of the PM_{10}. An even tinier fraction, those smaller than 1.1 micron, constituted 57.5 per cent of the total PM_{10}. These are more deadly because they are more toxic than PM_{10}. The average concentration of PM_{10} in Kolkata is around 300 microgramme per cubic metre in winter.

The study also revealed that the selection of monitoring instruments was critical to get the correct profile of pollutants. Therefore, in the size distribution study the WBPCB attempted to compare two types of particulate samplers. The first was the Anderson sampler which is automatic, and the second was a manual one made in India. When data from these two were compared, a wide gap was noticed. At times, the Indian sampler recorded more $PM_{2.5}$ fraction than the PM_{10} concentration, something theoretically impossible. Therefore, the study has recommended the use of automatic monitors which conform to international standards.

Even without doing a source apportionment study, the WBPCB suspects that automobiles contribute significantly to particulates of the size class of 1.1 micron and account for nearly 50 per cent of the air pollution load. It forecasts a decline in the share of pollution from industrial sources but an increase from automobiles .

In another study, in which the PAH composition of $PM_{2.5}$ and PM_{10} fraction was analysed for various compounds, the WBPCB identified potent carcinogens — benzo (alpha) pyrene and indeno (1,2,3 cd) pyrene. The WBPCB is also conducting studies on sulphate and nitrate particles and chloride concentrations. The sulphate values in the city correspond to eight-10 per cent of the PM_{10} (in the range of seven-14 microgramme per cubic metre), which is very significant. Several health effect studies show that SO_2 gets converted into sulphate particles, which are finer in nature and more toxic.[1]

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CSE conference: The leapfrog factor, April 2004, New Delhi

cubic metre. These exceed even the recently proposed Indian provisional standard of 75 microgramme per cubic metre for $PM_{2.5}$.

The CPCB's pilot monitoring of 24-hourly $PM_{2.5}$ in 2002 at the ITO traffic intersection revealed that levels were exceeding the USEPA limit on almost 95 per cent of the days. The monitoring was discontinued for a while following technical snags and restored afterwards. The CPCB has now started pilot monitoring in a few sites in Delhi for which the board has procured USEPA-certified instruments, says a CPCB official.

Limited $PM_{2.5}$ data is available from a few other sources as well. In August 2004, the World Bank had published $PM_{2.5}$ data monitored by the Georgia Institute of Technology, USA, in three Indian cities — Delhi, Mumbai and Kolkata during 2001-02. This report showed that daily levels during winter were as high as 350 microgramme per cubic metre. The average $PM_{2.5}$ levels were 132 microgramme per cubic metre in Delhi, 56 microgramme per cubic metre in Mumbai and 108 microgramme per cubic metre in Kolkata. The World Bank, in its report, says, "Compared with the US standard, it is clear that the concentrations in these cities are alarmingly high."

The West Bengal Pollution Control Board (WBPCB) also carried out short-term monitoring in Kolkata, which showed daily levels during the winter of 2003 reaching peaks like 378.8 microgramme per cubic metre, while averaging 162.1 microgramme per cubic metre in the city. This is a serious public health issue in the city (see Box: *Dissecting pollutants in Kolkata*).

The proposal of the CPCB is to initiate $PM_{2.5}$ monitoring in 10 critically polluted cities from 2005 onwards and add 10 cities each year thereafter. The cities will be prioritised on the basis of their non-attainment status (exceeding air quality standards). There are many glitches to be sorted out still. Officials have to standardise methods used by various institutions while monitoring $PM_{2.5}$. A committee under the aegis of CPCB is evaluating policy and guidelines to prevent, monitor and control $PM_{2.5}$ in ambient air. It has proposed "uniform standard monitoring methodology", equivalent to the USEPA federal reference method.

Gaseous pollutants

SULPHUR DIOXIDE

Between 1960 and 1980, SO_2 was considered the most critical pollutant by NEERI, which had initiated monitoring in India. Studies by NEERI during the 1970s and 1980s show that SO_2 pollution is largely the result of industrialisation and surge in urban transport.

SO_2 emissions are associated with fossil fuel combustion in the industrial, transport and domestic sectors. They have reduced markedly in the recent years. Long-term data in Indian cities shows that SO_2 is more or less under control in most. The CPCB's data for 2004 shows that the country is meeting the standards. Within this range, nine locations in Jamshedpur, Gajraula, Nagda and Nashik have higher levels (see Table 3.3: *Low levels of* SO_2). Experts hold that a dramatic change in the urban fuel matrix, like a shift from biomass-based fuels to liquefied petroleum gas (LPG) and from coal to kerosene as a cooking fuel have largely contributed in lowering SO_2 levels.

SO_2 is no longer a pollutant of concern. It is said that the cities that have switched to low-sulphur industrial fuels and other energy sources have been able to control and lower SO_2. Exposure to this gas is now more confined to industrial sites where coal use is still high, and roadside areas.

Sulphates

Low levels of SO_2 in the ambient air, however, can be deceptive as they may be adding to the very serious problem of sulphate particulates, which are deadlier than PM_{10} or $PM_{2.5}$. Though there is no systematic and regular monitoring of the dangerous trend of SO_2 converting into sulphate particles, preliminary estimates from the Delhi-based Defence Research and Development Organisation (DRDO) indicate a positive correlation between SO_2 and sulphates of suspended particulate matter (SPM) in Delhi.[10] The World Bank study of 2004 on source apportionment of $PM_{2.5}$ in Delhi and other metros show that the sulphate levels varied between 5.2 and 19 microgramme per cubic metre in Delhi. Sulphates, on an average, formed about 10 per cent of $PM_{2.5}$ in Delhi, Mumbai and Kolkata.[11]

Similar studies done by Indian Institute of Technology (IIT) Kanpur in Kanpur city, reveal that low ambient SO_2 levels can be misleading. In spite of reasonably high SO_2 emissions, ambient levels of SO_2 in Kanpur continue to be deceptively low.[12] IIT Kanpur has reported considerably high sulphate levels in the city ranging between 2.8 and 43.6 microgramme per cubic metre. These are considerably high compared to the levels reported in the US and European cities, ranging between 1.9-18.4 and 0.34-9.0 microgramme per cubic metre respectively. High PM_{10} levels in cities possibly provide an ideal environment for the formation of sulphate particulates.[13] The CPCB details a similar situation in Vadodara, Gujarat, where despite low ambient SO_2 levels, the conversion into sulphates is expected to be high.[14] The studies suggest that pollution control agencies should not be complacent about low SO_2 levels as sulphate particulates are potentially very harmful and need proper measurement.

Nitrogen dioxide

Conforming to the global trend, NO_X is emerging as the new national challenge. Generated when combustion occurs at very high temperatures, NO_X includes a range of oxides of nitrogen, but principally, nitric oxide (NO) and NO_2. A sizeable fraction of the vehicular NO_X emissions is NO — it can be as high as 95 per cent. NO once emitted readily oxidises to form NO_2 in the ambient air, which is a highly reactive gas and has greater adverse health impact. This also aids in the formation of yet another oxidant, O_3.

In India ambient NO_X is measured as NO_2. It is recording a steady rise in many cities (see Table 3.4: *Pockets of high* NO_2 *levels*). The CPCB's 2003 *National ambient air quality status* report showed that in six stations NO_2 levels exceeded the annual average standard in the country. Of these, four were located in the residential areas of Dhanbad, Pune and Kolkata.

In north Indian cities, including Delhi, Dehradun, Lucknow, Varanasi and Faridabad, the annual average levels, though lower than the standard of 60 microgramme per cubic metre (residential areas), show a distinct rise from 2000. Eastern cities, including Howrah, Kolkata, Dhanbad, Jamshedpur, Jharia and Sindri, have much higher levels compared to north Indian ones. The levels have continued to increase in Jharia and Dhanbad. During 2003, Kolkata recorded alarming annual peak level of 245.1 microgramme per cubic metre in Howrah Municipal Corporation — this is amongst the highest in the country. These levels are three times higher than the standard.

Southern Indian cities including Coimbatore, Bangalore, Visakhapatnam and Salem, show a steep rise in NO_2 levels over five years (2000-2004). Cities in western India are relatively better off

Table 3.3: **LOW LEVELS OF SO_2**

SO_2 levels are below standards in all sites but moderately high in Jamshedpur, Gajraula and Nagda

Locations	Annual average* 2003	Locations	Annual average* 2004
Bistupur Vehicle Testing Centre (I), Jamshedpur	47	Bistupur Vehicle Testing Centre (I), Jamshedpur	44
Golmuri Vehicle Training Centre (I), Jamshedpur	42	Golmuri Vehicle Testing Centre (I), Jamshedpur	40
Raunaq Auto Ltd (I), Gajraula	39	Chemical Division Labour Club (I), Nagda	37
Chem Div Labour Club (I), Nagda	37	Raunaq Auto Limited (I), Gajraula	36
Nal Stop (R), Pune	36	Nashik Municipal Council Building (R), Nashik	35
Swargate (R), Pune	34	VIP Industrial Area (I), Nashik	32
Bhosari (I), Pune	32	RTO Colony Tank (R), Nashik	32
Nashik Municipal Council (R), Nashik	30	Eloor (I), Kochi	32
GEB III Phase, GIDC (I), Vapi	27	Nal Stop (R), Pune	31
CETP Nandesari (I), Vadodara	27	Swargate (R), Pune	30

Notes: Standard for residential areas, 60 microgramme per cum; * in microgramme per cubic metre, I — industrial area, R — residential area

Sources:
- Anon 2004, *National ambient air quality status 2003,* Central Pollution Control Board, New Delhi
- Anon 2005, *Ambient air quality data year 2004,* Central Pollution Control Board, New Delhi

Table 3.4: **POCKETS OF HIGH NO_2 LEVELS**

In 2003, NO_2 levels exceeded the standard in all hotspots. However, in 2004, the levels declined at some sites in Kolkata, Howrah and Pune

Locations	Annual average* 2003	Locations	Annual average* 2004
Cossipore (I), Kolkata	83	Cossipore (I), Kolkata	73
Howrah Municipal Corporation (I), Howrah	83	Regional office (I), Udaipur	64
Nal Stop (R), Pune	76	Lal Bazaar (R), Kolkata	63
Lal Bazaar (R), Kolkata	76	Ananda Rao Circle (R), Bangalore	61
Swargate (R), Pune	70	Town Hall (R), Delhi	60
Regional office, MIA (I), Udaipur	69	Mayapuri Industrial Area (I), Delhi	56
Bandhaghat (I), Howrah	67	Bistupur vehicle testing centre (I), Jamshedpur	56
Regional office (R), Dhanbad	66	Nal Stop (R), Pune	55
MADA (I), Jharia	63	M/s GEE PEE Electroplating and Engineering Works (I), Noida	55
BIT (I), Sindri	62	Graphite India Limited (I), Bangalore	54

Notes: Standard for residential areas, 60 microgramme per cum; *in microgramme per cubic metre, I — industrial area, R — residential area

Sources:

- Anon 2004, *National ambient air quality status 2003,* Central Pollution Control Board, New Delhi
- Anon 2005, *Ambient air quality data year 2004,* Central Pollution Control Board, New Delhi

with almost constant to declining NO_2 levels, though the levels indicate an increasing trend in Nagpur, Nashik, Udaipur, Nagda and Indore. Solapur and Pune, which had recorded consistently high levels, show a slight decline after 2002. One of the reasons attributed to lower levels being recorded in Pune is the shifting of the monitoring stations away from heavy traffic sites (see Graphs 3.4 A–D: *NO_2 trend in selected cities of India*).

Air quality data, particularly from roadside sites, in cities like Ranchi, Kolkata, Pune and Bangalore show high levels of NO_2 thus bearing out the impact of traffic. Even in Delhi, NO_2 levels in the heavy traffic areas of ITO traffic intersection and Town Hall have exceeded standards.[15]

The steady increase in NO_2 in cities indicates that the problem is likely to grow with growing motorisation. This is quite consistent with the trend that has been observed in developed Asian countries, the US and Europe. The new technologies that are being phased in to control PM, CO and HC worldwide are believed to have a trade off with higher NO_X emissions.

Nitrate particles

NO_X, like SO_2, goes through atmospheric transformation and converts into harmful secondary nitrate particles. There is very limited information on the level of these in the ambient air of urban India. A study carried out by DRDO found that the ambient levels of NO_2 during winter and pre-winter seasons is much lower than the permissible level, as NO_2 converts into nitrate (NO_3). The NO_3 fraction in particulates was observed to be in the range 0.23-7.2 per cent during pre-winter and 0.12-7.3 per cent during winter in two locations. The share of NO_3 in particulates was higher in the location closer to vehicular traffic. The DRDO concluded, "The conversion of NO_2 into nitrate has proportionately increased the particulate concentration."[16] Official air quality monitoring is not tracking the formation of these harmful secondary particles for proper risk assessment.

Carbon monoxide

CO emitted predominantly from petrol vehicles can reach high levels in areas with high traffic density. The CPCB mentions that CO measurement should be conducted near traffic intersections, highways and commercial areas where traffic density is high. Generally areas with a high population density have a large number of vehicles and higher CO levels.

The CPCB has not been able to develop adequate capacity to monitor CO nationwide. It is monitored on a regular basis in Delhi and on a limited scale in a few other metro cities, including Kolkata, Mumbai, Bangalore and Chennai. It is not possible to construct regional trends for CO as CPCB does not report nationwide CO data in its NAMP report. State Pollution Control Boards (SPCBs) report this data sporadically.

CO data, though scant, still shows considerably high levels in other cities. In Faridabad — a city adjacent to Delhi — short-term monitoring during 2003 in four locations found the levels in the range 2,810-2,910 microgramme per cubic metre — exceeding the eight-hourly average standard of 2,000 microgramme per cubic metre.[17] In Bangalore, monitoring during September and October 2003 in six locations found CO levels in the range 1,740-8,250 microgramme per cubic metre.[18] As discussed later, CO monitoring is done on a limited scale because it requires automatic monitoring facilities and most cities have only manual ones.

Ozone

Ground-level O_3 is not emitted directly from any emissions source. It is produced and destroyed in a cyclical set of chemical reactions involving NO_X, VOCs, heat and sunlight. When ambient temperatures and sunlight levels remain high for several days and the air is relatively stagnant, O_3 and its precursors can build up and produce more O_3 than would normally occur on a single high temperature day. O_3 can also be transported to areas away from pollution sources, thus elevating O_3 levels even in areas with low VOC or NO_X emissions.[19] Even at low concentrations, O_3 can cause tissue injuries to the lungs and result in significant impairment of pulmonary functions.

However, the piecemeal information available from short-term monitoring of O_3 impedes trend analysis. In Delhi, short-term monitoring by CPCB from January to February 2003 at six locations revealed that O_3 ranged from 4-21 microgramme per cubic metre.[20] O_3 monitoring during August and September 2003 at Sharda Nagar in Kanpur showed that maximum levels could shoot

Graphs 3.4 A-D: NO_2 TREND IN SELECTED CITIES OF INDIA

Notes: City annual average concentrations are computed as weighted averages for 2000-2004. During 2004, Agra, Kozhikode and Palakkad had below detectable level of NO_2 concentration; Standard for residential areas = 60 microgramme per cubic metre

Sources:

- Anon, *National ambient air quality status,* Series of reports from 2000 to 2003, Central Pollution Control Board, New Delhi
- Anon 2005, *Ambient air quality data year 2004,* Central Pollution Control Board, New Delhi

up to 135 microgramme per cubic metre.[21] Short-term monitoring in Bangalore during December 2003 revealed daily levels in the range 1.47-3.55 microgramme per cubic metre.[22] Nothing conclusive can yet be said on the basis of such limited information.

A study — aimed at assessing the effect of air pollution on peri-urban agriculture in the surrounding areas of Varanasi — by the Benaras Hindu University and Imperial College of London found relatively high ambient O_3 levels in a least-polluted rural area.[23] Impact of O_3 was found to be greater at a faraway rural site during summer. The measured ambient concentration was found to be as high as 55.70 ± 3.2 parts per billion (ppb) during summer. This shows the least monitored pollutant in India can prove to be hazardous if not monitored and controlled adequately.

It is very difficult to explain the available O_3 data for cities like Delhi. In 1998, USEPA along with the state of Texas had assessed Delhi's air quality monitoring programme. Their report — *Recommendations of the US Environmental Protection Agency and the State of Texas concerning the Delhi, India Air Monitoring program*, had pointed out the limitations of the two O_3 monitoring sites in Delhi — Siri Fort and the ITO traffic intersection. The report pointed out that it was not correct to measure O_3 in heavy traffic sites with high NO_X concentration. It explained, "It is probably not a good choice, given the scavenging capacity of nitric oxide for O_3 , therefore, reduced O_3 concentrations are likely." The report had recommended that more representative downwind sites be selected for O_3 monitoring.

The complexities related to O_3 formation also have implications for programmes to reduce it. For example, scientists say that relatively small amounts of NO_X enable O_3 to form rapidly when VOC levels are relatively high but O_3 production is quickly limited by removal of NO_X. Under these conditions, NO_X reductions are highly effective in reducing O_3 while VOC reductions have little effect. Such conditions are called, "NO_X-limited."[24]

Conversely, when NO_X levels are relatively high and VOC levels low, NO_X forms inorganic nitrates or nitrate particles but relatively little O_3. Such conditions are called "VOC-limited." Under this, VOC reductions are effective in reducing O_3. The highest levels of O_3 are produced when both VOC and NO_X emissions are present in significant quantities on clear summer days.[25] None of these conditions have been assessed in Indian cities to understand the risk.

LEAD

Air-borne lead is emitted during the combustion of petrol in which tetra-ethyl lead is added as an anti-knock agent to increase the octane number and as a lubricant for the valve seats of engines. Lead emissions have serious health fallout. Indian cities have largely been able to overcome the problem of lead pollution by completely switching over to unleaded petrol in 2000. The lead specification of leaded petrol, which was 0.56 gramme per litre (gm/l) during 1994, has been reduced to a trace amount of 0.013 gm/l in Euro I and II equivalent unleaded petrol. It has been further reduced to 0.005 gm/l in the Euro III equivalent unleaded petrol available in 11 Indian cities.

Lead levels have also reduced in the ambient air — they have dropped by over 70 per cent in cities where they are monitored. For instance, in the traffic intersections of Delhi, the ambient lead levels dropped by nearly 74 per cent in 2001 compared to the levels recorded in 1994. They are currently far below the standard.

However, a recent study in Kanpur showed that despite complete phasing out of leaded petrol in 2000, lead levels are higher than the National Ambient Air Quality Standard of 1.0 microgramme per cubic metre. Secondary lead smelters and reprocessing of batteries are held responsible for this.[26]

BENZENE

There is hardly any information available on the levels of air toxics that include a wide range of VOCs, including benzene, toluene and xylene, as these are not yet routinely monitored under NAMP. The absence of a central database to comprehensively collate the data generated from special and short-term studies means that only limited and indicative data are available. But even this meagre information, which CPCB publishes in its special reports, provides sufficient proof of the mounting toxicity of air. For instance, high benzene levels have been reported by CPCB from its short-term monitoring in Kolkata and Kanpur. Benzene levels, monitored on an eight-hourly basis, in a few sites in Kolkata in October 2002, ranged from 38.25 to 97 microgramme per cubic metre.[27] The USEPA and the International Agency for Research on Cancer have listed benzene as a carcinogen. The WHO estimates that four in one million persons are at risk of leukemia on exposure to benzene to a concentration of 1 microgramme per cubic meter.[28]

In Kanpur, between June 1999 and May 2000, benzene levels were reported to exceed the UK standard of 16 microgramme per cubic metre by 1.4 times at five locations and peak levels hit 90 microgramme per cubic metre during November 1999.[29] The CPCB reports that in Delhi the monthly average concentration varied from two microgramme per cubic metre at the Jawaharlal Nehru University campus in July 2003 to 26 microgramme per cubic metre at the ITO traffic intersection in November 2003.

In Mumbai, CPCB, along with NEERI, conducted a short-term emissions inventory study of VOCs, including benzene, toulene and xylene, and reported an annual average level of 24.36 microgramme per cubic metre. VOC monitoring should be strengthened nationwide immediately.

Tracking other toxics

PM is further dissected to track toxic gases and substances that get absorbed in it. These include benzene-soluble organic fraction (BSOF) and PAH. These toxic fractions of PM come primarily from combustion sources. Limited studies in Kolkata show that the levels of this organic fraction can reach 79 microgramme per cubic metre during winter.[30] Even more horrific levels — 160 microgramme per cubic metre during 2002-2003 — have been recorded in the roadside areas of Kanpur.[31]

POLYCYCLIC AROMATIC HYDROCARBONS

The concentrations of PAH in air are extremely worrying given their highly carcinogenic properties. However, the levels of their presence have not yet been assessed adequately in Indian cities. The limited data on PAH — a group of highly toxic compounds — shows that their levels are extraordinarily high in Mumbai, varying between 24.5 and 38.8 nanogramme per cubic metre.[32] In Kolkata, the PAH level is 31 nanogramme per cubic metre while that of benzo(a) pyrene is 8.5 nanogramme per cubic metre.[33] The WHO states that there is no safe level for benzo(a) pyrene, a PAH compound that is deadly even in very small concentrations.

Under the aegis of the Indo-Norwegian programme of institutional cooperation, jointly implemented by IIT Kanpur, and the Norwegian Institute for Air Research, Norway, a study on health impacts of indoor and ambient exposure of PAH was conducted in 2005 in Kanpur. Ambient PAH data generated by analysing $PM_{2.5}$ for this project, showed that the levels varied from 4-59 nanogramme per cubic metre. This matches with the range reported for Delhi at 6-53 nanogramme per cubic metre in 2000 and in Mumbai 24-38 nanogramme per cubic metre in 1996-97 (both analysed in PM_{10}). But these levels are alarmingly higher than the range reported for Lista, Norway, at 0.01-1.32 nanogramme per cubic metre in PM.[34]

The investigators stated, "The levels can be even higher in Kanpur when analysis for PAH is done on PM_{10} and if volatile component is also included." The study further concluded, "Cancer risk due to PAHs exceed at all locations and there is an immediate need to control and prevent PAHs."[35]

3.3 The hotspots

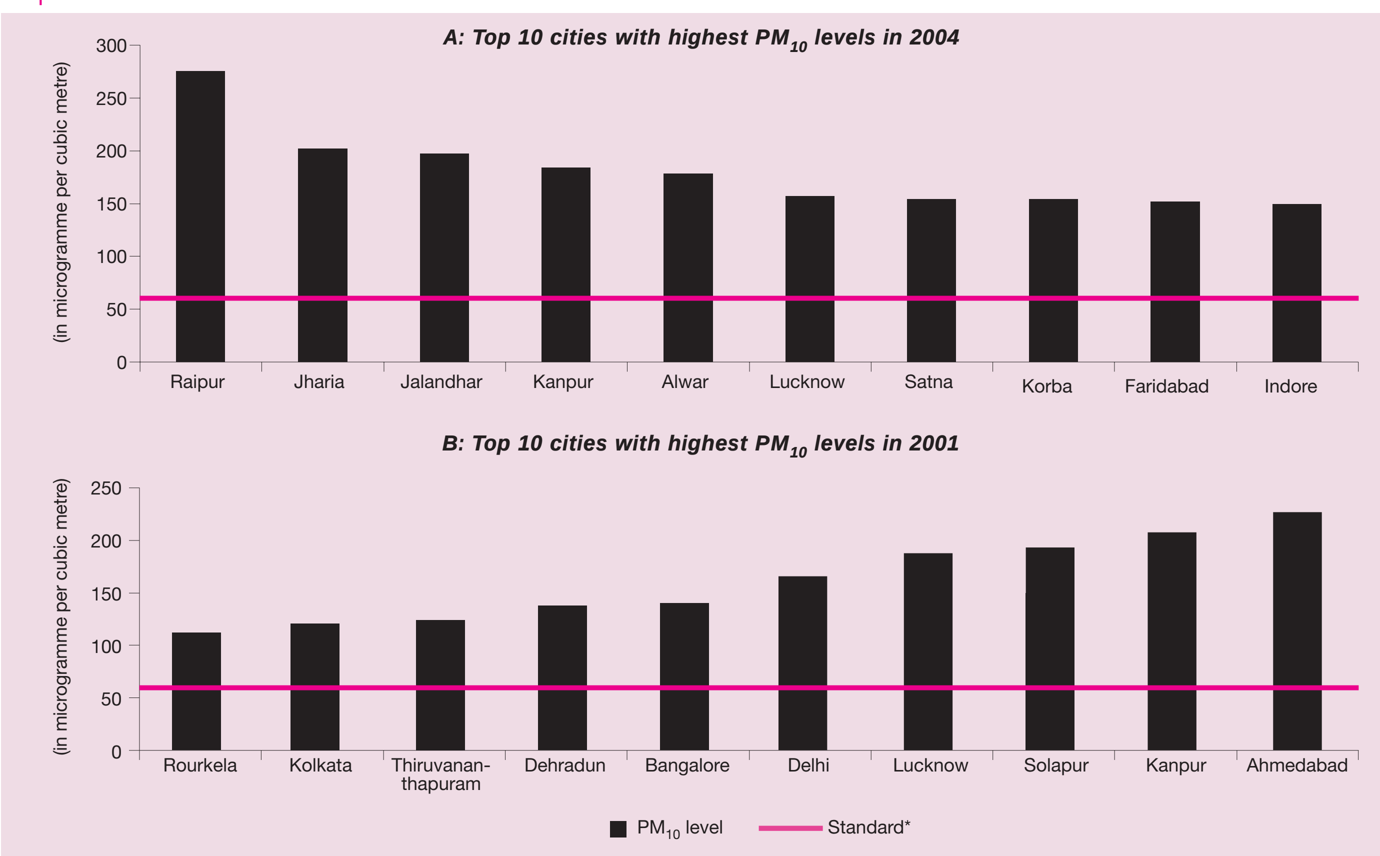
Air pollution has assumed proportions of a nationwide crisis. The mushrooming of pollution hotspots across the country is frightening. The top 10 PM_{10} hotspots identified in 2004 are largely concentrated in north India, with a few are scattered across western and eastern parts of the country. The worrying trend is the proliferation of new hotspots every year. According to CPCB sources, the first official effort to identify non-attainment cities in India on the basis of particulate pollution was attempted in 2001-02. Based on the data for 1995-2001, about 53 cities were identified as non-attainment areas — 27 big and 26 smaller ones. This increased to 65 in the latest tally published in the annual report of the Union ministry of environment and forests (MoEF) for 2004-05 when data for 1995-2003 were considered.[36]

Since 2003, CPCB has begun ranking cities according to their PM_{10} levels. Thus, the ranking of residential areas released in 2003 (based on PM_{10} data for 2001) and that of 2005 (based on 2004 PM_{10} data), show that while some, including Kanpur and Lucknow, have consistently remained among the top 10, newer cities have also begun acquiring a dubious status. An obscure town — Raipur — was the top hotspot in 2004. There are still a large number of towns and cities that are not even part of the air monitoring grid and the status of their air quality is not even known. Big cities — though still very polluted — are no longer the dirtiest. This shows that every year, especially with the expansion of the monitoring network, newer cities and even smaller towns, are scaling up as chart-busters (see Graphs 3.5 A-B: *The dirty 10)*.

Air quality in key hotspots

There is a mixed trend in particulate pollution levels in bigger metros. Though most record high pollution levels, they have started showing a downward trend in their annual average levels after 2000. It is very difficult to draw conclusions on the basis of the annual average levels, especially when the local perception in most cities is that the pollution levels are getting worse.

Graphs 3.5 A-B: **THE DIRTY 10**



Notes: * For residential areas annual average standard is 60 microgramme per cubic metre. The data shows average PM_{10} level of residential areas only

Sources:
- Anon 2005, *Most polluted cities*, Press Information Bureau, New Delhi, October
- Anon 2003, *Parivesh — highlights 2002*, A newsletter of the Central Pollution Control Board, New Delhi

SOMETHING IN THE AIR?

Stakeholders believe that vehicles are responsible for poor air quality in cities

How do researchers view urban air quality trends and management in India? The World Bank, which conducted a survey of stakeholders as part of its south Asia urban air quality management (AQM) initiative, tried to capture stakeholders' perception of air quality trends in cities, effectiveness of various policy measures, perception of key actors and barriers to effective management. The survey covered Bangalore, Chennai, Delhi, Hyderabad, Kolkata, Mumbai and a few other cities. This questionnaire was sent to 81 stakeholders in 2004.[1]

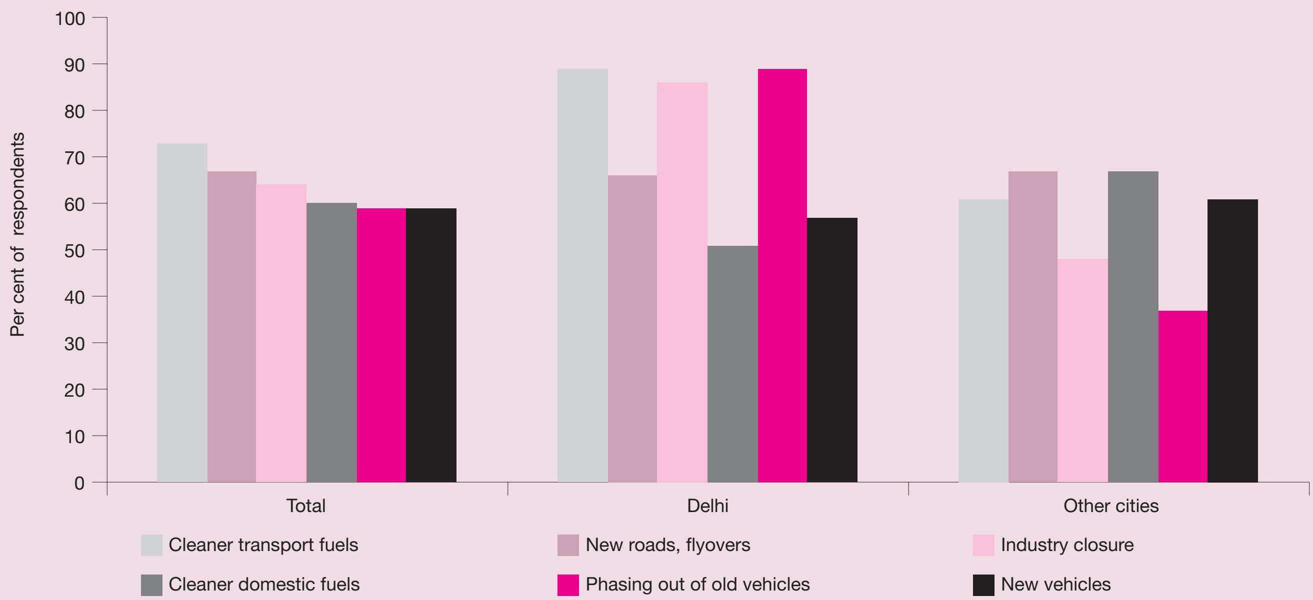
Air quality trends

While 88 per cent respondents listed adverse impacts on health as the most important consequence of pollution, nearly 50 per cent said that air quality in their cities was deteriorating. More than 90 per cent viewed this as serious or moderately serious. The survey found major differences in perception on air quality trends. In Delhi, 63 per cent said the air quality was improving, while 67 per cent in other cities said it was deteriorating. Half of those who felt that air quality was improving, reported that it had deteriorated initially before improving again. Most government officials believed that air quality had improved (although less than one-fourth resided in Delhi). The academia were more inclined than others to say that air quality was deteriorating. Respondents viewed particulate matter with greatest concern, followed by CO and oxides of sulphur and nitrogen. Ozone (O_3) ranked low. Quite a few expressed concern about HCs, especially benzene.

The survey concluded that contrary to popular perception that the air pollution is growing, air quality had actually improved in most cities between 1993 and 2002. But between 1998 and 2002, Delhi's air quality data didn't show any change. There was, however, a steady decline in the levels of particulate matter less than 10 micron in size (PM_{10}) in Mumbai and a general decline in Hyderabad. During 2001-2002, a decline was observed in Chennai as well as in an industrial area of Kolkata. The World Bank observed that limited air quality data restricts conclusions. Some perceptions may not be supported by data. This underscores the importance of systematic data collection and analysis and equally important, information dissemination.

CLEANER FUELS TOP THE POLL CHART

Respondents' views on the impact of various measures on air quality



Two studies by the World Bank in India brought to focus the air quality trend in five metros of India. In August 2004, the World Bank first released the findings of its stakeholders' survey on air pollution in Delhi, Bangalore, Chennai, Mumbai, Hyderabad and Kolkata. The survey found that while public perception in most cities — barring Delhi — was that air pollution was increasing, actual air quality had improved. On the other hand, in Delhi, where the widely-held perception was that air quality had improved, data showed pollution levels had only stabilised. Thus, air quality data did not match people's perception, concluded the study (see Box: *Something in the air?*).

Does this perception cast doubts on the accuracy of data? Is this due to meteorological factors? Or are the levels so high that minor variations are not noticed? Or shouldn't the impact of even a few actions show up and spur confidence to take stronger action?

These issues were scrutinised in detail by the World Bank in a subsequent study to assess more systematically the impact of action on particulate levels in Delhi, Mumbai, Chennai, Kolkata and Hyderabad. Its study, based on the air quality data of CPCB, SPCBs and NEERI, correlated air quality trend with action taken in these cities to conclude that PM_{10} levels "do not seem to be rising and in some cases, may even be falling, which suggests that targeted measures taken in recent years have met with some success."[37] This study found that PM_{10} levels fell between 1993 and 2002. It even

What is causing air pollution?

Transport was considered the most important source of pollution by 78 per cent of the respondents of the survey, presumably on account of the large number of gross polluters among public transport vehicles. This was followed by industry and finally domestic fuel use and construction and other urban activities. The largest number of respondents cited that improvements in fuel quality had a positive impact on air quality. Construction of new roads and flyovers, closure of industries and cleaner domestic fuels played a secondary role, they felt. Delhi, which has implemented various pollution control measures, such as phasing out old vehicles and relocating/closing industries, was rated as a proactive city by 89 per cent respondents (see: *Cleaner fuels top the poll chart*). Asked to respond to what they felt were "activities with negative impact on air quality", 53 per cent of the respondents cited construction and 36 per cent public transport and growing vehicular sources.

Ranking measures for impact

According to most respondents, improvement in the quality of transport fuel had a positive impact. However, several measures were perceived to have had little, if any, impact. The highest percentage of respondents considered that there was little impact due to zoning to segregate different land-uses, followed by bans on open burning of refuse. In Delhi, newer vehicles were listed as having a negative impact simply because they meant more vehicles. Respondents were divided over the effectiveness of some of the measures like use of cleaner fuels in industry (46 per cent replied that it had a positive impact), a shift from industry to services (43 per cent) and compliance with industrial regulations (41 per cent).

Has the government failed to act?

Respondents were asked to rank institutions in terms of the efforts made to address air quality concerns. The judiciary, followed closely by the bureaucracy, was considered most proactive. In fact, 60 per cent said that the judiciary was the most or second most active institution in AQM. Around 53 per cent ranked the government as second and 45 per cent placed non-governmental organisations (NGOs) third.

Barriers towards managing air quality

Lack of political will was seen as the biggest problem by 59 per cent of the respondents. Poor decision-making by key persons was held responsible by 52 per cent, and a lack of information and knowledge at the decision-making level by 51 per cent of the respondents. Delhi residents viewed lack of political will, lack of information and lax standards as serious impediments. Residents in other cities, on the other hand, saw other factors like outdated technology and corruption as the greatest challenges. Residents of Delhi were most optimistic about AQM.

estimated that this decline might have led to nearly 13,000 less premature deaths and a greater reduction in annual incidence of respiratory illness in the five cities between 1990 and 2002.

Despite substantial progress, the PM_{10} levels are the highest and dangerously above the national standards in Delhi and Kolkata. The study tried to find some logic to the air quality trend in these cities. Meteorology plays an important role in influencing ambient air quality. Implementation of the same intervention in two cities, with different meteorology and/or mix of sources, is unlikely to produce same results. But drawing inferences from the evident trends has limitations beyond a point. The study emphatically argued that there was a need for strengthening of data collection, management and dissemination. It cited NEERI data, which indicated that Hyderabad and Chennai were already meeting standards in both residential and industrial sites in 2002. But the SPCB data for 2002 showed that industrial areas of these cities were not complying, while the residential areas of Hyderabad were. In Chennai, the SPCB has no monitoring locations in residential areas.

The World Bank report, therefore, "Raises question about the representativeness of the data collected by NEERI. Given these very large differences, in ambient pollutant concentrations… it is not possible to draw conclusions about whether or not Chennai or Hyderabad might have met the national respirable suspended particulate matter (RSPM) {PM_{10}} standards in 2002"[38] (see Graph 3.6 A: *Inexplicable PM_{10} data*). The study warned that cities would require a strong framework for monitoring and analysis. It thus indicated that widely-held perceptions about air pollution levels in most cities could not be established scientifically on the basis of the existing database.

CSE's analysis of the available data also confirms that PM_{10} annual average levels are decreasing in a few cities (see Graph 3.6 B: *Inexplicable PM_{10} data*). Closer scrutiny reveals that the 24-hourly levels could be still very high and increasing over the years. For example, in Ahmedabad, while the annual average level of PM_{10} is declining after 2000, the trend in the daily violation of standards is just the reverse — increasing consistently. While in 2000, the daily violation was 69 per cent, by 2003 it touched 80 per cent of the days monitored. In Pune, on the other hand, both the annual average and daily exceedance levels are increasing consistently since 2000.

Graphs 3.6 A-B: **INEXPLICABLE PM_{10} DATA**

A. Difference in data reported by SPCB and NEERI in Chennai

B. In Bangalore, residential areas show consistent drop

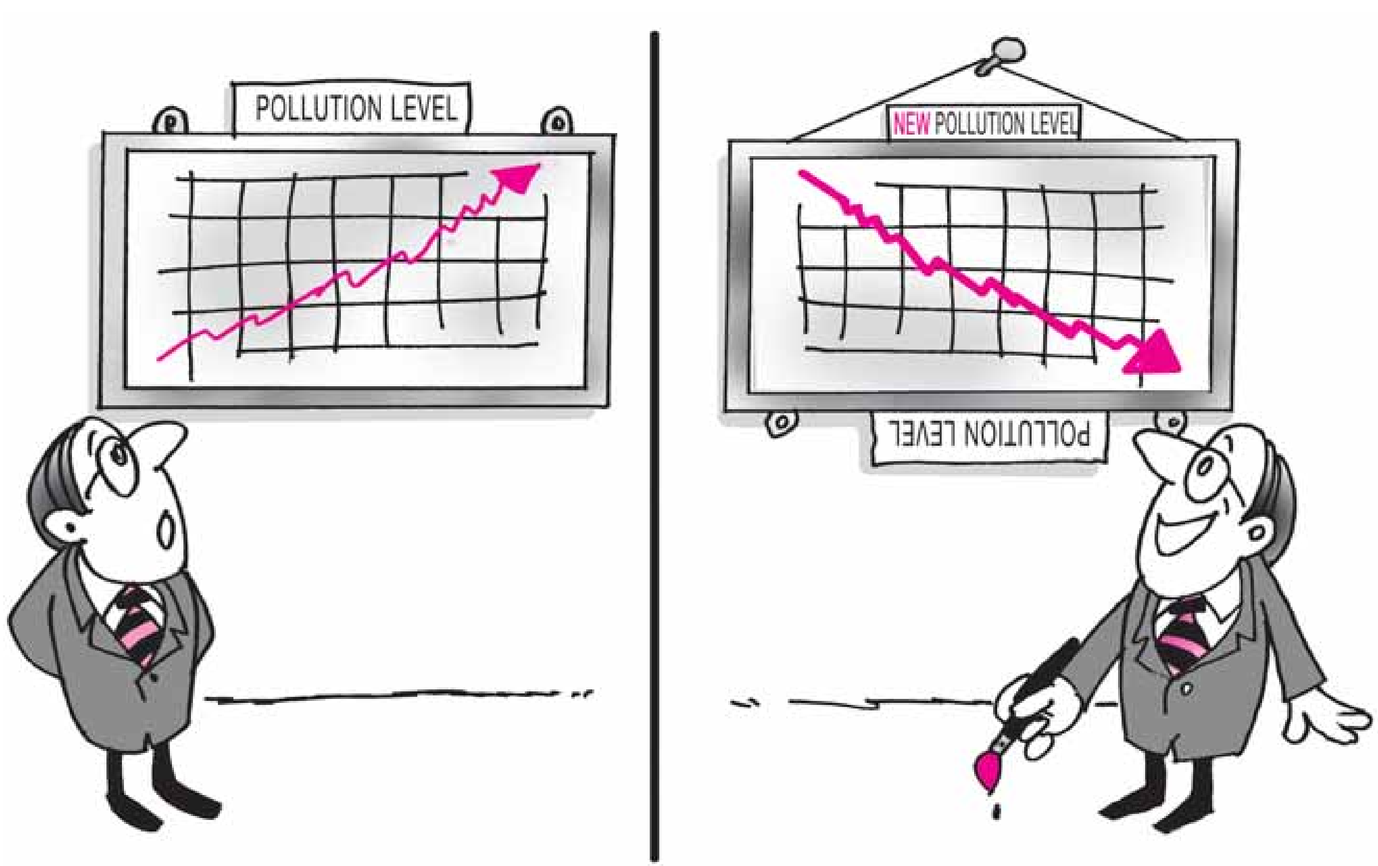
Notes: SPCB — State Pollution Control Board; NEERI — National Environmental Engineering Research Institute

Sources:

- Graph A: Anon 2005, *For a breath of fresh air,* World Bank, New Delhi, p 51
- Graph B: Anon, *National ambient air quality status,* Series of reports from 2000 to 2004, Central Pollution Control Board, New Delhi

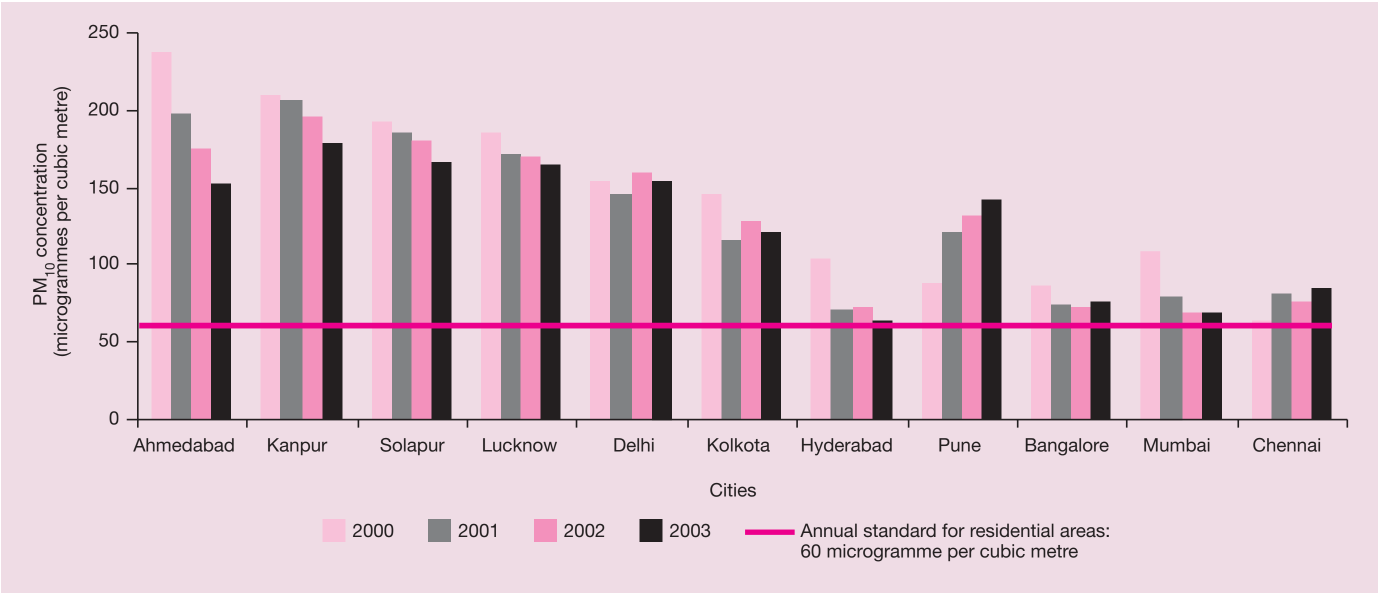
Worse, Kanpur and Lucknow record daily violation for nearly 90-100 per cent of the days monitored. Thus, there is no reason to feel complacent over the dip in the annual average levels (see Graph 3.7: *Falling levels?* and Graph 3.8: *Certainly not*).

Moreover, cities that record comparatively lower levels require cautious data interpretation. The annual average levels show that Chennai and Hyderabad are already very close to meeting the standards, as observed by the World Bank. But a more detailed break-up of air quality trends in different locations of Chennai, provided by the Tamil Nadu Pollution Control Board shows that many locations in Chennai register exceedingly high levels that would require urgent action. We will see in the subsequent sections that



Graph 3.7: **FALLING LEVELS?**

Data shows that annual average PM_{10} levels are falling in a few cities...

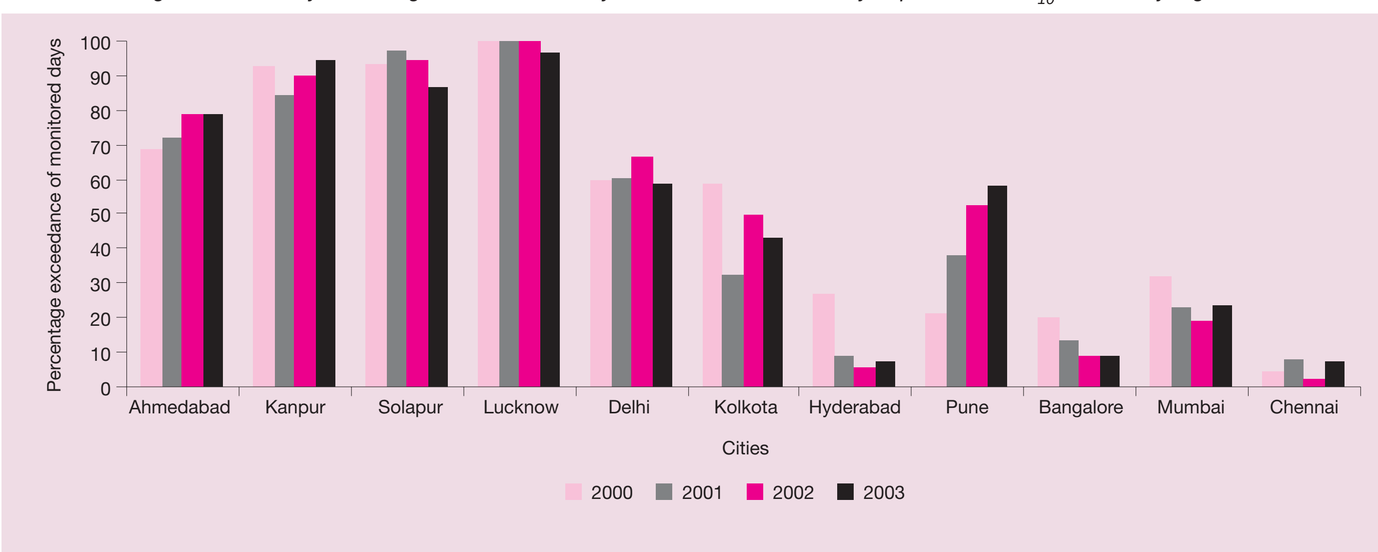


Note: Surat and Agra have not been included here for the want of adequate time series data

Source: Anon, *National ambient air quality status,* Series of reports from 2000 to 2003, Central Pollution Control Board, New Delhi

Graph 3.8: **CERTAINLY NOT**

...but increasing number of days violating standards in many cities indicates that daily exposure to PM_{10} is still very high



Note: Daily violation is computed on an average for the city. Data for daily violation for 2004 is not available

Source: Anon, *National ambient air quality status,* series of reports from 2000 to 2003, Central Pollution Control Board, New Delhi

inappropriate and poor air quality data often hampers proper risk assessment. This will have to be kept in mind while interpreting the trend to chart action for these cities.

3.4 Air quality monitoring in India

The goal of air quality management (AQM) is to protect human health and ensure the overall welfare of animal and plant life. If air quality in a city fails to meet prescribed standards then people, especially those sensitive to air pollution-related diseases, fall prey to unacceptably high health risks. The governments need to assess different pollution sources and find strategies to control them.

AQM has matured considerably in the industrialised West, where sophisticated tools have been developed for rigorous planning and implementation. But AQM capacities are not uniform across the Asian region and fall woefully short of the desired benchmark. Monitoring capacity fluctuates at different levels of sophistication in different cities (see Box: *Air toxins and public health crisis in Asia*).

The WHO and UNEP have benchmarked 20 Asian cities according to their capabilities for air quality management. Under this programme, a number of indices have been considered. These reflect the quality of monitoring in terms of accuracy, precision and

AIR TOXINS AND PUBLIC HEALTH CRISIS IN ASIA

There are several ways to improve air quality planning in Asian cities

The Asian region faces many problems — poverty, migration, growing cities, urban, indoor and trans-boundary air pollution, atmospheric brown cloud and climate change. However, air pollution is the most serious issue. People living in the vicinity of heavy traffic and industrial areas are exposed to high levels of air pollution. There are many other sources contributing to the problem in the region. For example, particulates from forest fires are a threat. The recent study on the Asian brown cloud has demonstrated this.

Strategic framework for AQM

A strategic framework for air quality management (AQM) in Asia has been prepared under the project, Air Pollution in Megacities of Asia (APMA), in collaboration with the Clean Air Initiative (CAI-Asia). The project is aimed at introducing rational AQM in Asian countries. The region faces many challenges — lack of commitment in AQM policies, limited coordination and integration among implementing agencies, weak institutional capacity and regional differences in regulating emissions sources. Coupled with this are the legal loopholes that allow dumping of obsolete technologies in different countries. Lack of transparency and harmonisation compound the problem. Therefore, public awareness, risk perception and risk communication are very important.

Governance challenges

These include resolution of conflicts arising due to duplicated responsibilities, *ad hoc* awareness raising, inadequate communication strategies, deficiencies in information dissemination, high costs of awareness raising programmes, AQM strategies based on incomplete knowledge, lack of baseline research on risk communication and limited financial resources.

Emissions challenges

Instead of prevention, tailpipe measures are being undertaken, making the process ineffective. Besides, there is a lack of adequate emissions inventories, source apportionment, timely emissions standards and low-cost alternative technologies.

Air quality modelling challenges

Air quality modelling depends on the quality of emissions data and sufficient experience in conducting source apportionment studies. There is no regional harmonisation of the dispersion models. There is a lack of quality assured topographical and meteorological input data for advanced models.

AQM challenges

Lack of spatial coverage and baseline data. The systems are not always perfectly maintained. There is a lack of quality assurance plans, which ensure data quality. There is minimal collaboration among different agencies. Standard operating protocols are required for monitoring analysis and presentation of data. Monitoring networks and devices need to be harmonised in the region. Adequate attention should be paid to trans-boundary air pollution. Placing monitoring devices at places where people are not living does not reveal the actual exposure. Therefore, the focus should be on monitoring hotspots at regular intervals.

Clean Air Implementation Plans

According to the strategic framework for AQM in Asia, the Clean Air Implementation Plan (CAIP) should include rapid assessment of sources, monitoring of results from a minimal set of monitors, simulation of spatial distribution of air pollutant concentration, comparison with air quality standards, assessment of adverse impacts, control measures for mobile, stationary and area sources and alternatives such as public transport systems and road planning. CAIPs should be implemented in incremental steps tailored to policy goals and resources. Information from the CAIPs should also be made widely available. Outdoor air pollution in Asian cities can be solved by CAIPs. Bangkok, for instance, has implemented this plan. Emissions reduction for vehicles is not sufficient. Industrial and other sources are also important.

World Health Organization (WHO) air quality guidelines

Following the WHO guidelines is important as these protect human health. As for particulates, which are a major problem in India, WHO guidelines of 1987 — 70 microgramme per cubic metre — are still much lower than Indian standards, which are 75, 100 and 150 microgramme per cubic metre for sensitive, residential and industrial areas, respectively. However, the WHO has turned to looking at the exposure-response relationship because there is no threshold value of PM as it has health effects at every level. The exposure-response relationship means that even at 50 microgramme per cubic metre of PM_{10}, there can be some increase in the daily mortality. O_3 standards should also be promulgated in India. Thus, leapfrogging to a new AQM paradigm is necessary.[1]

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air pollution scientist
European Commission Joint Research Centre, Italy
CSE conference: The leapfrog factor, New Delhi, April 2004

the representative nature of data. Data assessment and availability indices reflect how databases are processed to enhance value and made available for decision-making; emissions estimate index that assesses emissions inventories for decision making; management enabling capabilities index that assesses the administrative and legislative framework for emissions control strategies and implementation (see Table 3.5: *Indexing capability*).[39]

The study found that most cities carry out routine calibration and flow rate checks to ensure accuracy of data. However, only a few formally validate their results and a handful have established formal data quality objectives and audits.

Most cities carry out limited to simple statistical analysis of data. Very few make use of data with health indicators in epidemiological studies or put to use meteorological and emissions data to produce dispersion models or forecast pollution episodes. Data is available as annual summary reports. Only six of the 20 cities surveyed issued alerts during poor air quality episodes. Estimation of emissions is generally the most limited component of management capability.

This exercise was repeated for 23 Asian cities once again by

Table 3.5: **INDEXING CAPABILITY**

Taipei (China) and Hong Kong rank high on air quality management capacity. Indian cities fall woefully short

Selected Asian cities	Score
Taipei (China)	Excellent
Hong Kong	Good
Singapore	Good
Chennai	Moderate
Hyderabad	Moderate
Lahore	Limited

Source: Dietrich Schwela 2002, *Air quality management, A sourcebook for policy-makers in developing cities,* German Technical Cooperation, Eschborn, Germany

WHO-UNEP's Air Pollution in Megacities of Asia (APMA) project and CAI-Asia, a network of Asian cities, development agencies, civil society institutions and industry, during 2003-04. This was an extensive benchmarking process, which revealed a wide spectrum of variations in the management capability (see Box*: Benchmarking AQM in Asian cities*). The system of grading is based on a number of criteria related to management practices, data quality and management capacity. These studies reveal poor use of data and very basic analytical capacity to support policy-making.

It is therefore important to assess India's air quality management system to understand its capacity to meet the pollution challenge.

Who monitors air in India?

The organisational structure of air quality monitoring is decentralised in India (see Figure 3.1: *Air quality monitoring structure)*. The CPCB — the apex central body responsible for pollution control — coordinates the air quality monitoring network in the entire country. CPCB directly operates only a few monitoring stations in Delhi. SPCBs and pollution control committees are responsible for air quality monitoring at the local level in states and union territories respectively. Many SPCBs have set up monitoring stations under the State Ambient Air Quality Monitoring (SAAQM) programme. In addition to the state-operated monitoring stations, independent research organisations and various industries have begun setting up monitoring stations. NEERI, a government research agency, organises independent monitoring in seven metros to feed the central database on air quality. Sometime SPCBs outsource the air quality monitoring to educational and research institutes. All these agencies together generate the national database on air quality under NAMP.

Until 2004, under NAMP, 290 stations were spread across 92 cities/towns. Of these, nearly 80 per cent were operational. The total number of stations since then has increased to 326, covering 116 cities/towns in 28 states and four Union Territories.

The CPCB is responsible for coordinating with all agencies concerned to ensure uniformity and consistency in data generation. It also provides financial and technical support.[40] It publishes an annual air quality database called *National ambient air quality status* that includes data for the four criteria pollutants — TSPM, PM_{10}, NO_2 and SO_2 — that are routinely monitored. Monitoring of

BENCHMARKING AQM IN ASIA

Richer Asian cities have better air quality management (AQM) capabilities

The APMA (Air Pollution in Mega Cities of Asia) project, together with CAI-Asia (Clean Air Initiative), carried out a study to benchmark AQM capability of Asian cities. The outcome was aimed at facilitating learning from good practices and understanding the processes by which this could be achieved. The study was begun in 2002 and the first phase covered 12 cities with representative regional coverage. Completed in 2004, the second phase of the study included 23 cities. It is estimated that there are about 5,000 cities in Asia with a population of over a 100,000 people each. Millions living in the largest cities are exposed to some of the highest air pollution levels in the world. These regularly exceed WHO guidelines and national standards, with PM_{10} being the main pollutant.

Air pollution and economic development in Asia have a certain pattern; cities are in different stages of development (see: *Stages of evolution)*. AQM capacity in these cities was identified by seven main components — policies, governance, emissions, air quality modelling, monitoring, health, environmental and economic risk assessments, and financing of AQM.

The benchmarking sought to identify the strengths and weaknesses of a city's current capabilities by developing necessary indicators to assess each component of AQM capability. Each indicator was then grouped in an index of AQM capability, which is a useful tool to identify deficiencies and allow a comparison between cities that are at different stages of economic development.

Earlier, CAI-Asia had carried out a questionnaire-based survey in 64 major cities of Europe. Four sets of indicators (indices) representing the key components of AQM capability were used. These were air quality measurement capacity index, data assessment and availability, emissions estimate and management-enabling capabilities index. Each of the four component indices consisted of a number of indicators with ratings designed to determine a city's capacity with respect to a particular element of management capability.

Each carried a maximum of 25 score points, with intermediate score bands to assess the effectiveness of capability like minimal, limited, moderate, good and excellent. By adding these, an overall assessment of capability was obtained with a maximum score of 100.

The cities have been classified in different classes based on their air quality management capability. Among these classes, stage I is indicative of basic AQM. *Ad hoc* monitoring and control measures characterise cities belonging to this stage. Stage II cities have *ad hoc* legislation, beginning of monitoring and tailpipe and stack emissions controls. In stage III cities, there is a trend towards more comprehensive and continuous monitoring and AQM action plans. In stage IV cities, pollution levels drop, there are extensive and more sophisticated policies and an emerging focus on air pollution prevention. Stage V cities record decreasing levels of air pollution, undertake routine review and updates in legislation and monitoring policies and have a strong focus on air pollution prevention.

In the first step, the air pollution development level of cities is assessed. Next, the air quality capability index is determined. These are then validated with the AQM profiles of cities. A number of city authorities in Asia were requested to complete the questionnaire. Each question was allocated a score. The more the positive responses, the greater was the management capability of the city. The responses were reviewed and validated. Profiles were composed for each city. These contained descriptions of the AQM systems. For validation purposes, clarifications were sought or meetings conducted to obtain additional information. For the overall assessment of AQM in the 23 cities, the combined results, coupled with the profiles for each city, were taken into consideration. Expectedly, cities with a structured approach to AQM, one which combines monitoring, data analysis and legislation, scored the most.[1]

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STAGES OF EVOLUTION

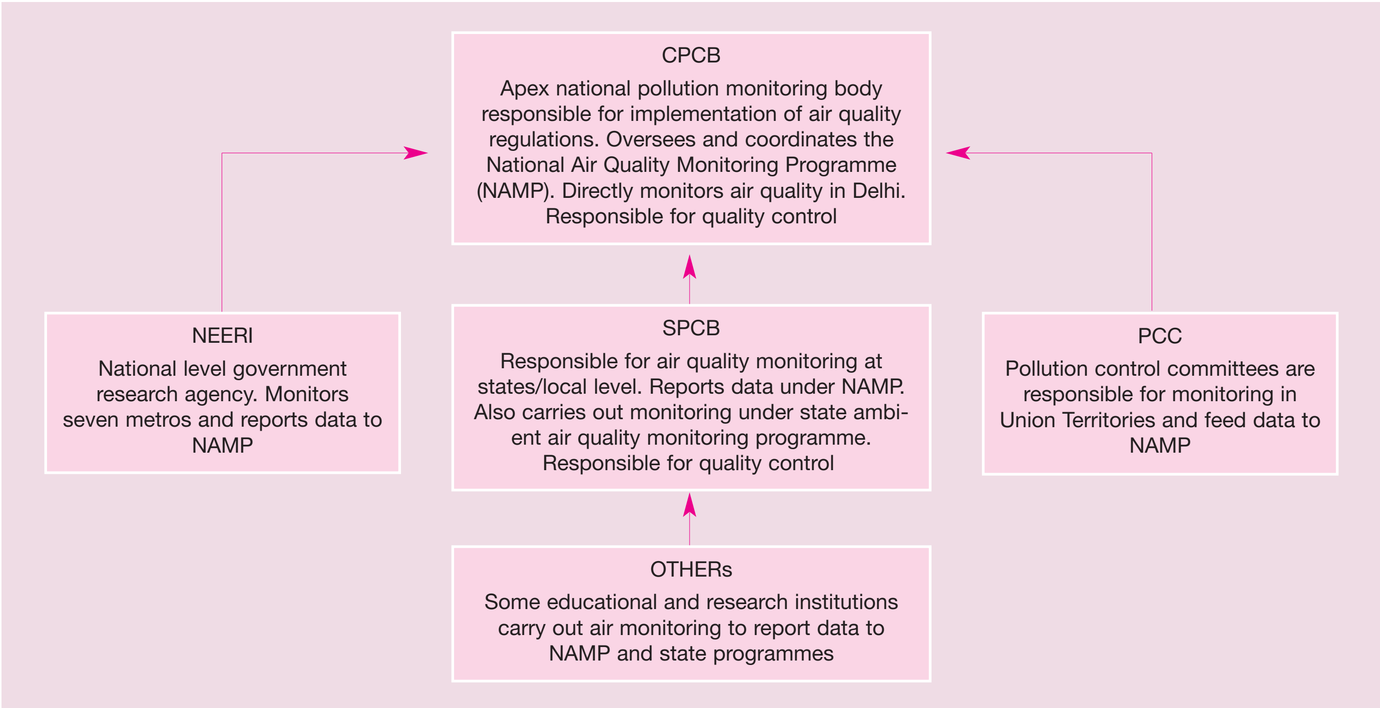
Air quality is stable in cities where management systems are well entrenched and standards are enforced regularly

Stage and cities	Description
Stage V — Excellent capacity Hong Kong, Osaka, Seoul, Singapore, Tokyo, Taipei (China)	Air quality levels are typically stable and below limits. Air quality is managed routinely with well-established indigenous institutional capacity. Comprehensive control strategies exist and air quality and emissions standards are enforced on a regular basis
Stage IV — Mature capacity Bangkok, Beijing, Busan, New Delhi, Shanghai	Air quality levels improving and approaching standards. AQM increasingly comprehensive and well structured. External donor involvement limited to specialised areas. Regular AQM activities funded from local resources. Continuous monitoring. Emphasis on development of medium-term strategies for key sources of pollution. Emerging emphasis on prevention. Enforcement of standards becoming standard practice
Stage III — Evolving capacity Ho Chi Minh, Jakarta, Kathmandu, Kolkata, Manila, Mumbai	A systematic approach being implemented, often with extensive external donor support. Continuous monitoring. Sustainability of institutional capacity not ensured from local resources. Pollution levels high but stable. Reduction in levels of certain pollutants as a result of control measures. More structured approach to enforcement emerging
Stage II — Basic capacity Dhaka, Hanoi, Surabaya,Yogyakarta	Initial legislation, standards and control measures exist. Regulators heavily dependent on external donor support and local specialised institutions. Pollution levels high and increasing. Monitoring often manual and limited to few stations. Enforcement of regulations very weak
Stage I — Minimal capacity Colombo, Karachi	Cities unable to establish basic AQM capacity. Rising pollution levels common. No comprehensive air quality legislation and standards in place. Limited and ad hoc approach to monitoring and pollution control

Notes: * This table only includes the cities in the benchmarking study — stage II; AQM — air quality management

Figure 3.1: **AIR QUALITY MONITORING STRUCTURE**

Several agencies are involved in monitoring for NAMP. But a strict monitoring protocol is needed to ensure quality data



meteorological parameters — that have a bearing on the pollutant concentration — such as wind speed and direction and relative humidity and temperature, are also integrated with the monitoring of air quality. CO and air toxics are monitored on a limited scale in a few cities.

The earliest set of air quality data was generated in 1978, when NEERI began monitoring in 10 cities — Ahmedabad, Mumbai, Kolkata, Kochi (Cochin), Delhi, Hyderabad, Jaipur, Kanpur, Chennai and Nagpur. These monitoring stations represented a nationwide cross-section of different geographical and ecological regions and also land-use classes, including industrial, commercial and residential.

More extensive monitoring began when CPCB initiated the National Ambient Air Quality Monitoring Programme (NAAQM) in 1985 under the Air (prevention and control of pollution) Act, 1981. The NAAQM — now called NAMP — was started with the setting up of a few stations at Agra and Anpara in Uttar Pradesh.[41] Since then, the monitoring network has been steadily expanded to reach the current mark of 326 stations.

However, with the exception of Delhi, these are not reported under NAMP. Their data is reported in special reports published by CPCB and SPCBs from time to time.

Effective air quality planning requires accurate data. Otherwise it is difficult to assess the true gravity of the risk. However, generating good air quality data — the first step towards good AQM — still remains a challenge in India. The lack of sheer rigour and discipline needed at the time of monitoring often undermines quality of data. Monitoring in India leaves much to be desired in terms of number of pollutants being monitored, selection of sites, methods of monitoring and techniques applied to collect data and quality control of data. Enforcement of guidelines needed for integrity of data remain weak. There are a large number of parameters, including monitoring, network design of monitoring sites, maintenance and calibration of equipment and quality audits of data, which come into play.

Standards: an elusive benchmark

The obvious starting point of AQM is to first study if an area has an air pollution problem. Monitoring helps in assessing the level of pollution in relation to the ambient air quality standards. Standards are a regulatory measure to set the target for pollution reduction and achieve clean air. Though there is no set definition of clean air, CPCB defines it as ambient air pollution levels 50 per cent below the ambient air quality standards set for each pollutant round the year.[42]

Many pollutants, though not all, are supposed to have a threshold above which the health of some people may be adversely affected. But carcinogens like benzene, PAH like benzo(a)pyrene do not have a safe threshold limit. Authorities need to take steps to keep their levels as low as possible. Some governments, however, still set standards for some of these to drive regulation of pollution sources.

The WHO sets health-based air quality guidelines that provide a guide to governments in setting their own standards. National standards of any country can be further modified by factoring in technological and economic considerations for attainment of those standards locally.

In India, CPCB is responsible for setting the National Ambient Air Quality Standards notified under the Air (Prevention and Control of Pollution) Act 1981. The standards for the criteria pollutants, including PM_{10}, TSPM, SO_2 and NO_2, have been set for 24 hours and annual average levels. CO — that can have an immediate lethal effect — has standards based on an eight-hourly average. Currently, India has not even set standards for O_3. Globally the standards for O_3 are set even for one hour as its immediate health effects can be quite serious.

Though largely patterned along WHO guidelines, Indian

NO STANDARD FOR $PM_{2.5}$

Even though $PM_{2.5}$ has been recognised as a health hazard, appropriate standards for it are tied up in red tape

A decade after ambient air quality standards were set for PM_{10}, the Union ministry of environment and forests (MoEF) is working to adopt standards for finer particulates with size less than 2.5 micron ($PM_{2.5}$). New Delhi-based Central Pollution Control Board (CPCB), constituted an expert committee in 2002, to "evaluate policy and guidelines to prevent, monitor and control fine particulate matter in ambient air." The expert committee, in its third meeting held in February 2004, had recommended a provisional daily air quality standard of 75 microgramme per cubic metre on the basis of a study done by the WBPCB.

Even this provisional daily standard did not come easily. The availability and cost of equipment for monitoring $PM_{2.5}$ at a number of stations to generate data seemed to present an insurmountable obstacle for the committee. After two meetings, a sub-committee suggested, "Recommendation of standards for $PM_{2.5}$ might be deferred for the time being." Instead, it offered a more convoluted route as an alternative to $PM_{2.5}$ standards. It proposed that BSOF of PM_{10}, mostly associated with fine particulates, be taken as a measure of $PM_{2.5}$ and recommended a standard of 30 microgramme per cubic metre as the standard for BSOF in PM_{10}.

But the committee did not accept this. The evidence presented by WBPCB, showing a correlation between PM_{10} and $PM_{2.5}$ levels, ultimately made the committee adopt the daily provisional standard of 75 microgramme per cubic metre. This was to be reviewed at a later date after more data was generated. The proposal awaits the approval of the MoEF and a gazette notification. "We want to implement the standards as soon as possible," says B Sengupta, member secretary of CPCB and also a member of the expert committee.[1]

standards, specifically for CO, are more stringent. But this has very little relevance as the government does not have any established legal framework to ensure that they are met.

The CPCB, however, has initiated a process to adopt air quality standards for new pollutants. In fact, this is an evolving process. Ambient air quality standards were first revised in 1994 to include a new category called RSPM or PM_{10}. The aim was to assess smaller particulates of size less than 10 microns. Since separate monitoring facilities were not available to monitor PM_{10}, CPCB laid down that 40 per cent of the TSPM should be considered as RSPM as a proxy for PM_{10}. The intrinsic logic to this was that an increase in TSPM would automatically indicate a proportional increase in PM_{10}.

Currently, a committee has been set up by CPCB to propose further modifications in established standards and also to set standards for $PM_{2.5}$. In February 2004, it finalised the provisional 24-hourly standard for $PM_{2.5}$ at 75 microgramme per cubic metre. $PM_{2.5}$ monitors are being procured in Delhi for studying six sites under a World Bank-aided project and another three under a Canadian grant. Pilot monitoring has begun in three sites. The final notification on provisional standards is awaited (see Box: *No standard for $PM_{2.5}$*).

While India is still dragging its feet on setting $PM_{2.5}$ standards, the US is continually revising and tightening standards for fine particles to address the public health challenge despite persistent opposition from the vehicle industry (see Box: *US scientists rise*).

The CPCB will have to urgently pay attention to establish O_3 standards and expand capacity for O_3 monitoring, which is critical

US SCIENTISTS RISE

Demand even tighter PM standards to protect public health

After adopting the annual average standard of 15 microgramme per cubic metre and a daily standard of 65 microgramme per cubic metre for particulate matter of size less than 2.5 micron ($PM_{2.5}$) in 2004, the US Environmental Protection Agency (USEPA) is now deliberating on further tightening them. There has been considerable support from the health community for these initiatives. It is now exerting pressure on the committee in the USEPA, which is currently reviewing ambient standards. In March 2005, health scientists from New York University School of Medicine, supported by 100 eminent doctors, scientists, professors, clinicians, and researchers from the US and Canada, signed a statement of concern addressed to the chair of the Clean Air Scientific Advisory Committee (CASAC) of the USEPA. They urged him to lend support for further tightening of the fine particulate standards in the US.[1] According to the statement, "The USEPA's final criteria document, synthesising the results of these studies, provides extensive evidence that serious health effects are occurring with exposures allowed by the 1997 standards. Based on these data, we believe that strengthening of the 24-hour and annual average fine particle standards is now needed to protect public health... The recommendations by USEPA staff scientists — to strengthen the form and level of the standards — are based upon sound science. Therefore, the ranges proposed — between 25-35 microgramme per cubic metre for the 24-hour standard and between 12-14 microgramme per cubic metre for the annual average standard — are well supported by the health evidence and the results of the risk assessment."[2]

In December 2005, the USEPA proposed the new standards. Among the various changes proposed, the 24-hourly $PM_{2.5}$ standards have been tightened to 35 microgramme per cubic metre from the current standards of 65 microgramme per cubic metre. The annual standards have not been changed and remains at the current level of 15 microgramme per cum. Environmentalists are not happy with the EPA proposals that are considered a water down version of the recommendations of the CASAC.

California even separately regulates the more harmful PM fraction, sulphate particles. California's ambient air quality standard for sulphates was established in 1976, based on a critical harm-value methodology so that public health could be protected, even though insufficient information was available at that time.[3] California has a 24-hour sulphate standard of 25 microgramme per cubic metre.[4]

Table 3.6: **STANDARD DIFFERENCES**

Indian standards are based on land-use, allowing higher pollution levels in industrial areas. There are no standards for O_3 and $PM_{2.5}$

Air pollutants	Time-weighted average	WHO, 1999 (in µg/cum)	India (in µg/cum)[a,b]			USEPA July 1997 (in µg/cum)
			Industrial	Residential	Sensitive	
Nitrogen dioxide	Annual average 24 hours 1 hour	40 200	80 120	60 80	15 30	100
Sulphur dioxide	Annual average 24 hours 3 hours 1hour 10 minutes	50 125 500	80 120	60 80	15 30	80 365 1,300
Carbon monoxide	8 hours 1hour 30 minutes 15 minutes	10,000 30,000 60,000 100,000	5,000 10,000	2,000 4,000	1,000 2,000	10,000 40,000
Lead	Annual average 24 hours	0.5	1.0 1.5	0.75 1.0	0.50 0.75	1.5
PM_{10}	Annual average 24 hours		120 150	60 100	50 75	50 150
SPM	Annual average 24-hours	* *	360 500	140 200	70 100	
$PM_{2.5}$	Annual average 24-hours					15 65
O_3	8 hours 1 hour	120				157 235
Ammonia	Annual average 24-hours			100 400		

Notes: WHO — World Health Organization; USEPA — US Environmental Protection Agency; PM_{10} — particulate size less than 10 micron
$PM_{2.5}$— particulate size less than 2.5 micron; µg/cum — microgramme per cubic metre
* — no definite guidelines mentioned
a. Annual average of minimum of 104 measurements in a year, taken twice a week, 24-hourly at uniform intervals
b. 24-hourly/eight-hourly values should be met 98 per cent of the time in a year. It could exceed in two per cent of the time, but even then not on two consecutive days
Source: Anon 2000, *Air quality status and trends in India*, Central Pollution Control Board, New Delhi, p 56

from the public health point of view. O_3 is usually measured as an hourly concentration. Maximum hourly concentrations during the day signal severity of the pollution. High peak levels can have immediate health effects.

Air toxics still remain outside the scope of Indian regulations. However, discussions have begun on the introduction of standards for them. Though WHO guidelines stipulate that these pollutants do not have a safe threshold, minimal standards are under consideration For example, the CPCB's proposals included adopting an annual average standard of 10 microgramme per cubic metre for benzene from 2005 and subsequently reducing it to five microgramme per cubic metre by 2010.[43] This process has not begun yet. Only a few countries have set standards for benzene. The Netherlands adopted an annual standard of 3 ppb (nearly 10 microgramme per cubic metre) in 1993 and Germany in 1998. The UK has adopted 5 ppb (nearly 16 microgramme per cubic metre) and set a deadline for reducing it to 1 ppb (nearly three microgramme per cubic metre).[44] But the UK government also heeds the advisory that benzene is a genotoxic carcinogen and, in principle, exposure to it should be kept minimum.

The CPCB is also espousing an annual average standard of five nanogramme per cubic metre for benzo(a)pyrene, taken as a measure of a melange of toxic PAHs in the air. This will subsequently be reduced by one nanogramme every year to reach one nanogramme per cubic metre by December 2010.[45] This is similar to Europe's efforts. Under the European Union (EU) directive 2004/107/EC of December 15, 2004, Europe will enforce the benzo(a)pyrene target value of one nanogramme per cubic metre for the total content in PM_{10} fraction averaged over a calendar year.[46] Member states will have to undertake all necessary measures to ensure that from December 31, 2012, benzo(a)pyrene levels do not exceed target values.

Yet another critical dimension of the Indian air quality standards is that these are land-use based and are different for industrial, residential and sensitive areas. This classification has come under scathing attack. Critics feel that keeping norms for industrial areas more lenient than residential ones will expose a very large population to serious health risks. Only uniform and health-based standards can help mitigate the effects of air pollution. The WHO air quality guidelines do not distinguish between residential and industrial areas (see Table 3.6: *Standard differences*).

A study conducted by the East West Centre, Hawaii, on the spatial pattern of air pollution in Delhi, spanning 10 years, found that there is no basis for differentiating between pollution levels across land-use types in Delhi. The findings supported the fact that land-use based standards have no scientific validity. The study has

PUBLIC CAMPAIGN

Pressure from civil society resulted in national ambient air quality standards in Nepal

Situated in the Himalaya, Nepal does not have a severe air pollution problem. However, most big cities record high levels of particulate pollution. Gaseous pollutants, though below WHO and national standards, are also increasing. The levels of total suspended particulate matter (TSPM) and PM_{10} in Kathmandu, Biratnagar and Pokhara are higher than the standards prescribed by the WHO.

Despite increasing air pollution, the government has not taken any steps to implement control measures. Therefore, NGOs like Pro-Public launched a campaign through research, advocacy and capacity-building litigation. The organisation has consistently urged the government to set environmental quality standards or a national ambient air quality standard.

Environmental quality standard case

The ministry of population and environment (MoPE) — dealing with environmental issues — was established in 1995. After that till 1999, the country did not have an environmental quality standard. As per the Environment Protection Act (EPA) and Environment Protection Rules 1997, the MoPE has a statutory duty to set environmental standards for air, water, noise and industrial effluents. In 1999, Pro-Public filed a case against MoPE to force it to set environmental quality standards.

The ministry hired a team of consultants from the Institute of Engineering, Nepal. The report was prepared with expert consultation as well as a study of the required environmental conditions. This report was not given to the Pro-Public. However, being the petitioner, it obtained a copy from the court.

The organisation reviewed the report and organised a meeting on the proposed environmental quality standards. It also invited suggestions for improving them. The meeting was held on November 20, 2001. Various experts, scientists, academics, lawyers and representatives of organisations working on environmental issues participated. Suggestions for improvements were compiled and submitted to the ministry. This meeting proved to be an important milestone for the setting up of a comprehensive national ambient air quality standard. For example, the parameters for benzene were not included in the proposed standards, though it was found that in Kathmandu it was several times higher than WHO guidelines. Ultimately, standards for benzene were set. Later, environmental quality standards also included the annual and 24-hour average limits for gaseous pollutants.

Thus, after more than two years, the Supreme Court of Nepal in November 2001 issued orders to set standards for air, water and noise levels as per the MoPE's statutory duty. National ambient air quality standards were gazetted on July 4, 2003.

Pro-Public is now actively campaigning for the enforcement of environmental quality standards in the country. According to it, there is an urgent need for effective implementation, compliance and monitoring of standards. This requires adequate human resources such as environment inspectors (EIs). An EI would effectively implement and monitor environmental activities.

The ministry, with the environment sector programme support of the Danish International Development Agency, has set up six stations to monitor air pollution levels in Kathmandu. Besides, monitoring stations need to be set up in other cities of the country. There is also a need for an independent organisation that can monitor and report on environmental issues. Towards this end, the Supreme Court of Nepal has formed a special monitoring cell.[1]

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CSE conference: The leapfrog factor, New Delhi, April 2004

argued that though industrial activities have gradually moved out of the city, there is a greater build-up of commercial activities near and within residential areas. This is held responsible for increasing vehicular emissions near residential areas.[47]

India has taken early steps in introducing air quality standards. Most Asian countries that have begun regulating air pollution have followed WHO's health-based guidelines. However, some countries have not adopted air quality guidelines yet. Some are still in the process. Pakistan, for instance, is now in the process formulating standards. For some countries like Nepal even adoption of basic standards has been a struggle. In fact, a civil society campaign had to be launched to get the government to adopt air quality standards (see Box: *Public campaign*).

Indian standards do not have teeth, as these are not legally enforceable.

There are lessons to be learnt from other parts of the world. The best example is that of California, which has been allowed to set more stringent standards under the Clean Air Act (CAA) than the rest of the US, to meet its pollution challenge. State implementation plans are prepared to meet time-bound air quality targets. California Air Resources Board (CARB) takes the state implementation plan seriously, as there is a built-in accountability. Environmental groups can sue CARB for violating the requirements of the CAA. In fact, the state of California was sued by civil society groups. Furthermore, the Federal CAA has specified that California will lose billions of dollars in federal highway funds if CARB does not meet the clean air requirements (see Box: *Legally binding*).

Monitoring network: inadequate

The current monitoring network in most Indian cities is woefully inadequate with regard to the number of sites, pollutants monitored, frequency and quality of data generated. It is riddled with serious shortcomings and missed deadlines for data reporting.

Except for the big metros, most other cities have barely two to three (or, in rare cases, five) official monitoring stations. Bigger cities like Delhi, Mumbai, Kolkata or Hyderabad are better equipped. Delhi, with an estimated population of 14 million, covering an area of 1,486 square km, has 11 monitoring stations, which means one station to capture the air quality profile of an area as large as 124 square km (see Table 3.7: *Inadequate monitoring*).

There is a lack of consensus or guidelines on the desired grid density in critically polluted cities. The CPCB has adopted WHO guidelines for the air quality grid. According to these, there should be at least four stations to monitor SPM and NO_2 per 100,000 people. In fact, in its project proposal to the World Bank in 1997 on improving air quality monitoring in Delhi, CPCB had proposed

LEGALLY BINDING

In the US, each state must submit a plan to the EPA that demonstrates how it will maintain air quality

The USEPA uses six "criteria pollutants" as indicators of air quality, and has established for each of them a maximum concentration, above which adverse effects on human health may occur. When an area does not meet air quality standards for one of the criteria pollutants, it may be subject to the formal rule-making process, which designates it as a non-attainment area. The Clean Air Act (CAA) further classifies O_3, CO, and some PM in non-attainment areas based on the magnitude of an area's problem. Non-attainment classifications may be used to specify what air pollution reduction measures an area must adopt and when it must reach attainment.[1]

Each state must then submit a state implementation plan (SIP) to the USEPA that demonstrates how it will achieve or maintain air quality that satisfies federal standards.[2] The SIPs are primarily made of state and local regulations. Once approved by the USEPA, a SIP requirement is federally enforceable. This, in turn, implies that USEPA or citizens as well as states and local air districts can enforce the requirements.[3] The SIP is a public document and citizens can enforce its regulatory provisions under section 304 of the CAA.[4]

The 1977 amendments to the CAA provided for the sanctions that USEPA could impose upon states that failed to submit adequate plans and for those that did not attain the standards by the deadline.[5] In especially difficult cases, USEPA could take action by writing a federal implementation plan (FIP). Possible sanctions, included the withdrawal of federal highway funds for all but the most critical safety-related highway projects and a ban on construction of new major stationary emissions sources.

In response to the failure to meet the 1980s deadlines, the 1990 CAA amendments specified attainment deadlines, that depended on how far an area was from reaching attainment in 1990 and a new "bump-up" provision for dealing with areas that failed to meet their attainment deadlines. In this provision, the USEPA administrator is directed to re-classify any O_3 non-attainment area, which is ranked below severe or that fails to attain the national ambient air quality standard by its attainment date to "the higher of (i) the next higher classification for the area, or (ii) the classification applicable to the area's design value."

Additionally, the 1990 CAA amendments provided more tangible penalties and sanctions for states that fail to submit a SIP or submit an inadequate one. These include the authority for USEPA to write a FIP as well as to impose two types of sanctions: (1) cutting off federal highway funds and (2) limiting the construction or modification of major new sources by requiring two-for-one offsets from other sources of the same pollutant in the same or in adjacent areas.[6]

An area — within five years from the date of being designated as non-attainment for the primary ambient air quality standards — has to fall in the attainment area according to section 172 (a). The secondary ambient air quality has to be achieved as expeditiously as practicable after the date such area was designated non-attainment.

increasing the number of monitoring sites in the city to 24. In the same document, CPCB had cited examples of the grid density in Germany, which has 541 monitoring stations for a population of 81.76 million. According to this, Delhi would need about 67 stations. But high costs preclude its application, CPCB said. Therefore, there should be a balance between costs and type of data needed.

The CPCB is working towards increasing monitoring stations across the country. NEERI, which had originally set up 10 stations in India, monitors seven metros with three in each city. Most SPCBs are cash-strapped and averse to setting up new stations. Ground realities reflect a sordid scenario. The SPCBs are already finding it difficult to keep operational the 295 stations that exist. During 2003, under NAMP, monitoring was carried out only in 201 stations.[48] The CPCB shares the capital cost of setting up monitoring stations. But state governments provide finances for their operation and maintenance (O&M), which is often insufficient.

By 2010, CPCB plans to add 110 new monitoring stations under NAMP. Official deliberations on further expanding and strengthening NAMP have already begun. In order to initiate automatic monitoring in polluted cities, CPCB has also decided to initiate monitoring of SO_2, NO_2, CO, O_3, benzene, toulene, xylene (BTX) and PM_{10} in the 16 cities identified by the Supreme Court (SC). B Sengupta, member secretary, CPCB, says that there are plans to initiate $PM_{2.5}$ monitoring in 10 non-attainment cities by 2007-2008. In the same cities, automatic monitoring of the four criteria pollutants and other air toxics, including O_3 and BTX, will be initiated. PAH monitoring is also expected to increase in metros.[49]

Opinions differ on an appropriate grid density. Most experts agree that the current grid density is inadequate to capture the air quality profile. But experts are also sensitive to the high capital investments involved. Given the serious resource crunch and limited technical skills in this field, many advise against setting up elaborate monitoring systems. They instead suggest acting on the information currently available from the present network.

The network design is largely defined according to the stated goals. "There are no universal rules for network design since any decision will be determined by the overall monitoring objectives," says Dietrich Schwela, an air pollution scientist formerly with WHO. A large number of criteria would govern decisions such as where most people live, pollutants they are exposed to, the kind of exposure they face from their micro-environment and the need for a daily alert system.

The system in Indian cities is not designed to satisfy such explicit goals. The few fixed sites are not able to generate data that represents the air quality profile in different parts of the city. Given this constraint, authorities focus on pollution hotspots such as traffic-congested city centres, industrial areas, residential sites and select 'urban background' sites, which serve as a typical case and provide guidelines for the intense pollution levels. Sometimes, fixed-site monitoring is supplemented with short-term monitoring at various urban locations with the help of mobile units. Data from short-term monitoring brings out wide variations in the air quality in different micro-situations. For instance, short-term monitoring of 22 traffic intersections in Delhi during 1997 and subsequent monitoring showed that there could be wide variations at different sites, not otherwise captured by existing fixed stations.

Moreover, a network should also be designed to meet specific needs. For instance, composite epidemiological studies in Indian cities would require monitoring of not only highly-exposed populations in polluted areas but also of the controlled ones in areas

Table 3.7: **INADEQUATE MONITORING**

Current monitoring network in Indian cities is inadequate to assess the pollution risk

City	Number of monitoring stations	Manual/ automatic	Pollutants monitored	Area of the city (in sq km)	Population** (in million)
Ahmedabad	11	Manual	Regular monitoring: SO_2, NO_2, SPM, PM_{10}, PAH	190.84	4.52
Bangalore	Five stations and one mobile station operated by the Karnataka SPCB. Plans one online	Five manual	Regular monitoring: SO_2, NO_2, SPM, PM_{10}, Limited monitoring: CO, O_3, benzene, toluene, xylene	225.0	5.6
Chennai	Tamil Nadu SPCB operates eight stations. Six stations under NAMP	Eight manual	Regular monitoring: SO_2, NO_2, SPM, PM_{10},	174.0	6.4
Hyderabad	Andhra Pradesh SPCB has increased stations to 20 in the twin cities. Data of seven stations is reported by CPCB under NAMP	All manual	Regular monitoring: SO_2, NO_2, SPM, PM_{10} Limited monitoring is done in stations operated by SPCB but not reported under NAMP. It includes CO, VOCs	172.6	5.5
Kanpur	Five (NAMP)	Manual	Regular monitoring: SO_2, NO_2, SPM, PM_{10} Limited monitoring: $PM_{2.5}$	299.0	2.6
Lucknow	Five (NAMP)	Manual	Regular monitoring: SO_2, NO_2, SPM, PM_{10}	447.5	2.2
Solapur	Two (NAMP)		Regular monitoring: SO_2, NO_2, SPM, PM_{10}	33.11	0.87
Pune	Three (NAMP)	Manual	Regular monitoring: SO_2, NO_2, SPM, PM_{10}	243.96	3.7
Faridabad	Two (NAMP)	Manual	Regular monitoring: SO_2, NO_2, SPM Limited monitoring: CO	2,105*	1.05
Mumbai	Three (NAMP)	Manual	Regular monitoring: SO_2, NO_2, SPM, PM_{10} Limited monitoring: CO, benzene, VOC, PAH	429.89	16.3
Kolkata	Air quality is monitored by NEERI in three stations. State board is operating around 17 manual and two online stations	Manual and automatic	Regular monitoring: SO_2, NO_2, SPM, PM_{10} Limited monitoring: CO, VOCs	1,340	13.21
Delhi	11	Three automatic, rest manual	Regular monitoring: SPM, PM_{10}, SO_2, CO, O_3 Limited monitoring: benzene, PAH, $PM_{2.5}$, VOC	1,487	13.78

Notes: *Total geographical area of Faridabad district; ** Population figures are for urban agglomerations; PM_{10}— particulate size less than 10 micron; $PM_{2.5}$ — particulate size less than 2.5 micron; SPM: suspended particulate matter, NO_2: nitrogen dioxide; SO_2 — sulphur dioxide; CO — carbon monoxide; VOC — volatile organic compounds; PAH — polycyclic aromatic hydrocarbons; CPCB — Central Pollution Control Board; NEERI — National Environmental Engineering Research Institute; SPCB — State Pollution Control Board; NAMP — National Air Quality Monitoring Programme; Table is based on the various submissions of state governments and state agencies to Environmental Pollution (Prevention and Control) Authority for the National Capital Region

Sources:
- Anon 2004, Final report on particulate pollution reduction strategy in seven critically polluted cities, Environmental Pollution (Prevention and Control) Authority, New Delhi, *mimeo*
- Anon 2003, *National ambient air quality status* report, Central Pollution Control Board, New Delhi

with lower pollution levels. The level of sophistication will have to be improved and the monitoring network will have to be supported with a system of baseline data generation on mortality and morbidity rates. Only then it will be possible to assess health impacts of air pollution. Similarly, the current network ought to be adequately designed to capture the impact of air pollution on the urban periphery and its trans-boundary effects.

The monitoring network density should take into cognisance the fact that different pollutants have different health risks and concentrate on those posing the greatest threat. In many Western countries, the health effects of NO_2, particulates and O_3 are of grave concern. Concentrations of SO_2 and air-borne lead have fallen in recent years. So, with the exception of some industrial locations, these pollutants have ceased to be a health problem. Such a situation has called for the monitoring network to reduce SO_2 and air-borne lead to a minimum (for example, restricted to sites monitoring the long-term trend and any remaining pollution hotspots such as industrial sites) while expanding the monitoring networks for NO_2, PM_{10}, $PM_{2.5}$ and benzene.[50] However, extensive SO_2 monitoring facilities do exist in Indian cities though its levels are way below standards. Globally, monitoring of TSPM is being replaced by that of PM_{10} and $PM_{2.5}$ as these are more harmful from the health point of view. Though the levels of O_3, benzene, sulphate and other air toxics are expected to be very high in Indian cities, the monitoring network has not been adapted accordingly to enable adequate monitoring of these pollutants.

As the profile of the sources of pollution undergoes a change, it becomes necessary to monitor additional pollutants. So, a network that was once assumed to have a satisfactory number of monitors, might have to be expanded. Under NAMP and SAAQM, monitoring of pollutants like CO, benzene, PAH and O_3 — that show high concentrations and are a cause for concern — is sporadic and not undertaken even at the regular monitoring stations. These are not even remotely in the reckoning at special sites. Monitoring of air toxics like benzene and PAH is also grossly inadequate. In its 1977 general guidelines, WHO underscored the fact that the number of stations for certain pollutants could be increased or decreased depending on the extent of industrialisation, density of traffic and types of fuel used.[51] The WHO-UNEP report of 1994 recommends that monitoring activities in major Indian cities be expanded to cover more pollutants and a wider geographical area. It suggests that localised air quality assessments be carried out to identify specific problems and provide detailed recommendations for pollution abatement (see Box: *Pin them down*).

As the SC stepped in on August 2003 to demand an action plan to control particulate pollution in seven Indian cities, the state governments concerned drew up a common minimum programme that fleshed out their proposals to improve air quality surveillance. An overview shows a minimal attempt to add a few monitoring stations and, in some cities, a couple of more pollutants for monitoring. These initiatives would require a more composite approach.

In the meantime, some state governments have urged the Union government to step in to standardise the process of setting up more monitoring stations. The Andhra Pradesh Pollution Control Board, for instance, has written to MoEF to standardise the process of instrument procurement by developing uniform purchase protocol so that each SPCB can avoid the cumbersome process of procuring instruments for setting up monitoring stations. State governments have also demanded stronger technical support from the central agency to improve the system for audit and review. The CPCB is in the process of upgrading the guidelines for air quality monitoring.

PIN THEM DOWN

The West regularly monitors criteria pollutants like sulphate particles, $PM_{2.5}$, 1,3-butadiene and toxic metals like cadmium, arsenic, nickel and mercury in the ambient air

The US

The USEPA regularly monitors criteria pollutants — SO_2, NO_2, PM of size less than 10 micron (PM_{10}), CO, lead, O_3 and PM of size less than 2.5 micron ($PM_{2.5}$). In addition, the CAA requires that USEPA regulate 188 toxic air pollutants from industrial sources. Besides, the California EPA monitors sulphates and visibility-reducing particles.[1]

Australia

The EPA monitors SO_2, NO_2 , TSPM, PM_{10}, CO and O_3 on a regular basis. In addition, the department of environment of the Government of Australia has come up with plans to monitor benzene, toxic pollutants and pollen.

The UK

Eight pollutants — SO_2, NO_2, PM_{10}, benzene, 1,3-butadiene, CO, lead and O_3 — are measured regularly and the public is informed about the daily ambient concentrations of the criteria pollutants.[2]

Europe

The AQM Network (EUROAIRNET) has been set up by the European Environment Agency to monitor pollutants in various cities of European Union member states. The priority pollutants are SO_2, NO_2, O_3, PM_{10}, $PM_{2.5}$ and lead. The second priority list includes TSPM, CO, benzene, PAH, cadmium, arsenic, nickel and mercury.[3]

Minimum criteria not met

The premise of any monitoring programme is to generate reliable data for a region. The period and frequency of sampling are taken into account so that statistically reliable averages can be obtained. For proper monitoring, some basic criteria have to be met.

Most stations fall woefully short of fulfilling these and continue to violate the basic norms. While there are many such instances, the most glaring of them is failing to meet even the minimum requirement of monitoring for at least 104 days in a year. A minimum of 104 daily measurements in a year, taken twice a week, 24-hourly at uniform intervals, is required for computing the annual arithmetic averages of pollutants for stations or cities. It is difficult to assess the annual average levels if this limit is not met.

The CPCB, in its *National ambient air quality status 2003* report published in 2004, accepts the fact about inappropriate data. Of the 295 stations, ambient air quality monitoring was carried out at 201 monitoring sites. Adequate data was received for SO_2 only from 182 stations, for NO_2 from 180, for PM_{10} from 166 and for TSPM from 160 stations.[52] This means that insufficient data was received from the remaining stations as monitoring was done for less than 50 days in a year. The data for these monitoring sites had to be rejected.

On many occasions, it was found that even 24 hourly monitoring was not done properly and the averages were provided on the basis of just eight or 16 hours of monitoring. The CPCB officials tried to explain this discrepancy on the basis of power failures, rain and instrument failures.

Failing to discipline the system, CPCB responds by bending the rules. It has relaxed the criteria for minimum monitoring from 104 to 50 days in a year. It states in its October 2000 report, *Air Quality Status and Trend in India*, "In case target frequency of monitoring twice a week — 104 days in a year — could not be met at some locations, 50 days of monitoring per year is considered adequate for the purpose of data analysis for air quality status."[53]

Manual monitoring compromises quality

Ideally, a city should have an efficient automatic network, measuring all major pollutants and providing data continuously to a central control — with public display of the daily data. But the high cost of such a computerised system does not allow wide application in most cities.

Only a few big metros like Delhi have hybrid systems — a combination of manual and automatic monitors. The city has three automatic monitoring stations, the rest being manual. There are two mobile monitoring vans with automatic facilities. Manual systems can be set up with low investments, are simple to operate and can generate useful baseline information. For instance, a major limitation of the manual technique for particulate monitoring is that it does not allow measurement of daily peak values, which could be correlated with the information on wind direction. This, in turn, could provide a more in-depth analysis of problem sources in cities.[54]

If manual systems are used with passive sampling methods, only monthly and weekly averages of data are possible, while with active sampling, as is currently used under NAMP, 24 hourly averages are possible. Moreover, due to lack of standardisation, manual monitoring in India seriously compromises data quality.

The automatic online system allows instant generation and access to real time data, has considerable scope for refinement and is more accurate. But these monitors are difficult to handle and require highly skilled personnel to run them. Lack of timely sourcing of spares and components can also be problematic. Automatic monitoring systems cost around US $200,000.[55] The level of sophistication associated with their operation, along with required skilled personnel poses a serious challenge to the monitoring protocol and practices.

However, critically-polluted cities in India cannot delay the decision to adopt automatic monitoring as there is an urgent need to include more pollutants (like $PM_{2.5}$, O_3 and other air toxics) for monitoring. These will require more sophisticated systems. Automatic monitoring will also help generate more reliable and accurate data for routine pollutants. Given the challenge of risk assessment, cities like Delhi, which are now stepping up the number of pollutants to be regularly monitored, would have to scale up their capacity as well. Planning will have to be done in terms of not just upgrading technology but also developing skills. In Delhi, the ongoing effort to set up a $PM_{2.5}$ and air toxic monitoring network will require leapfrogging from the present manual and semi-automatic to automatic monitoring systems.

The UNEP's *Male declaration on control and prevention of air pollution and its likely transboundary effects for south Asia* states, "Certain sensitive parameters like O_3 cannot be monitored or assessed reliably using manual monitoring techniques. The manual monitoring techniques cannot depict the maximum and minimum concentrations as averaging of the pollutants is done over a period of four to eight hours, depending upon the prevailing concentration. The chemical methods are also not well-established to monitor low and high-level concentrations. The acceptability of any method would have to be commensurate with both ambient air quality and emissions standards"[56] (see Box: *Snags in manual monitoring*).

Quick, online measurement and data generation can also help cities set up more effective risk communication through a daily system of public broadcasts, by using an air quality index based on pollution peaks on a daily basis.

Quality audits of monitoring stations

Quality assurance and quality control are needed to ensure credibility of the data. The CPCB, in its *National ambient air quality status* report of 2003, admits to the problem, "As NAMP is being operated through various monitoring agencies, a medley of personnel and equipment get involved in the sampling, chemical

SNAGS IN MANUAL MONITORING

Limitation of monitoring instruments, lack of standardisation and indisciplined testing practices can influence quality of data significantly

Indian monitoring stations widely use the high-volume sampling method for monitoring PM in air. This is inexpensive and can be used by any laboratory possessing average equipment and skills.[1] The CPCB scientists admit that calibration of these samplers used by different State Pollution Control Boards (SPCBs) falls woefully short of the standard practice due to lack of calibration facilities and inadequate auditing.[2] It needs trained and experienced personnel.[3] As a result, it is difficult to maintain accuracy and integrity of data. In many cases, this also results in underestimation of pollution levels. What plagues the current manual method?

Particulate matter

The World Bank report of 2004, points out that different measuring techniques and instruments give varying results on ambient concentration in the same location. Therefore, regulatory agencies in industrialised countries define particles that have to be measured very precisely. For example the USEPA has designated instruments and methods for measuring $PM_{2.5}$ These are particles with size less than 2.5 micron. The EPA has set strict performance criteria which include the precision and accuracy of the flow-rate controller, frequency of recording, adequate temperature control and filter temperature measurements among others. But such precise procedures and definitions have not been adopted or enforced in the south Asian region.[4]

Information from CPCB confirms this. For instance, the flow rate of air through the sampler (specified as not less than 1.1 cubic metre of air per minute) needed to capture the near-accurate level of ambient PM levels, needs regular checking.[5] But often these procedures are not followed. The WBPCB scientists point out problems with maintaining the required flow rate in PM_{10} high-volume samplers, especially during winter when particulates reach very high concentrations.[6]

Similarly, as the particulate loading on the filter papers increases during sampling, the air flow rate drops. This requires constant vigil and correction. Steps are also required to check humidity of the filter paper. At some places, recommended procedures for such corrections are not followed.[7, 8] CPCB scientists warn that this can lead to loss of volatile PM to the extent of nearly 10-25 per cent.[9]

An audit study, conducted by S K Goyal, scientist at the National Environmental Engineering Research Institute (NEERI), Nagpur, assessed the quality of ambient PM monitoring in three cities and found that the average error ranges from 10 to 17 per cent and the maximum from 18 to 26 per cent. The reason, incorrect flow measurement and calibration.[10] Even inconsistent power supply and voltage fluctuation affect monitoring. This often leads to inadequate sampling and inaccurate data.[11]

Sulphur dioxide

The most common way of measuring SO_2 in India is the 'West and Gaeke method'. This has a low-cost operation. An assessment audit of National Air Quality Monitoring Programme monitoring stations in different cities has revealed that there are wide variations in the procedures adopted for sampling and analysis, sometimes leading to wrong results.[12]

Some serious drawbacks have been attached to this method. For example, it is very sensitive to the amount and purity of the chemical reagents that are added during laboratory analysis. If there is deviation analyses and data reporting. This increases the probability of variation and personal biases reflecting in data. This is the reason why monitoring data should be considered more as indicative rather than absolute."[57] It is unfortunate that the countrywide network of NAMP stations, which incurs a cost of more than Rs 4.93 crore annually for O&M — as per the Auto Fuel Policy committee report — cannot generate reliable and accurate data.

Reliability and accuracy depend on the calibration status of monitoring instruments. If the errors in the instruments are too high, integrity of data cannot be maintained. The CPCB officials attribute the problems of quality control and assurance to inadequate calibration of equipment, improper sample collection that skews analysis and lack of skilled personnel.[58] Lack of continuous power supply and improper siting of monitoring stations also influences data generation. Most of the time the personnel deployed for regular air quality monitoring in either NAMP or any other monitoring programme, is not adequately qualified and lacks experience and motivation. Sometimes there are not even clear-cut instructions for acceptance and rejection of samples.[59] Lax field supervision undermines the accuracy of monitoring programmes.

The CPCB acknowledges that due to financial constraints many organisations and institutes do not pay enough attention to various elements of quality assurance. As a result, levels of some pollutants can be underestimated. This is particularly worrisome in the case of NO_2. It is increasingly being pointed out that the current method being followed by pollution control boards to monitor NO_2 and SO_2 might be underestimating the actual levels by a wide margin (see Box: *Instrumental*).

There are no clear plans still, either at the Union government or at the state level, to develop a composite approach for revamping the system. The CPCB has recently contracted out the review of NAMP stations to independent private institutions.

Outsourcing of monitoring to private agencies is being considered as a possible option in India. According to a senior CPCB official, a committee is looking into this issue. Though exact details are not available, the official has clarified that CPCB is assessing workable models of outsourcing. The current state of affairs of quality control in SPCB and CPCB makes a framework for

from the recommended quantity of chemicals, this technique can overestimate or underestimate the ambient levels of SO_2. It can be overestimated by as much as 12-15 per cent or underestimated by about 9-16 per cent.[13] Similarly, to obtain correct results, great care should be taken to maintain the required temperature during sampling and analysis.[14]

Nitrogen dioxide

For ambient NO_2 monitoring, the 'modified Jacob and Hochheiser method' is followed. This can capture 82 per cent of the NO_2 levels. The CPCB has recommended this in place of the older BIS-approved method of 1974 as this can only capture 35 per cent of the NO_2 levels.[15] But CPCB has found that all state laboratories are not following the improved method.

Even the recommended method suffers from poor quality assurance. Operational parameters like flow rate, duration of sampling, sample dilution, temperature controls are not followed. The CPCB carried out a survey of the NO_2 measurement technique applied by the SPCBs. It found that most state boards maintained the flow rate of one litre per minute against the recommended rate of 0.2-0.5 litre per minute.[16] The CPCB has asked for upgradation of the high-volume samplers used for NO_2 monitoring to ensure that the required flow rate can be maintained.[17] Further studies carried out by a NEERI scientist found that the absorption efficiency of this method varies, despite maintaining the recommended flow rate. The average absorption efficiency is, therefore, 64 per cent at a flow rate of 0.23 litre per minute, against 82 per cent, as envisaged in the reference method for a 24-hour sampling duration.[18] Laboratory evaluations have shown that this method for determination of NO_2 is highly sensitive to different sampling conditions.

The CPCB compared the measurement performance of different laboratories of SPCBs. It found that laboratories were good at measuring higher concentrations of SO_2 and NO_2 more accurately than lower concentrations.[19]

INSTRUMENTAL

Calibration and audits are an important part of any monitoring exercise. They influence the quality of data

After studying CPCB's air monitoring data, Indian Institute of Technology (IIT) Delhi states that the monitoring equipment and related instruments need to be calibrated once every six months.[1] At the minimum, one calibration point in an instrument of all the monitoring equipment needs to be checked every fortnight. If the deviation from the norm is wide, the entire equipment should be calibrated.

However, monitoring agencies do not have adequate calibration facilities and worse, facilities are not even available at most places in the country. On site calibration is not done as reference facilities are not portable. So monitoring systems have to be taken to the calibration agencies. This increases the cost of transportation, sometimes damages the instruments and a lot of time is lost. Monitoring may also have to be suspended.

Even the cost of calibration is prohibitive. For instance, calibration of a portable calibrator for flow rate calibration costs Rs 28,000. A calibrator is priced at Rs 15,000. A stopwatch costs Rs 1,000 whereas the calibration costs Rs 2,500.[2] As a result, calibration in many cases is not as per requirement, making the system vulnerable to significant errors. Even correction is not always possible. Sometimes the frequency of calibration is decided arbitrarily, even when it is known that regular calibration of monitoring instruments is a must for reliable data generation. During a separate study conducted by NEERI scientist S K Goyal, substantial errors were observed due to poor maintenance of equipment and lack of proper training of personnel. He concluded that it was difficult to quantify such errors, something which could make a mockery of the monitoring exercise.[3]

Very few accredited air-monitoring labs are in operation in India. The CPCB laboratory received accreditation from the National Accreditation Board for Testing and Calibration laboratories (NABL) India in 2003-2004. Of the CPCB's six zonal offices, Kanpur and Kolkata have NABL certification. The CPCB has recently prepared quality control plans for analysis of various parameters in their laboratories.[4] Some SPCBs have facilities to get the calibration done from outside. However, the CPCB now plans to create calibration facilities in its zonal offices for the SPCBs.[5]

The CPCB has also initiated a project, with support from the department of science and technology, to develop standard gas mixtures to carry out inter-laboratory comparisons of gas measurements and calibration.[6]

strict compliance of monitoring protocols necessary.

In the meantime, there is already a movement towards involving other agencies. According to a CPCB official, presently 56 monitoring stations under NAMP are outsourced to different agencies. For instance, in Ahmedabad, SPCB has handed over three stations to the Gujarat Environmental Management Institute since August 2002. A large number of government departments in Ahmedabad are taking the initiative of setting up monitoring stations. The Gujarat Pollution Control Board, the Ahmedabad Municipal Corporation, the Ahmedabad Urban Development Authority and the Industrial Associations plan on setting up 16 more stations.[60] As of May 2005, they have set up 11.

However, the skills of agencies aiming to take up monitoring in different cities need to be assessed to ensure quality and credibility of data. The CPCB claims that it has taken steps to minimise dubious data by considering the possibility of initiating third-party auditing of its monitoring stations. It identifies such agencies through an international bidding process. Similar efforts will have to be made even at the state level to audit stations operating under the state ambient AQM programme.

3.5 Risk communication

Easy access to the latest air quality data is vital for risk communication. In India, for a long time delays in the dissemination of data remained a serious hurdle. There was a considerable time lag in data reporting — nearly one to two years. According to CPCB, manual data processing from across the region takes a long time. However, of late, the time lag for all stations in Delhi has been reduced considerably. From stations with online monitoring systems, it is possible to access the current data almost on a daily basis. The CPCB has attempted to improve this online system of data reporting to enable SPCBs to directly feed data from different cities to the central database called Environmental data bank, for further processing. Nearly, 240 stations from round the country currently report data online. However, there is still a time lag in publishing of processed and analysed national air quality data by CPCB under NAMP.

But experts are of the opinion that cities should move towards building the capacity to relay data on daily basis. The strategy of the Government of UK, presented to the British parliament in January 2000, states, "A key part of this strategy involves giving out clear and up-to-date information on air quality. It also allows public scrutiny of the effectiveness of our policies. Information on air quality can also help influence people to behave in more environment-friendly ways".[61]

The EU, for instance, has made it binding on its member states to keep the public informed on a routine basis. "Member states shall ensure that up-to-date information on ambient concentrations of SO_2, NO_2, PM and lead is routinely made available to the public as well as to appropriate organisations such as environmental organisations and consumer organisations, for example, the broadcast media, press, information screens or computer network services," says the air quality directive of the Council of the EU.[62] Public broadcast on air quality has been made mandatory in the US also. The CAA of USA underlines, "The reporting agency shall make prominent public notice of the daily (air quality) index report on at least five days per week. Prominent public notification consists of (1) furnishing the daily report to one or more of the appropriate news media (radio, television, newspapers), and (2) making the daily index report publicly available at one or more places of public access."[63]

Global experience has shown that data on the concentrations of pollutants holds no meaning for people. Agencies have found it more appropriate to use an index or rating system that groups the concentrations of several pollutants into broad bands and describes air quality in terms of good, moderate, poor and hazardous. Rating of the air quality or using numerals to denote the quality — known as air quality indices — is the most commonly used method (see Box: *Health alerts*). These are flashed on a daily basis through public information systems to alert people. This can serve the dual purpose of alerting people to take adequate protection to reduce health risks and also galvanising city authorities to take emergency measures to mitigate the severity of pollution.

HEALTH ALERTS

Several countries are rating air quality and making the information available in the public domain

USA

The CAA in the US requires that metropolitan areas collect air quality data and report it daily by putting up prominent public notices like an air quality index. In 1976, the USEPA established a nationally uniform air quality index. The revised index assigns colours and a brief description to ranges of ambient concentrations of pollutants: green for "good", yellow for "moderate", orange for "unhealthy" for sensitive groups and so on.[1] The overall index is based on the sub-indices of six pollutants — PM_{10}, $PM_{2.5}$, SO_2, CO, NO_2 and O_3. For each pollutant, the sub-index is calculated on the basis of the actual ambient concentration in relation to the air quality standard for the pollutant. After the sub-indices are calculated, the highest among them is declared the overall air quality index. The values are reported on a scale of 0-500, which represents a very broad range of air quality, from pristine air, to air pollution levels that present imminent and substantial health threats to the public.

In most cases, a sub-index value of 100 is associated with the numerical level of the short-term standard (24 hours or less) for each pollutant. Different approaches are taken for NO_2, (for which no short-term standard has been established) and for $PM_{2.5}$. The index value of 50 is associated with the numerical level of the annual standard for a pollutant, if there is any, at one-half of the level of its short-term standard. The pollutant responsible for the highest index value (the reported air quality index) is called the critical pollutant.

Mexico (Mexico City)

Pollution emergency is issued in three phases:

Phase I alert: This is applicable when PM_{10} levels exceed 1.75 times the standard or when the O_3 concentration reaches 2.40 times the standard, or when PM reaches 1.25 times and O_3 2.25 times the standard in a deadly combination.[2] Phase I alert requires a 30-40 per cent cut in industrial emissions, halting of 50 per cent of government vehicles, stemming street repairs to minimise traffic jams and issuing a note of caution to drivers not to use cars. The most polluting vehicles, identified by a hologram, are stopped from plying on alternate days. But if the emergency lasts for more than two days, then all polluting vehicles are banned as long as it lasts. Vehicles using gasoline or alternative fuels (officially certified as low-emissions vehicles) are exempt along with some others that provide medical services. The public is kept informed about the health hazards.

Phase II: Phase II alert comes into force when either O_3 or PM_{10} reach three times the standard. Under it, the cutback in industrial emissions is required to be of the order of 50-75 per cent, schools are closed (to reduce the number of vehicles taking children to school, or school opening times are delayed until the temperature inversion has lifted during late morning and air quality improved). Besides, the one-day-a-week ban on vehicles is extended to two days a week to try to reduce vehicle use by 40 per cent. The most notable alert issued was in January 1989, when schools were given a month off.

Phase III: Phase III emergency calls for closing down of industries in addition to curtailing of other activities.

Australia

The air quality index for each pollutant is calculated at each monitoring station to get a comprehensive profile. The highest figure is taken to reflect the overall air quality index for the station. The EPA issues a smog alert when the ambient level of a primary pollutant (CO,SO_2, PM_{10}) leads to classification of air quality as poor (that is, when the index crosses 100) at any two stations in the city, or when the index of any secondary pollutant (O_3 or NO_2) exceeds 100 at any single station.[3] This means that even if a pollutant like suspended particulate matter (SPM) or SO_2 crosses the standard by a fraction at any two stations in a city, the government issues a smog alert.

The air is considered very good, when every pollutant is within one-third of the standard; good, when all of them are within two-thirds of the limit; fair, when they are all within the limit; poor, when any one of them exceeds the standard; and very poor, when any one of them exceeds the standard by 50 per cent. Each category is also represented by bands of different colours.

France

The air quality index here is known as ATMO and was developed in 1992. There are 10 levels (the first represents excellent quality and the 10th atrocious). It takes into account four pollutants — SO_2, NO_2, O_3 and PM_{10}. Based on their atmospheric concentration, four sub-indices are calculated for each. The worst of the four sub-indices is taken as the air quality index for the city. The number and description of the overall index are the same as those for the sub-indices.

In Paris, the declaration of a pollution emergency and informing the public about it is done in two steps.

Level 1 pollution emergency: When concentrations of SO_2, NO_2 or O_3 reach level 1, the public and the local authorities are informed about the state of pollution. In Paris region (*Ile de France*), AIRPARIF — the organisation in charge of monitoring air pollution — informs the public daily about pollutant exceedance, measured levels in a day and hour, places of non-attainment and causes of exceedance. It also issues a pollution forecast and makes announcements on the potential health effects of the current levels of pollution.

The AIRPARIF also informs local authorities about the exceedance situation for each pollutant. If the conditions persist after 24 hours, AIRPARIF keeps the local authorities regularly informed. The following actions taken during level 1 pollution emergency: if the responsible pollutant is SO_2, local authorities recommend the point sources of pollution to (a) limit indoor maximum temperature to 19°C during cold periods, (b) minimise combustion, particularly fuels with high sulphur concentration, and (c) close industries with high sulphur emissions. If NO_2 or O_3 are responsible for the level 1 emergency, local authorities recommend car drivers to (a) postpone trips to the Paris region, (b) bypass Paris city, (c) utilise public transport system, (d) practice car-pooling, (e) use other existing non-polluting transport systems and (f) bring down the speed of cars. If level 1 pollution emergency continues beyond 48 hours, industrial operations are curtailed or even shut down. Use of low-sulphur fuels is made compulsory.

Level 2 pollution emergency: A level 2 pollution emergency is declared when levels exceed alert thresholds. An alert threshold is considered to be surpassed even where pollution levels actually do not do so, but there is a high probability of exceeding the next day as estimated by prediction models. If SO_2 levels exceed the alert threshold, industries are asked to minimise operations or close down. Power plants are asked to stop operations immediately, in case of NO_2 crossing the alert threshold. If either NO_2 or O_3 cross the alert threshold, heavy vehicles are banned, 10 per cent taxis are stopped and cars are allowed to ply only on alternate days. To discourage private transport, public transport is made free.

The UK

Public is informed about air quality on an hourly basis. Information on five air pollutants is updated every hour. The Air Pollution Information Service of the department of the environment, transport and the regions uses four colour bands to describe levels of pollutants. These are classified as low, moderate, high and very high, based on the ambient concentration. Overall air quality is described keeping the worst-case scenario in mind. For example, if all but one of the pollutants records 'low' levels, the air quality is still described as highly polluted.

The CPCB, along with IIT Kanpur, has developed an air quality index for daily reporting of data. But this has not been implemented. It has, however, begun using a system of classifying average concentrations of air pollutants into low, moderate, high and critical, based on the level of exceedance from the air quality standards. But this is applied mostly to classify cities on the basis of the average concentration of pollutants and not for health alert systems for the public.

The trace of a daily alert system, developed in a few Indian cities, is still very rudimentary. The CPCB officially relays some data to the media. Based on their own monitoring, some private agencies have also begun circulating data to the media, which are very broadly classified in relation to air quality standards. But these systems are not standardised and there is no official quality control.

3.6 Resource allocation

The main reason for not being able to spruce up India's pollution monitoring network is lack of funds. While evaluating the functioning of SPCBs for the Eighth Plan (1992-93 to 1997-98), the Planning Commission found this to be an important factor behind inadequate monitoring in states like Bihar, Haryana, Maharashtra and Karnataka.[64]

According to estimates provided by the expert committee report on the Auto Fuel Policy of August 2002, the O&M cost of the existing 290 ambient air quality stations in India comes to about Rs 4.93 crore per year.[65] Further strengthening of NAMP stations and their continuation up to 2006-07 will cost Rs 241.3 crore. Inclusion of new monitoring parameters would cost an additional Rs 121.5

crore. This means the total estimated budget will escalate to Rs 362.8 crore to fund the proposed expansion of the monitoring network during the Tenth Plan (2002-03 to 2006-07).[66] The Planning Commission had also suggested that MoEF consider financial requirements for relocating monitoring stations, the need for which arises due to dynamic changes in locational features of some stations over the years.[67]

Financial allocations are abysmally low due to the low priority accorded to AQM. The CPCB is a grant-in-aid institution of MoEF. Its annual budget for 2005-2006 is Rs 39 crore, which is around three per cent of MoEF's total budget of Rs 1,235 crore and, in turn, it has apportioned a minuscule amount for air quality monitoring system. This has led to a situation in which donor support is becoming important. The World Bank had given a grant under its environmental management capacity-building programme to strengthen and set up online and automatic monitoring stations to monitor $PM_{2.5}$, other gases and meteorological parameters. But even this remains underutilised tied up in red tape.

3.7 Air quality management in India

Almost five decades of air quality monitoring worldover have shown that it alone cannot comprehensively quantify patterns of air pollution over space and time. Action plans can be drawn up only if they are conjoined with other assessment techniques. Precise estimates of pollution sources, along with their contribution to the total pollution load and the rate at which the sources are expected to increase are also required. Any city can have various sources, including transport, industry, domestic, refuse burning, re-suspension of road dust and construction activities, among others. But the weakest link in air quality planning in India is that it is still not possible to arrive at a reliable source-wise pollution load estimate for an effective strategy to control it.

A poor information base, ineffectual institutional capacity and an ineffective legal framework for AQM have been the restraining factors in air quality planning and the reasons why it has remained ad hoc and fragmented in India. Risk assessment, risk communication and compliance with standards are critical challenges in India and also in most parts of Asia.

Despite these weaknesses, AQM has begun taking hold in India as well as in many parts of Asia. The experience demonstrates that despite the weak science, it is possible to act based on experiences and knowledge elsewhere. But this also does not mean that development of proper AQM systems should perpetually remain on hold.

Where is the pollution coming from?

The basic instruments for urban air quality planning include emissions inventories, source apportionment studies and air quality modelling. Emissions inventory helps to estimate the relative contribution of different sources to the pollution load. This needs to be updated regularly to account for the new sources of pollution being added and impact of mitigation measures. Also, on the basis of a model of how emissions are dispersed, experts conduct dispersion modelling to calculate the expected ambient concentrations at particular receptor sites where ambient concentrations are measured.

Experts go for further refinement. With the help of chemical analysis of particles, chemically distinct source types are characterised as a part of source apportionment. In this, experts use

AMIT SHANKER / CSE

WEAK INFRASTRUCTURE: Several factors restrain air quality planning in India, which is the reason why it is ad hoc and fragmented

Table 3.8: **QUICK FIX**

Summary results of selected emissions inventory and source apportionment studies in Delhi, Mumbai and Kolkata (relative contribution of different pollution sources)

Pollutants	Transport (in per cent)		Industries (in per cent)	Domestic and other sources (in per cent)
	Diesel exhaust	Petrol exhaust		
TSPM	3 - 22		6 - 98	2 - 85
	8	4		
PM_{10}	15	8	19	58
$PM_{2.5}$#	15 - 61	2 - 21		46- 72
NO_X	69 - 74		25 - 41	2 - 7
	34	18		
SO_X	5 - 10		82 - 95	4 - 14
	4	0.5		
CO	48 - 92		3 - 34	10 - 18
HC	95		5	

Notes: #Ambient level; TSPM — total suspended particulate matter; PM_{10}— particulate size less than 10 micron; $PM_{2.5}$ — particulate size less than 2.5 micron; NO_x — nitrogen oxide; SO_x — sulphur oxide; CO — carbon monoxide; HC — hydrocarbon; * — aggregate; ** — individual

The table represents the results of the following studies

- Ranjan Kumar Bose 1989, 'Environmental implications of energy use in Delhi', *Encology,* Lavanya Prints Pvt Ltd, Vol 5, No 6, p 4
- Anon 2002, *Modelling and surveillance of dispersion and movement of pollutants in Delhi,* Central Pollution Control Board, cited in Report of the expert committee on Auto Fuel Policy, Government of India, p 44
- Anon 1992, *Air pollution aspects of three Indian megacities*, National Environmental Engineering Research Institute, cited in Urban air pollution in megacities of the world, United Nations Environment Programme, World Health Organization
- Anon 2004, *Towards cleaner urban air in south Asia: tackling transport pollution, understanding sources,* south Asia urban AQM, World Bank energy sector management assistance programme, World Bank, Washington DC, p 71
- Anon 2002, *Air accounts for NCT Delhi,* National Environmental Engineering Research Institute, cited in Report of the expert committee on Auto Fuel Policy, Government of India, p 44
- A Vinod Kumar *et al* 2001, 'Source apportionment of SPM at two traffic junctions in Mumbai', *Atmospheric Environment,* Bhabha Atomic Research Centre, Mumbai, Indian Institute of Technology Mumbai, Vol 35, pp 4245-4251
- Jitendra Shah *et al* (ed) 1996, *Urban air quality management strategy in Asia: Greater Mumbai report,* World Bank, Washington DC, USA, pp 19-22

detailed chemical analysis of particles in the atmosphere to match their characteristics at given receptor and source locations (fingerprinting), also called receptor modelling.[68] Receptor models are called "top-down" in contrast to "bottom-up" methods, which use emissions inventory data, activity patterns and dispersion modelling from the source to predict concentrations at a receptor site.

Air quality modelling approaches predict specific pollutant concentrations at various places and the impact of different interventions on those concentrations. This is done by combining information on pollution sources with meteorological data in the form of mathematical equations. All these help in assessing the contribution of different sources to the total air pollution load, the rate at which these pollutants are being emitted and forecasting trends in air pollution concentration. These provide the basis for policy action for setting air quality targets and monitoring of goal attainment.

AQM has not attained this level of sophistication in India yet. Regulatory institutions lack the capacity to undertake exercises of desired scale and quality. Impediments prevail in the form of lack of quality data on emissions for different sources and technical capacity to use these tools for decision-making. So much so that it is not even possible to explain the trend in air quality in different cities or assess the possible impact of any action.

A few studies that exist in India are mostly rapid studies and only indicative. The CPCB has conducted limited emissions load estimations and projections based on basic modelling. Other agencies, like NEERI and independent research bodies, have begun undertaking pollution inventory and source apportionment studies of limited scale and scope and have generated limited results for a few cities. Some of the existing studies are nearly a decade old. Only a couple of recent ones, conducted with support from international development agencies, are comparatively more rigorous. However, these are based on extremely inadequate databases (see Table 3.8: *Quick fix*).

Experts have pointed towards such hurdles as the lack of locally appropriate source profile and emissions factors for pollution sources, including vehicles, industry and power plants and biomass burning, to arrive at precise estimates. In the absence of data, mostly generalisations and assumptions are made in estimating type, kind and emissions potential of sources. In the absence of locally appropriate emissions factors for pollution sources, especially vehicles and industries, these are mostly borrowed from USEPA. According to Rakesh Kumar, head and chief scientist, Mumbai zonal centre, NEERI, "Emissions factors of all the sources, at least the major sources, in the present condition shall have to be developed and used. One of the major uncertainties in emissions factors of major sources in urban centres is vehicular sources. India still has large numbers of vintage technology vehicles, two and three-wheelers and other types of utility vehicles."

This is clearly a regulatory lapse. The SPCBs directly monitor and control industrial emissions under the Air (Prevention and Control of Pollution) Act 1981 but they have not utilised their powers effectively to profile emissions from industrial sources. Some estimates do exist for larger industries but are almost non-existent for smaller ones. Similarly, vehicle certification agencies and the concerned regulatory bodies remain complacent about profiling emissions from vehicles by assimilating several factors such as vehicle type and speed, traffic activity for vehicle type and speed, percentage of each vehicle type fuelled by a specific fuel, engine design, presence of pollution controls, age, state of maintenance, driver behaviour and traffic conditions.

There have been a few rudimentary attempts by the Dehradun-based Indian Institute of Petroleum (IIP) and the Pune-based Automotive Research Association of India (ARAI) to develop emissions factors. But these are inadequate and totally outdated, though regulators and researchers have used them to calculate pollution load from the transport sector.

The IIP first compiled vehicle emissions factors in 1985 and subsequently revised them in 1994 for in-use vehicles based on experimental measurements of emissions rates. The revision was supposed to account for the change in technology in the late 1980s due to the opening up of the market. But IIP scientists are candid about the limitations. These estimates were based on an extremely limited sample size, without taking into account the age of vehicles.[69] Moreover, these estimates were based on a static sample of a year, which rules out the scope for future projections in emissions trends as they would not be able to account for new control technologies and new engine designs expected to come into the market. Subsequently, ARAI came up with a few emissions values in the mid-1990s, which show a wide variation for the same class of vehicles. For instance, the emissions factor for CO emissions from three-wheelers has been taken as 13.9 gramme per kilometre (gm/km) but the results varied from 5.1 to 39.4 gm/km.[70] Even ARAI scientists admit that these can only be a broad indicator. Nothing happened thereafter.

Answers to why official initiatives are so weak are hard to find. Some beginning has been made as ARAI has initiated the process of developing emissions factors for vehicle categories. But all this is still at a preliminary stage.

Despite the data limitation, the few studies that exist are the only indicators of the pollution profile of a few big cities in India. One of the earliest source inventories was prepared for Mumbai by NEERI in 1968. Experts point out that during the early days the key focus of the researchers was industrial pollution. Industrial stack dispersion studies started in the early 1980s.[71] After the 1990s, interest shifted towards vehicular pollution. Limited emissions inventories are available for the large cities of Delhi and Mumbai.

There are even fewer studies on source apportionment. The World Bank — that conducted such a study in India (published in March 2004) — reports that the level of detail required in such studies is considerable and presents difficulties. It organised the first chemical analysis of $PM_{2.5}$ in a study that was carried out from 2000 to 2001 in Delhi, Mumbai, Kolkata and Chandigarh. A number of earlier studies have largely examined lead in particles along traffic corridors because of the widespread use of leaded gasoline in India until 2000.[72] CO and NO_2 were also studied to some extent.

These studies have not been carried out outside a few metros, which means that there is no pollution profile available with the World Bank of other Indian cities.

Nonetheless, results from the existing studies help in bringing out a broad pattern in terms of relative contribution of different polluting sources in Indian cities.

Contributors to gaseous pollution

The results point towards the fact that vehicles contribute the maximum NO_X, VOC and CO in Indian cities. Many of these studies, conducted over time in a few metros, show that the transport sectors' share of NO_X and VOC emissions is very high. The relative share of vehicles to the NO_X load is estimated to be as high as 66 per cent in Delhi[73] and 52 per cent in Mumbai.[74] A study by USEPA in 2003 found that of the total vehicular NO_X emissions, buses, trucks and passenger vehicles contributed maximum NO_X in Pune.[75] It cautioned about high VOC emissions in the city. It further reported commensurately high emissions rate of toxics like acetaldehyde, 1,3 butadiene, ammonia, benzene and formaldehyde. These high emissions rates clearly call for more studies. The USEPA study recommended improving the emissions factors for in-use two and three-wheelers in India.

Similar results are found in other studies. Studies conducted by CPCB on VOC emissions confirm high contribution of vehicles in both Delhi[76] and Mumbai.[77] The trend has been confirmed with regard to CO emissions in both cities. During the 1990s, vehicles contributed 76 per cent of CO in Delhi[78] and 48 per cent in Kolkata.[79]

Estimates for most other Indian cities are not available. The relative contribution of other sources in industrial cities could be different. Industries and power plants are also significant contributors of NO_X and SO_2. But the fact remains that at least in the big metros, the share of non-transport sources pales into insignificance in the face of rapidly-rising vehicular pollution.

Contributors to particulate pollution

Studies show that particulates are emitted by a variety of sources — transport, industry, power plants, refuse burning, re-suspended road dust among others. Estimates with regard to the transport

AMIT SHANKER / CSE

POLLUTERS ALL: particulates are emitted by a variety of sources — transport, industry, power plants and refuse burning

TINY KILLERS

The Work Bank tracks $PM_{2.5}$

The World Bank has measured and chemically analysed $PM_{2.5}$ and matched it with the source profile in select Indian cities, including Delhi, Mumbai, Kolkata and Chandigarh to understand its sources. The study, conducted during 2001-2002, over different seasons measured $PM_{2.5}$. And the particles were analysed for carbon, metals and ions. During this analysis different types of hydrocarbons were subjected to detailed speciation. This revealed the following:[1]

- Average concentration of $PM_{2.5}$ is alarmingly high, when compared with US daily standards of 65 microgramme per cubic metre. The levels are 132 microgramme per cubic metre in Delhi and 108 microgramme per cubic metre in Kolkata. Mumbai recorded a lower level of 56 microgramme per cubic metre. Carbon constituted about half of $PM_{2.5}$, while sulphates made up about 10 per cent of $PM_{2.5}$ in the three cities.
- Road dust was the largest contributor in all three seasons; biomass combustion was second.
- Contribution of diesel fuel used in all sources (stationary and mobile) exceeded that of petrol. Despite the large number of two-stroke petrol two-wheelers — that are known to emit high particulates — diesel particulate emissions dominate. The study suggests that emissions reduction from diesel vehicles should be given priority. In some seasons, contribution of diesel to the total ambient $PM_{2.5}$ could be very high — 61 per cent during summer in Kolkata, 23 per cent during summer in Delhi and 25 per cent during spring in Mumbai.
- The study could not distinguish between mobile and stationary sources of diesel particulates, but did consider a couple of assumptions: (i) if diesel is attributed to mobile sources, then vehicles become the largest contributors in one season, and (ii) if diesel, petrol, secondary sulphates and secondary nitrates are attributed to vehicle exhaust — which may not be correct — then vehicles become the largest contributors in most seasons.
- The high carbon content measured points to the importance of fossil fuel and biomass contribution to fine particulate air pollution in these cities.
- The study also found contribution of unidentified sources to $PM_{2.5}$ levels very large.
- It concluded that a number of sources, rather than one dominant source, contribute to elevated ambient concentration of fine PM.

sector's contribution to the total particulate pollution load in cities are mixed and controversial. This is largely because the contribution of vehicles to particulate load does not appear to be overwhelmingly dominant. Therefore, this is used to argue against taking any aggressive action to control vehicular pollution. The relative contribution of these sources vary considerably depending on the size fraction of PM considered for the study.

Most available studies largely conducted during the 1990s have considered TSPM that also includes coarse dust as the basis of their assessment. These studies, though of different scope and method, broadly show that vehicles' share to the total particulate load varies from 3-22 per cent of the total TSPM load in key metros. The contribution of vehicles to the total TSPM load in Mumbai, for instance, was estimated to be 11.4 per cent in 1992.[80] At traffic intersections, the share increased to 15-18 per cent during the same time frame.[81] In Delhi, during 1988-1989, vehicles' contribution to the TSPM load was found to be three per cent.[82]

Contribution of vehicles to PM pollution increased significantly when subsequent studies considered finer particulates, PM_{10}. A World Bank study of 1996 estimated that the transport sector was responsible for nearly 30 per cent of PM_{10} ambient concentration in Mumbai during the early 1990s.[83] Yet another study conducted by NEERI during 2002 in Kanpur found that vehicles along with off-road diesel gensets contribute 22-39 per cent of PM_{10} load in the city.[84] Roadside contribution to automobile exhaust was found to be even higher in Kanpur.

NEERI conducted another study in Mumbai during 2004 that found significant contribution from vehicles. According to this, diesel and petrol vehicle emissions accounted for 6-54 per cent at different locations while industrial sources varied from 6-42 per cent of PM_{10} at these sites.[85]

A World Bank study published in March 2004, which chemically analysed $PM_{2.5}$ in Delhi, Kolkata, Mumbai and Chandigarh to profile contribution of pollution sources is more robust. It was funded by the World Bank and conducted by the Georgia Institute of Technology, the US, along with other agencies. The study revealed that vehicle emissions, re-suspended road dust and solid fuels could be the chief contributors of these tiny particles. It found that depending on the seasons, contribution of diesel fuel combustion varied from as high as 23 per cent in Delhi, 25 per cent in Mumbai to an astounding 61 per cent in Kolkata.[86] Diesel combustion sources may also include stationary ones. If the combined impact of diesel and petrol combustion is considered, the contribution of vehicles to $PM_{2.5}$ can be quite significant. This is really worrying as air toxic exposure studies in California have found that even at much lower contributions, nearly 70 per cent of all cancer risks due to outdoor air pollution are attributable to diesel particulates. Other significant contributors identified include biomass burning and road dust (see Box: *Tiny killers)*.

These studies point out that rigorous data generation and better accounting of small particulate pollution will bear out the significance of vehicular and other sources to pollution load with greater accuracy.

It is, however, important to note that this is not always clear from the existing and limited pollution inventories. As a result, the policy interpretations of the existing findings and use of the results of these studies for policy-making are often mired in controversy.

3.8 Modelling politics

The nascent science of air pollution estimation and modelling taking shape in India has created more confusion than clarity in decision-making, especially with regard to a mitigation strategy for particulate matter. Regulators use lack of good studies as an excuse to delay action and at the same time avoid taking decisions and preventive action based on existing knowledge and information.

Even without composite inventories and source apportionment studies, action, largely driven by the judiciary, has already begun. The emerging science worldwide on the adverse health impacts of particulate pollution gives credence to this action. Even without the precise estimates of relative contribution of different pollution sources, judicial intervention in Delhi has targeted transport, industry and power plants together to lower pollution levels in the city. Since the early 1990's, a series of actions have been initiated under different judicial orders to control these sources.

Amidst these strong measures, transport, one of the most rapidly-growing sources, has emerged as the priority target of mitigation in Delhi and a few other metros. But this focus on transportation has unleashed a strong counter-reaction from the industry and regulators alike and many attempts have been made to shift focus away from them. The most common argument used by both officials and the industry is that there are other bigger sources of air pollution, including power plants, industries, road dust or refuse burning. So look elsewhere.

The automobile industry, refineries and even official reports have begun questioning the magnitude of vehicles' contribution to the particulate pollution load in cities and argue for lax action, while drawing legitimacy from existing inventory studies.

Within such a context, rapid and ad hoc inventories, instead of being a robust policy guide, fall victim to lobby politics. There are a number of examples.

When science becomes politics

The Auto Fuel Policy roadmap that was charted by the committee set up by the Union ministry of petroleum and natural gas under the chairmanship of R A Mashelkar, director-general, Council for Scientific and Industrial Research, in 2001, was crafted on the basis of the pollution load projections from inventories prepared by NEERI and the Central Road Research Institute (CRRI). These studies were also the basis of the decision to delay the implementation of Euro IV standards in India's critically-polluted cities. These inventories had found that if the business-as-usual scenario is allowed to continue till 2010 in cities like Delhi, the pollution load due to traffic would remain virtually the same as in the base year of 2000, despite a 50 per cent step up in traffic loads as newer technology is expected to replace the existing ones.[87] So the results did not justify advancement of Euro IV norms in these cities.

The overriding conclusions of these studies have been that other sources emit more particulates than vehicles and, therefore, vehicles do not require stringent controls. NEERI's source apportionment study in Kanpur, which cited various studies conducted in India and other countries, including its own study in Kanpur, to indicate that vehicles contribute significantly to RSPM or PM_{10}. They further concluded that in northern and central India, the contribution of natural dust, re-suspension of road dust and off-road sources like diesel gensets to the total PM_{10} is also high.

First of all, both the NEERI and CRRI studies have their respective limitations that have undermined the final results. Such inadequacies are evident in the approach of the NEERI study. For example, the NEERI report admits that though a 24-hour monitoring for 10 days was planned as per the standard practice for the study, it could not be adhered to due to frequent power breakdowns and dust storms. But as the figures in the report are based on a 24-hour basis, the truth is that it does not meet the rigour demanded by scientific monitoring. The report has made far-reaching conclusions based on unrepresentative and inadequate monitoring. Moreover, the study has clubbed two different and important sources of pollution together — on-road vehicles and non-road sources like diesel generator sets — to estimate pollution load. This is grossly misleading for policy action.

Similarly, the CRRI study on road traffic and air pollution in major cities and trends in growth of vehicle population and air pollution in different cities concludes that particulate trends in most cities do not establish any direct relationship with the pattern of automobiles though some cities like Delhi show significant contribution from traffic.[88] These conclusions are based on the actual survey of vehicle fleets. But a close scrutiny shows that the survey also suffers from limited sample size, inadequate and unscientific time frame and the lack of a clear rationale for selection of locations for correlating air pollution and traffic volume. For instance, monitoring has been done only for a day in all the sites, which cannot be considered representative. Worse still, in some sites, monitoring was done on Sundays when there is minimum traffic on the road.

Confounding parameters, weak database and flawed design plague these studies. Doubts about the reliability of emissions factors and deterioration factors persist and further shroud the results of these studies. For instance, while the emissions deterioration rates for petrol vehicles improve with the improvement in technology and show variation with age, the deterioration rates used for diesel vehicles are more astonishing. All diesel vehicles — right from new ones to 20-year-old ones — are shown to have no deterioration. The report admits that emissions load calculation can vary widely depending on the selection of emissions factors. It states, "Variation of 10-20 per cent in emissions factors is likely to result in 15-25 per cent variation in the estimation of PM load." When used cumulatively and deftly, even such small variations have the potential of making a huge difference to the total emissions load.

This indicates that controversy will surround even the bare minimum decisions that get taken if the science of assessing air pollution remains weak.

A peculiar pattern is thus evolving in India. Instead of air pollution regulators developing these basic tools to sustain policy-making on a regular basis, short-term rapid studies from any agency remain the basis of AQM practices. Moreover, studies are not designed to find out the most health damaging sources, as for instance, CARB does for urban air toxics. Therefore, in most cases, studies are being used only to challenge the legitimacy of action driven by public opinion and courts. This was most strongly evident in the counter-reaction against the compressed natural gas (CNG) programme in Delhi, when it became so compelling for its detractors to prove its impact on particulate pollution as ineffectual.

First, the expert committee on Auto Fuel Policy confronted the public perception of air being cleaner in Delhi due to recent measures, especially the CNG programme. It claimed, "Popular perception that the air quality in Delhi has improved only due to CNG is not borne out by this technical study."[89] Other measures, including the improvement in emissions standards and fuel quality, have helped lower vehicular emissions by 84-88 per cent, while CNG's contribution is a mere 12-16 per cent.[90]

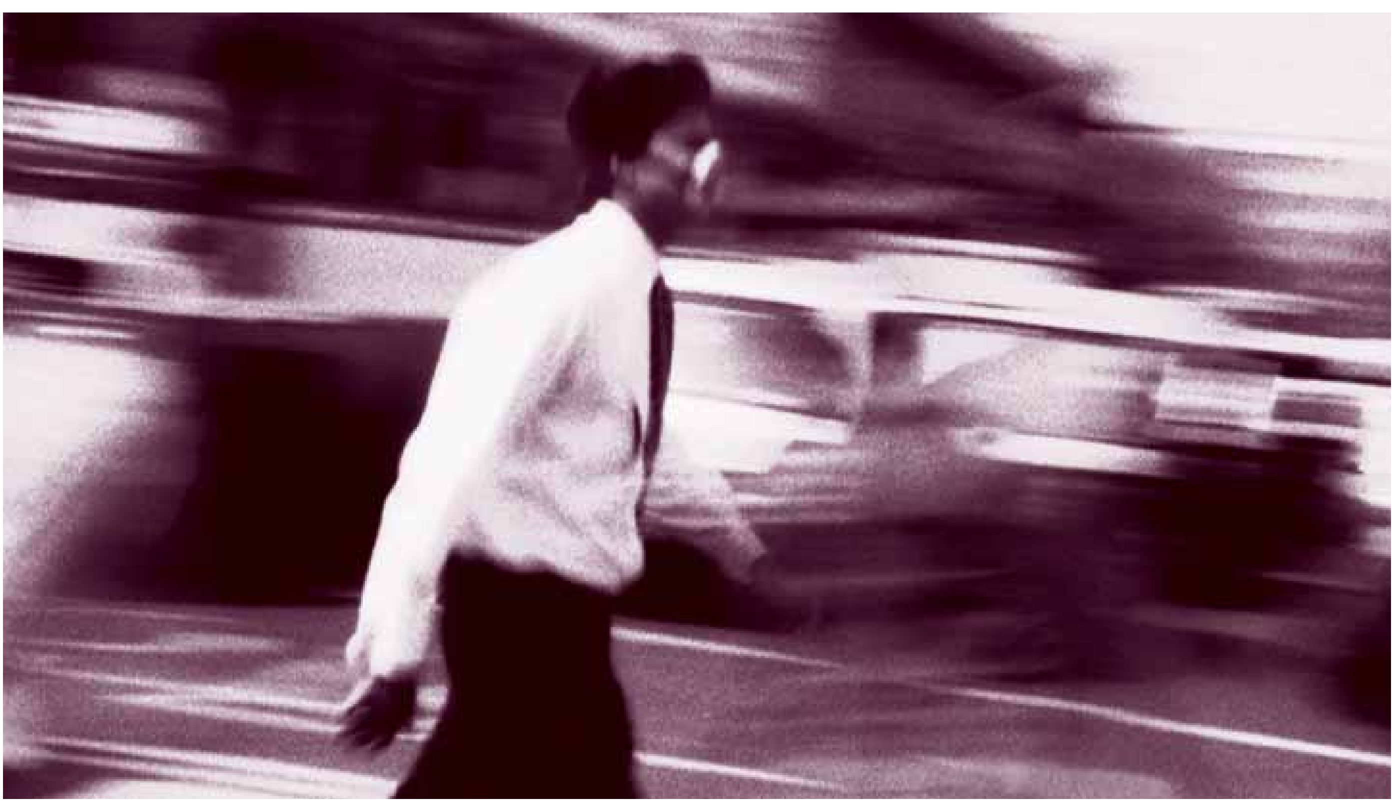
More studies followed. These were designed to disprove the benefit of the CNG programme. Experts at IIT Delhi conducted a study at the ITO traffic intersection in 2000 — when there were less than 275 CNG buses on the road — to prove that despite the implementation of the CNG programme, particulate and NO_X levels worsened at that particular site. They analysed the air quality data published by CPCB and surveyed the modal share and vehicle count at the same intersection. The study attributed the reason for rising NO_X levels to the 'high cost' of CNG conversion as it had hiked bus fares forcing 15 per cent shift of passengers from buses to two-wheelers, thus leading to higher pollution and congestion.[91] The anti-CNG bias reeked from the fact that its detractors did not consider the contributory factors that encourage motorisation in the city such as skewed taxes, easy finances and lack of travel demand management, which make riding two-wheelers and cars cheaper, while holding investment in CNG buses alone responsible for motorisation. It also looked away from the fact that instead of CNG buses if the government had invested in more expensive and upgraded buses, then by the same logic the impact on fares would have been similar and without travel demand management measures, the city might have seen a further shift towards two-wheelers, if that at all was the case.

Any emissions inventory, based on sound methodology but on a weak database, can become vulnerable to misleading interpretation as was evident in the recent efforts in Pune. During 2003-04, as part of a memorandum of understanding signed with the MoEF, the USEPA, with support from the US Agency for International Development and the US-Asia Environment Partnership (US-AEP), had jointly initiated a study to prepare a particulate emissions inventory and database system for Pune. The goal of this project was to work with key staff within India to develop an emissions inventory framework for the Pune region within seven working days[92], to create better understanding among regulators, academia and other stakeholders about emissions inventory, to use available data and methods to estimate emissions and to create a fully functional database to store and report emissions data. This provided hands-on experience to perform emissions estimates or to develop emissions database system. It created an extensive relational database system to report the emissions inventory data for 20 pollution sources for each ward and *taluka* covering three broad categories of pollution — mobile, stationary and area-wide. The first set of data show that of all sources, agricultural burning dominate the district-wide PM_{10} inventory.

Though the Pune regional inventory initiative was part of a training programme with no great claims about the results of the study based on limited local data and emissions factors largely borrowed from the USEPA, the results still became controversial as the vehicle industry and regulators used it to downplay the significance of vehicular pollution. The results indicated that vehicles contributed only four per cent of the PM_{10} in the Pune region, even though the study mentioned that if these emissions were to be summarised for just Pune city, agricultural burning emissions would be a much smaller contributor to local PM_{10} emissions. The study had also said that because of the short timeframe, rough assumptions and simplifications were used for emissions estimates and database development.[93]

Simultaneously, a team, including USEPA, US-AEP, University of California and Global Sustainable System Research, US, representatives along with MoEF and Pune city officials, carried out field activities between March 9 and 22, 2003. They collected data on vehicle technology distribution, driving patterns and emissions to estimate air pollution impacts of transportation in Pune. They then compared the overall per kilometre emissions from Pune's vehicles with the fleets in Los Angeles, Santiago and Nairobi. It was found that vehicles in Pune emitted comparatively higher CO, VOC and PM but lower NO_X and CO_2.[94]

Inventory studies are not sacrosanct and unless these are used along with a wide gamut of other criteria, including toxicity indicators and exposure assessment, to assess available policy options, misleading policy conclusions can get peddled. In India, therefore, studies are being carried out more to challenge action rather than provide guidance on action in different sectors to meet clean air targets. The level of confusion in India is high because inventory



PREETI SINGH / CSE

CHOKING CITIES: Despite high air pollution levels Indian studies are carried out more to challenge action rather than meet clean air targets studies are looked in isolation without any coherent framework for their interpretation.

In its March 2004 study, the World Bank pointed towards this problem, "Often, emissions inventories are constructed without carrying out dispersion modelling. Emissions inventories are useful in and of themselves, but their limitations should be recognised. What ultimately should drive policy is not which source is emitting more, but which source is likely to lead to greater exposure to health damaging pollutants."[95] It cited that, for example, a coal-fired power plant at the edge of the city, with a tall stack, may in absolute tonnage be the largest emitter of particles but may be contributing less — from the point of view of overall human exposure — than, let's say, all households burning biomass.[96]

Regulators world over add toxicity indicators to the weight or mass of particulate pollution emitted by different sources to prioritise the sources for targeted action, source apportionment studies help assess the contribution of different sources to the pollution load, such results need to be matched with the emerging science on the relative toxicity of pollutants. This will help in prioritising action. Detractors ignore the fact that if only the tonnage of pollutants, especially particulates without toxicity indicators, is taken as the basis, public health consequences of vehicular pollution will be grossly underestimated and natural dust will guide action. But Indian regulators do not link the quantum with toxicity factors of different fraction of particulates, including diesel particulate matter and sulphate particulates, and relate that to the science of finer particles to assess the relative priority for action.

The World Bank points out that the practice in south Asian countries, where emissions in tonnes of CO, SO_2, NO_X, SO_X and PM from different sources are added up and the percentage contribution is apportioned to different sources, is a mistake. It states, "This almost inevitably points to CO as constituting the largest fraction of the total weight of primary emissions and transport (primarily petrol vehicles) as the greatest contributor to CO. This points to the fact that transport is responsible for 70 per cent of air pollution. But toxicity of CO is much lower (on a weight basis) than the toxicities of other pollutants." So the study advises against adding different pollutants with varying toxicities on the basis of weight.[97]

Regulatory action by governments in the US and Europe show that the same logic is even more valuable while assessing the relative toxicity of particulates to prioritise action targeting specific sources, even as parallel action is initiated targeting all dominant sources of particulate pollution to control overall ambient levels. Particles emitted by a variety of sources and particulate load from biomass burning, road dust and coal burning can be very high as seen in some studies. While an integrated approach is needed to control emissions from all sources, this still does not lend support to lenient action in the transport sector responsible for a very toxic fraction of particulates.

Government does not lead

Apart from pleading inability to act on account of poor quality data, no official policy has been drafted till date by the MoEF to initiate composite inventory preparation plans, develop assessment systems on a regular basis or to improve air quality planning. State government agencies do not even have adequate capacities to undertake these studies.

Among the seven cities that submitted their action plans to the SC in 2003, only a few indicated they would undertake emissions inventories. They later expressed the need for technical support from CPCB to enable such studies.

Even when donor agencies offer support to the governments for composite emissions source inventory studies and development of emissions factors for different vehicles, nothing moves. So a move by the World Bank in India in this direction remained a non-starter. The reasons for abandoning the project for preparing emissions inventory are shrouded in mystery.

The emissions factor development project was originally conceived as part of the Environmental Management Capacity Building Technical Assistance Project of the World Bank. An MoEF official says, "Progress was sub-optimal in the first two years because the implementing agencies were not conversant with the nuances of handling the World Bank-aided project." Indian officials were also intimidated by the bank's stringent and inflexible set of guidelines. Another official says, "There are at least 10-12 stages that need to be crossed before anything concrete emerges." Yet another one quips, "There are innumerable terms of reference and project implementation plans that make the process tiresome and time-consuming. This has very often caused delays and lapse of deadlines." Despite working for almost two years to draw a plan, the programme was shelved.

Industry takes over science

Soon after the World Bank's withdrawal, four oil companies decided to collectively fund air quality monitoring and pollution inventory studies in six Indian cities — Delhi, Bangalore, Pune, Mumbai, Chennai, and Kanpur. It was decided that the study would be conducted by NEERI and ARAI in coordination with IOC's research and development centre. A steering committee was set up under the ministry of environment and forests and a technical committee under the CPCB to oversee the programme. Another technical committee was set by CPCB to monitor the ARAI project on emissions factor development for vehicles.

This study, however, was ominously linked to the clause that has crept in the government-approved Auto Fuel Policy, "The schedule for introduction of Euro III equivalent emissions norms in the entire country from April 1, 2010, together with Euro IV equivalent emissions norms in the 11 major Indian cities, would be reviewed in the year 2006 after the implementation of Bharat Stage (BS) II emissions norms in the entire country from April 1, 2005, and Euro III equivalent norms in major cities." Oil industry representatives stated that the new study would be the basis of the 2006 review and also the decision on the deadline for the implementation of the Euro IV standards.

Naturally, questions were raised about the oil industry arrogating the regulators' responsibility of air pollution planning tools. In the official committees set up to oversee the project, CPCB's role was relegated to being a mere advisor. This would be unthinkable in any other country where regulation lies in the hands of the governing authority. Moreover, strong doubts were cast on the quality of the air quality monitoring that was first initiated at 10 selected sites in Delhi by NEERI from May 2005 onwards.

The environment bureaucracy in the ministry tried to salvage the situation by wrestling back some control over this study. The technical committee under CPCB organised a technical review. The original outline of the scope and methodology for the entire project was reviewed and modified. The project aims to assess the contribution of sources to the ambient air quality levels, prioritise sources of pollution, and evaluate mitigation measures for different sources and develop action plans. Though a large number of pollutants including PM_{10}, $PM_{2.5}$, NO_X, SO_2, CO, VOCs and benzene, among others will be monitored at background, kerbside, residential and industrial sites, the pollution inventory and the source apportionment will be carried out only for PM.

It has also been decided that the inventory will be carried out in the zone of influence — within two km radius area around the monitoring stations. This will be matched by a source apportionment study. The data collected will be analysed for preparation of emissions inventory using appropriate techniques.

Since the project involves more than one agency, a common protocol/methodology has been designed. Following these changes the MOU of the study with the executing agencies have also been modified especially for Delhi, Mumbai and Bangalore where the project was already underway. The project is expected to commence in the remaining cities from May 2006.

The modification of the scope of the study has escalated the cost of the project beyond the funds — about Rs 1,350 lakh, committed by the oil companies. To meet the deficit CPCB has ventured to commit an additional funding of about Rs 700 lakh.

While this project has a great potential to strengthen the scientific basis of air quality planning, its continued link with one decision: implementation of Euro IV standards, threatens to create distortions.

The fact, however, remains that tools used to determine AQM policies are the responsibility of the air quality regulatory authority in other countries. An independent and non-partisan functioning is essential to ensure the integrity of the process, which demands independent environmental authority. But in India, the inability of regulatory authorities to develop strict, disciplinary and enforceable policy tools can make this immensely vulnerable to manoeuvring.

Yet, there is no attempt to strengthen and empower the existing regulatory institutions such as CPCB. The circumscription of the powers of CPCB need serious re-examination. More so because the Cabinet-approved version of the Auto Fuel Policy has also rejected the original proposal of setting up of an independent National Automobile Pollution and Fuel Authority (NAPFA) to take future policy decisions on automobile emissions norms and fuel quality standards. The NAFPA was rejected on the ground that such regulatory bodies already exist.

As decisions on air quality are influenced by inventory and modelling results, pollution loads can be underreported or interpreted to stave off taking tough and immediate decisions. Without adequate safeguards, this may happen even with more studies in place.

The government will have to focus on establishing a legal framework to facilitate enforcement of air quality standards, accountability and compliance. It would need to set up an independent and empowered regulatory authority capable of taking science-based decisions on AQM. Only this will enable scientific and technical capacity for composite management at the central and state levels.

3.9 City action plans

The ground reality is that it will take time for air pollution science and planning to strengthen in India. Even though the government is armed with adequate legal instruments, including The Air (Prevention and Control of Pollution) Act, 1981 and EPA 1986, which confer strong and sweeping powers on the MoEF and its agencies to take precautionary and corrective action on pollution control, it has failed to control rapidly rising pollution.

The courts began to intervene during the 1990s when residents in a couple of cities began to move them for more remedial action. The ongoing public interest litigation on air pollution in Delhi had begun in 1985. Similar cases were initiated in the high courts of Mumbai and Kolkata. The court action has crystallised the notion of hotspot AQM approach in the country.

The scope of the court's action has broadened considerably in recent years. There was a dramatic turnaround in 2002-2003, when the SC, within the ambit of the Delhi air pollution case, began intervening to direct action in other polluted cities as well. In its ruling of April 5, 2002, it warned, "If no immediate action is taken, then it may become necessary for some order being passed so as to bring relief to the residents of the city." This ruling listed nine cities, including Agra, Lucknow, Kanpur, Jharia, Varanasi, Faridabad, Patna, Jodhpur and Pune, as critically polluted.

This spurred MoEF to begin an action planning process in a couple of cities. Pune and Kolkata responded. But this did not make any difference.

When CPCB released the PM_{10} data for 22 Indian cities in January 2003, CSE drew the attention of the chief justice's bench in the SC to this list. In its hearing of August 14, 2003, the bench took serious note of the data. The SC observed that though air quality had improved considerably in Delhi since 1996, particulate pollution in other cities was turning into a crisis. It was a serious matter not only in the metros but also in relatively smaller cities like Kanpur, Solapur and Lucknow. The bench widened the ambit of the case beyond Delhi to include these cities along with the metros of Ahmedabad, Bangalore, Chennai and Hyderabad. It directed the Union government and the state governments concerned to draw up action plans to lower particulate pollution. Mumbai and Kolkata were let off the hook as the high courts were already hearing various pollution-related cases in these cities.

In the meantime, the Mashelkar committee that had proposed the Auto Fuel Policy in 2002, also identified 11 polluted cities for early introduction of tighter vehicle emissions norms. There was a considerable overlap between the list of cities covered by the Auto Fuel Policy and those being monitored by the SC.

As a result of these various developments, the key polluted cities of India began qualifying for early introduction of tighter regulations for vehicles and fuels. As mentioned earlier, poor air quality data and weak assessment of the impact of action on air quality hamper definite conclusions about the pollution trends in these cities. However, successive tightening of the emissions standards alongwith local policy measures for other pollution sources (industry and power plants) influenced pollution levels in some of these cities. The momentum is now building up in cities that came under the SC's surveillance in 2003 (see: *Report card*).

The judiciary has consistently invoked the constitutional provision of right to life and precautionary principles. The judicial process has demonstrated that it is possible to take action based on the existing information and knowledge, even as efforts are made to improve the monitoring and management system more holistically.

The seven cities have given an action plan to the SC, identifying the areas of interventions in different sectors — transport, industry, power plants and other sources. None of them, however, have proper AQM tools in the form of emissions inventory, source apportionment or emissions forecasting to provide detailed scien-

A COMMON MINIMUM PROGRAMME

The EPCA has taken the action plans of city governments and turned them into a common programme

A common minimum programme for all Indian cities has been agreed upon by the state governments and the Environment Pollution (prevention and control) Authority (EPCA). A series of interventions have been proposed by both in the sectors of transport, industry, power and other pollution sources.

The EPCA's recommendations, are in the light of the spirit of the SC order, that the seven cities — Ahmedabad, Kanpur, Solapur, Lucknow, Bangalore, Chennai, Hyderabad — have very high levels of particulate (PM) pollution and therefore need urgent and advance action beyond minimum national norms and plans. Most city action plans submitted by the state governments to EPCA have stated very high contribution of the transport sector to the total air pollution load. After reviewing the information submitted by the state governments EPCA observed that the rapidly-growing pollution sources like vehicles, threatened to overwhelm the small efforts at controlling pollution in these cities. While detailing out the action plans for the transportation sector in each city, EPCA has recommended some cross-cutting policy measures in the mitigation strategies. These would require proactive interventions from both state and central governments, In this action planning process the key concern of EPCA is to ensure firm and well-defined actions with a tight schedule for implementation and clarity of responsibility and accountability of the implementing agencies.[1]

- Advancement of vehicle technology and fuel quality standards to achieve significantly cleaner emissions levels.
- Introduction and expansion of gaseous fuel programmes to leapfrog and achieve drastic reduction in PM emissions.
- Appropriate policies to check rapid dieselisation of small and medium car segments, that are rapidly growing source of PM emissions in cities. Otherwise, this may nullify the reduction in emissions from moving public transport and commercial vehicles to gaseous fuels. Even two-wheelers contribute significantly to the PM pollution load, as is evident from data submitted by the Uttar Pradesh government for Kanpur. Therefore these would also require immediate regulatory intervention.
- Control emissions from on-road vehicles with improved inspection and maintenance programme, and representative test procedures. The current pollution under control certificate programme should be improved along the lines of new norms. Simultaneously, there should be a phase-in plan for centralised inspection centres based on advanced norms, test facilities and quality audit systems. The state governments were also advised to enforce emissions warranty for greater accountability for manufacturers.
- City transport plans need to be effectively linked to air pollution abatement programmes. Strengthening the public transport system and introducing proper transport demand management to restrict growth of private vehicles is vital.
- Effective strategies to prevent fuel adulteration are needed and make oil companies accountable for the quality of fuel at the retail outlets. For this it is vital to improve testing procedures and upgrade fuel quality standards. Penalties for fuel adulteration have to be made harsher and the list of defaulting retail outlets has to be made public.
- Petrol with one per cent benzene content should be introduced in cities — especially in those cities with a very high proportion of two-stroke two-wheelers, responsible for very high HC emissions.
- Strengthening of air quality monitoring and planning in cities is needed. Cities also need to develop capacities to monitor additional pollutants like $PM_{2.5}$, O_3, benzene and volatile organic compounds, CO and PAHs. It is important that the state governments concerned and the Union ministry of environment and forests undertake their own source apportionment studies and pollution source inventories for future planning and monitoring.

tific rationale for intervention and assessment of their impacts. But this is the first coherent step towards assimilating existing actions and building on them. All state governments have presented current practices and policies, which have largely stemmed from various existing national policies on emissions standards for old and new vehicles, local policies on gaseous fuel and public transport, and modicum of local efforts to control industrial pollution and other pollution sources (see Box: *A common minimum programme)*. The Environment Pollution (prevention and control) Authority (EPCA) is monitoring the implementation of action plans.

The overriding concern of EPCA during the early stages of the action plan preparation has been the tendency to propose minimum and lax efforts and citing of national laws and provisions as the basis of most actions. While presenting this programme to the SC, EPCA in its report of January 2004, critiqued the status quo approach and pointed towards the rapidly rising pollution sources and their toxicity that threatened to overwhelm the small efforts at controlling pollution in these cities. But the plans were not designed to deal with the problem on an urgent scale. This subverted the spirit of the SC order that critically polluted cities require more stringent action and that action plans should go beyond existing programmes and roadmaps to reduce pollution levels in a short period.

However, recognising the constraints of poor management capacities at city levels, EPCA accepted the city plans as the common minimum but focussed on disciplining and tightening their implementation. This common minimum programme is the first step that will keep evolving over time as milestones are met. In fact, EPCA found it significant that in the absence of an effective national action plan and air quality planning system for cities, Delhi's experience had become a model for other cities.

From the AQM perspective, the most significant step of the court-led process has been that it has pushed the cities towards a composite framework for addressing different pollution sources — industry, power plants, and developing proper AQM tools.

It has also strongly prodded them to act on the available knowledge to aggressively control the rapidly rising vehicular pollution. The EPCA took special note of the submissions by the state governments, which on the basis of preliminary assessment, point towards a very high share of vehicular pollution in some cities.

City action plans submitted by the respective state governments indicate that in Hyderabad, vehicles contribute 67 per cent of the pollution load, as opposed to two per cent from industries. In Kanpur, vehicles contribute 80 per cent as opposed to 14 per cent from domestic and six per cent from industrial sources. In Lucknow, the share of vehicles is 75-80 per cent. The Kanpur plan specifically shows that diesel vehicles are responsible for 23 per cent of the total particulate emissions from the transport sector. Even more disturbing is the contribution of two-wheelers — as much as 70 per cent of the particulate emissions from the transport sector — in Kanpur.

Simultaneously, the court-led process prodded both the Union and state governments to address the common key strategies, which cut across all cities, to curb vehicular pollution. These include tightening of the emissions standards roadmap, developing a public transport policy, controlling travel demand, expanding the clean fuel programmes and formulating an effective policy for in-use vehicles inspection programme, among others.

The SC's intervention is helping in disciplining enforcement and checking laxity of action as it demands time-bound action with accountability. To expedite the process, all state governments concerned have constituted a task force under the nodal authority of either the SPCBs or the chief secretary. This has helped overcome the problem of lack of coordination among implementing agencies. The requirement of periodic reporting and direct monitoring has set into motion a dynamic process that enables constant feedback on problems in different sectors and decisions to solve them through a consultative process.

The SC-led initiative is constantly trying to achieve the balance between composite and priority actions for effective impact. The SC has established important guiding principles to enable action. These have been outlined in the EPCA report of January 2004, "Though air quality planning is nascent in India and pollution source inventory inadequate, the precedence set by the Hon'ble SC in Delhi demonstrates that action can be started immediately. Priority actions can be drawn up based on science and evidence of harmful effects of air pollution and lessons from global good practices. In the case of particulates it is just not the quantum but also their toxicity that determines the immediate target of action".

The SC initiative has also spurred the MoEF to begin an executive process to coordinate city action plans. Initially, nine cities were listed in the April 2002 SC order. This was increased by four in May 2002 and seven in the subsequent order of August 2003. The MoEF and CPCB have expanded the list further to include 53 cities that have recorded pollution exceeding the permissible limit and to urge them to prepare action plans along the same lines as the seven cities under the surveillance of the SC.

Ministry officials say that these 53 cities have already submitted their action plans. State-level coordination committees have been formed to supervise implementation of these. The CPCB, which is coordinating the initiative, has recommended that the cities follow science-based AQM — set air quality targets, describe the air quality monitoring programme, provide inventory of emissions load and contribution of various sources, steps taken so far to control air pollution, roadmap for controlling air pollution from other sources and so on.

This initiative can build the foundation of a more robust air quality planning exercise nationwide. But the government process lacks effectiveness. In Gujarat, for instance, Ahmedabad is under the direct scrutiny of the SC. Bhanujan, chairman, Gujarat Pollution Control Board, says, "For other cities, district-level coordination committees have been formed to monitor progress. It is, however, evident that the reporting and monitoring systems are not as structured and rigorous as those for the cities in which the action was court driven."

However, air pollution regulators rue that the SC-led action plan process is heavily biased towards vehicular pollution. B Sengupta, member secretary, CPCB, says, "Most plans emphasise automobiles as the major air pollution source, which may not be the case for all cities like Jharia, Faridabad and Jodhpur."[98]

The CPCB, therefore, emphasises on source apportionment and emissions inventory from all sources for formulating action plans and recommends that till the time these are conducted, automobile pollution control measures, as included in the action plan, may necessarily align to the Auto Fuel Policy recommendations and directions.[99] This suggestion has been included in the official guidelines to various cities.

The official approach fails to take cognisance of the guiding principle of the court-led approach of taking extra steps forward in polluted cities. Instead, it pleads for status quo and more inventory and source apportionment studies. The penchant for studies though a legitimate area of intervention shows the officials' inability to act on the basis of the existing information and knowledge.

Regulators ignore the fact that the seven cities under the SC's surveillance have submitted sectoral plans considering all sources of pollution. But more importantly, they have submitted facts indicating that vehicles are the key source of pollution, which justifies accelerated action to curb this source. Therefore, regulators are disregarding targeted action in the name of comprehensiveness. This clearly is the diehard legacy of the Auto Fuel Policy debate and industry folklore that the transport sector does not require aggressive measures.

3.10 The way ahead

The SC's intervention in Delhi and other cities has exposed the need for a more structured national-level planning to address the deteriorating air quality elsewhere. The city-specific model of management, compliance and enforcement is still very weak. This exposes the inadequacy of current approaches in the states and the lack of initiative to set priority targets and strategies. For an efficient AQM, therefore, the country must establish a legal framework to facilitate enforcement of air quality standards.

Air quality governance in India has not matured enough to aid composite air quality planning. Indian planners seem to miss the point that the ultimate objective of setting standards for both mobile and point sources is to meet the National Ambient Air Quality Standards in all regions. National laws would need to be supported by strong state-level implementation plans. This is possible only if regional air quality targets are set and more stringent emissions laws are enforced in problem areas. This is the overriding logic that governs the standard-setting processes in countries like the US.

Therefore, the Union government needs to develop a national air quality plan that should also set regional targets to make it incumbent on the state governments to meet them in a time-bound manner. On the basis of these standards, non-attainment areas should be identified and remedial action should be taken to reduce pollution levels. Currently, there is no system to ensure that state governments meet the National Ambient Air Quality Standards.

REPORT CARD

Apart from Mumbai and Kolkata, which are being monitored by high courts, all other cities are under SC surveillance

1. AHMEDABAD

This city of 4.5 million (2001), has 1.49 million (2004) vehicles. Two-wheelers account for 73 per cent and cars 13 per cent of the fleet. Since 2000, cars are increasing at a faster rate (29.08 per cent) compared to two-wheelers (27.31 per cent)[1]. The number of buses have increased by only 0.97 per cent. According to CPCB, 85 per cent CO emissions are from petrol vehicles, 35 to 65 per cent of unburnt HC from two and three-wheelers. Diesel vehicles account for 90 per cent of NO_X emissions.[2]

Ahmedabad came under the SC's surveillance in 2003.

ACTION TAKEN

Transport sector

- Euro I implemented in 2000, Euro II and III norms from 2003 and 2005
- Ethanol blend petrol introduced in 2003
- All retail outlets in the city supply pre-mix 2T oil
- Ahmedabad Municipal Transport Services phased out 342 old buses. Ahmedabad Municipal Corporation (AMC) has phased-out 108 old vehicles
- Diesel-driven rickshaws banned by AMC. Heavy-duty vehicles diverted
- 88 PUC centres are working as per revised norms
- 143 AMC buses are running on CNG, so are 6,300 three-wheelers

Industrial sector

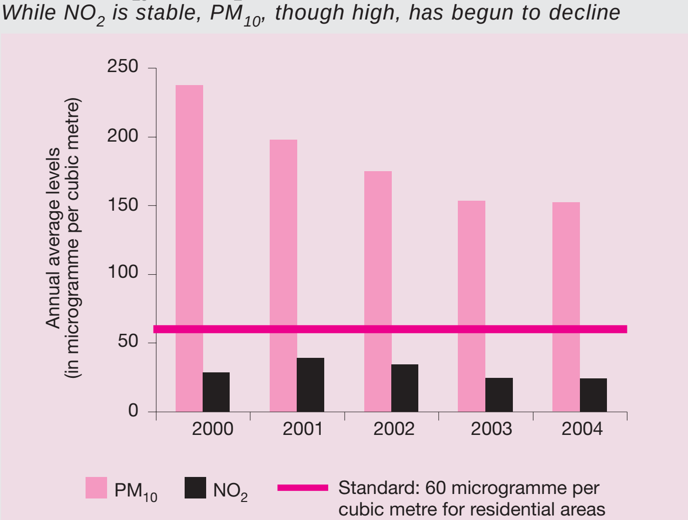
- Electrostatic precipitators have been installed in power plants. Seventy per cent of fly ash is re-used, rest goes to ash ponds
- Some industrial units use natural gas

Other measures

- Notice issued in newspapers to check open burning of garbage
- Hospital incinerators are monitored on a regular basis

Graph 1: PM_{10} AND NO_2 TREND 2000-2004

While NO_2 is stable, PM_{10}, though high, has begun to decline



Source: Anon, *National ambient air quality status,* Series of reports from 2000 to 2004, Central Pollution Control Board, Union ministry of environment and forests, New Delhi

2. BANGALORE

The city has a population of 5.68 million (2001) and a vehicular fleet of 1.9 million (2004). Its vehicle density is very high, almost as high as 3,448 vehicles per square km.[1] The fleet is increasing at an average rate of eight per cent annually.[2] Records show that as many as 400 private vehicles are registered each day.[3] The fleet is not the only problem, as the city is also known for its high level of industrialisation. It has about 1,552 industries within its outer ring road limits. Of these, 284 pollute the air.[4]

Bangalore came under SC surveillance from 2003.

ACTION TAKEN

Transport sector

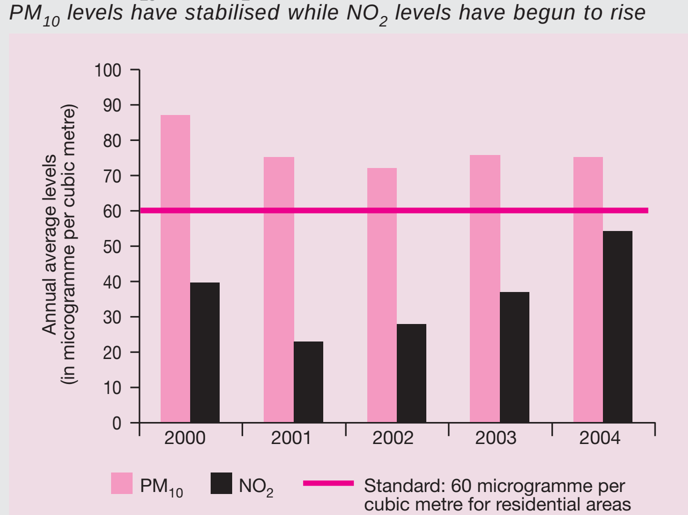
- Euro I and Euro II norms implemented in 2000 and 2003 respectively, Euro III norms from April 2005
- Nearly 31,820 auto-rickshaws are running on LPG (bi-fuel mode)
- Thirteen auto-LPG fuel-dispensing stations are currently operating to solve the problem of shortage of gas
- New PUC norms have been introduced by the authorities to control emissions from vehicles
- Government restricted the plying of more than 15-year-old commercial vehicles within the outer ring road limits from July 2003
- More than 90 roads were made 'one-way' to promote smooth flow of traffic and end traffic jams and congestion
- To renew the registration of 15-year-old vehicles, the government imposed a 'green tax' of up to Rs 500 per vehicle

Industrial sector

- Industrial boilers have been directed to use low-sulphur fuel

Graph 2: PM_{10} AND NO_2 TREND 2000-2004

PM_{10} levels have stabilised while NO_2 levels have begun to rise



Source: Anon, *National ambient air quality status,* Series of reports from 2000 to 2004, Central Pollution Control Board, Union ministry of environment and forests, New Delhi

3. CHENNAI

This city of 6.4 million (2001) has 1.4 million (MoSRTH 2003) vehicles. Two-wheelers constitute 75 per cent and cars 18 per cent of the city's vehicle fleet.[1] Being in the coastal area, the overall concentration of pollution remains low in the city, though there has been a recent rise. The Tamil Nadu Pollution Control Board says, vehicles spew 307.23 tonnes of pollutants daily. The air quality is affected mainly by vehicular emissions.[2] Two-wheelers contribute 33 per cent and three-wheelers 42 per cent.[3]

Chennai came under SC surveillance from 2003.

ACTION TAKEN

Transport sector

- Euro I and Euro II norms, implemented in 2000 and 2001 respectively Euro III in 2005
- Central bus stand shifted to outskirts to restrict inter-city buses
- No heavy-duty vehicles on major roads during peak hours
- New PUC norms implemented
- Pre-mix 2T oil for two and three-wheelers partially implemented
- Seven fuel-testing laboratories function to check adulteration
- Of the proposed 28 auto-LPG dispensing stations, 15 are functional
- MRTS phase I operating between Chennai Beach and Thirumylai
- Green tax imposed on vehicles older than 15 years from May 2003

Industrial sector

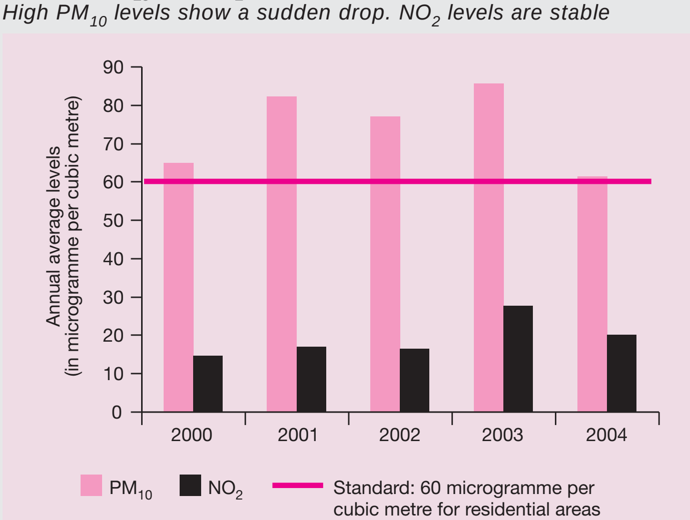
- There are 40,300 small-scale industries (March 2001). According to World Bank (2005), other than Chennai Port Trust and the Power Corporation, no industry is of major concern.[4] Dispersion is good
- Granting of consent/renewal to major industries mandates that units switch over to alternate cleaner fuels such as low-sulphur heavy stock and light diesel oil [5]

Other measures

- No incinerator allowed within the city. Common biomedical waste treatment facility set up [6]

Graph 3: PM_{10} AND NO_2 TREND 2000-2004

High PM_{10} levels show a sudden drop. NO_2 levels are stable



Source: Anon, *National ambient air quality status,* Series of reports from 2000 to 2004, Central Pollution Control Board, Union ministry of environment and forests, New Delhi

4. KOLKATA

One of the most densely populated cities, with 24,705 people per square km.[1] Only five per cent of land area is available for road space. Over the last decade, vehicles have increased by 52 per cent. It has more than 750,000 registered vehicles. Nearly 54 per cent of these are old and highly polluting.[2] According to CPCB, 55 per cent[3] are diesel-driven. The city is stricken by particulate pollution. According to the WBPCB, nearly two-thirds of PM_{10} comprises particles less than 1.1 micron size. This can be attributed to vehicular pollution. A World Bank study (2004) found that the contribution of diesel to $PM_{2.5}$ was nearly 61 per cent during summer.

The Kolkata High Court has issued directives to control air pollution.

ACTION TAKEN

Transport sector

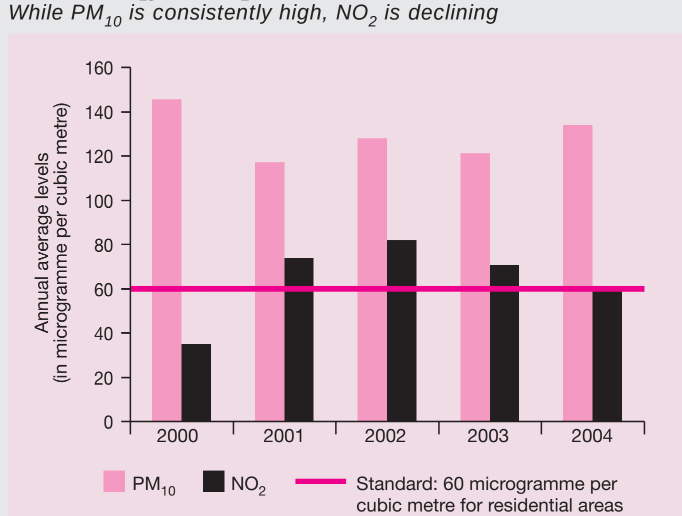
- Euro I and Euro II norms introduced in 1999 and 2001, respectively, Euro III in 2005
- New PUC norms implemented
- Ban on supply of loose 2T oil. Benzene content in petrol reduced to three per cent in 2000. This was brought down to one per cent in 2005.
- Kolkata has the metro rail as a mass rapid transit system

Industrial sector[4]

- Stricter location policy for new industrial units. Restriction on setting up of polluting industries (red category) in Kolkata metropolitan area
- Ensuring regulatory compliance for grossly polluting industries
- Stricter emissions norms for boilers, ceramic kilns, foundries and rolling mills of metropolitan area. Clean fuels mandatory
- Industries regularly complying felicitated with environment excellence awards
- City is reducing dependence on coal, with about 67 per cent coal-fired boilers and about 73 per cent coal-fired ceramic kilns already been converted to oil-based units

Graph 4: PM_{10} AND NO_2 TREND 2000-2004

While PM_{10} is consistently high, NO_2 is declining



Source: Anon, *National ambient air quality status,* Series of reports from 2000 to 2004, Central Pollution Control Board, Union ministry of environment and forests, New Delhi

5. HYDERABAD

Between 1992 and 2002, vehicles more than doubled from 0.48 million to 1.08 million. Two-wheelers constitute 75 per cent of the fleet.[1] Even though the city introduced multi-modal transport in 2003-04, this remains underutilised. There are 333 air polluting industries in the larger Hyderabad urban development area.[2]

Hyderabad came under the SC's surveillance in 2003.

ACTION TAKEN

Transport sector

- Euro II and Euro III norms enforced from 2003 and 2005 respectively
- Benzene content in petrol brought down to one per cent
- From 1999, pre-mixed 2T oil made mandatory for two-wheelers. Pre-mix lube available in 280 oil-dispensing units, as per 2004 data
- Restriction on registration of three-wheelers
- Government actions primarily focused on road construction and maintenance, and better traffic planning and management
- New PUC norms introduced
- Lorries and seven-seater three-wheelers restricted to certain routes
- Steps to check fuel adulteration
- Seven auto-LPG dispensing stations operational since July 2004
- Multi-modal transport system in place

Industrial sector

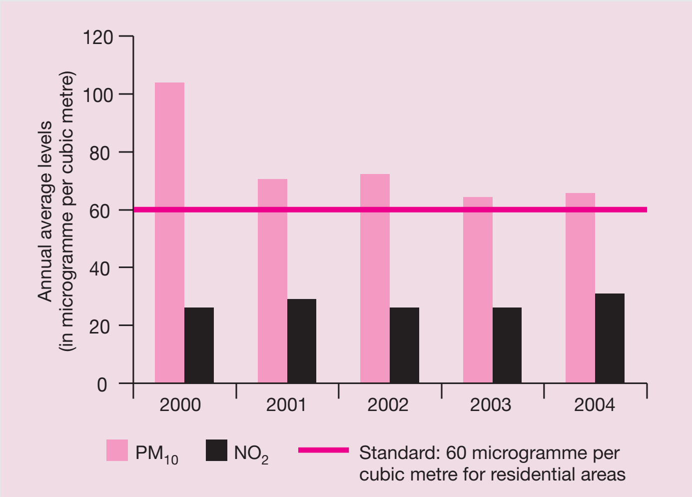
- Air pollution control devices installed in industries
- As of July 2004, 303 industries complying with norms, 25 have closed down and seven issued directions

Other measures

- Biomedical waste is incinerated
- Biomass burnt in the outskirts of the city
- Indoor biomass burning *chulhas* replaced with gas stoves
- About 10,183 hectares plantations completed by July 2004

Graph 5: PM_{10} AND NO_2 TREND 2000-2004

Both PM_{10} and NO_2 levels are stable



Source: Anon, *National ambient air quality status,* Series of reports from 2000 to 2004, Central Pollution Control Board, Union ministry of environment and forests, New Delhi

6. MUMBAI

This industrial and business capital of India has close to 1.1 million vehicles (2002), of which 45 per cent are two-wheelers, 36 per cent cars and taxis, six per cent heavy-duty vehicles and 10 per cent are three-wheelers.[1] There is a heavy influx of transit commercial vehicles. Most industries are located in the eastern and northeastern corridors of greater Mumbai with a few in the western region. Between 1993 and 2000, large and medium-scale industries decreased to 34 per cent from 44 per cent. There are 183 air-polluting industries in the region.[2]

Mumbai is under the surveillance of the Mumbai High Court.

ACTION TAKEN

Transport sector

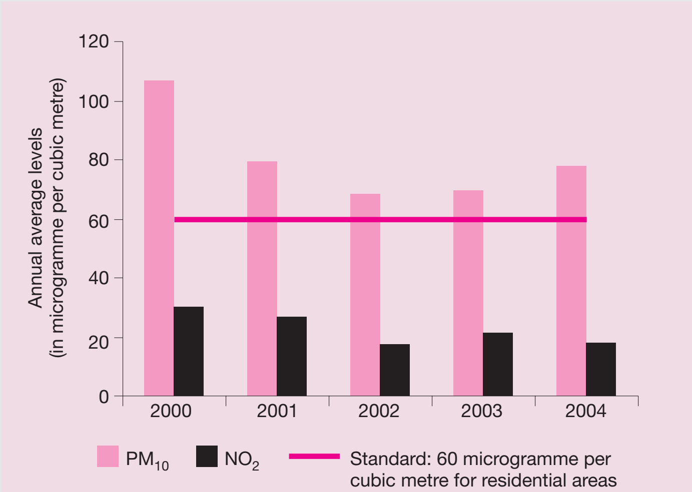
- Mumbai High Court had set up a committee under transport commissioner V M Lal in December 1999. The recommendations of this committee have formed the basis of a number of actions in Mumbai.
- Euro II and Euro III norms enforced in 2001 and 2005 respectively
- With effect from January 2003, all taxis more than eight year old to be phased out, unless converted to run on CNG/LPG[3]
- A large-scale conversion of taxis to CNG mode took place in 1998. As per 2002 data, about 35,000 CNG vehicles ply in the city.[4] Old commercial vehicles have also been converted to CNG mode
- The city has a network of 36 flyovers to ensure smooth traffic[5]

Industrial sector

- Since it is the industrial hub of India, units were targeted for emissions reductions. By 2000, a large number of industries switched over to natural gas available from a terminal near Mumbai[6]
- To curb pollution, the use of furnace oil in industries has declined between 1998-1999 and 2001-2002. There has been a shift towards using natural gas as industrial fuel[7]

Graph 6: PM_{10} AND NO_2 TREND 2000-2004

Both PM_{10} and NO_2 levels are stable



Source: Anon, *National ambient air quality status,* Series of reports from 2000 to 2004, Central Pollution Control Board, Union ministry of environment and forests, New Delhi

7. LUCKNOW

Lucknow, a city of 2.3 million (2001) has 633,729 vehicles (2003).[1] In its action plan submitted to the SC, the state government informed that vehicles contribute 75-80 per cent and industries 5-10 per cent of the air pollution load in the city.[2] Two-wheelers account for 80 per cent of the fleet. Three-wheeled vehicles, used for public transport, are largely diesel driven and extremely polluting.

Lucknow came under the SC's surveillance in 2003.

ACTION TAKEN

Transport sector

- Euro I norms introduced from 2000, Euro II in 2004
- New PUC norms introduced
- More than five-years-old diesel three-wheelers being phased out. Only scrubber fitted three-wheelers allowed to ply
- Pre-mix 2T oil dispensers installed in petrol pumps
- Oil companies have their fuel-testing labs to check adulteration
- Five per cent ethanol-blend petrol being sold since 2003
- From December 2002, circular railway system functioning as mass transit system
- Age limit for different categories of commercial vehicles is as follows: city buses (nine years), tempo-taxis (five years), maxi-cabs (seven years), auto-rickshaws (five years)

Industrial sector

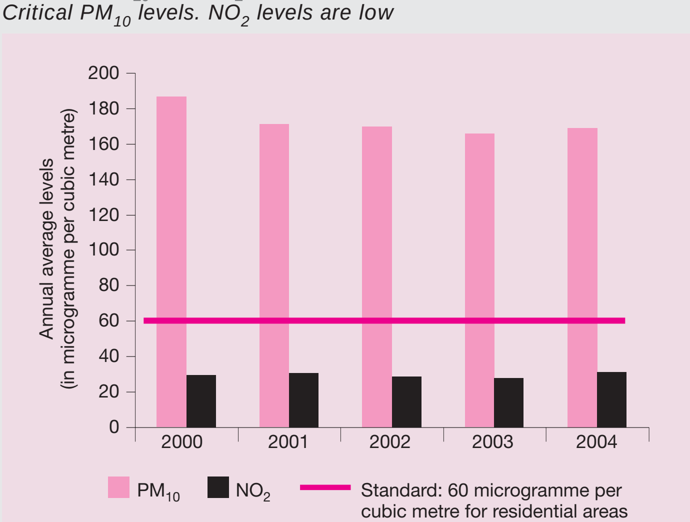
- All four major air-polluting units fitted with pollution control devices. One unit uses biogas
- Industries are monitored once every year
- City has no thermal power plant. About 40 air-polluting small-scale units need to be monitored

Other measures

- Six incinerators for treatment of biomedical waste
- Open biomass burning banned by municipal corporation

Graph 7: PM_{10} AND NO_2 TREND 2000-2004

Critical PM_{10} levels. NO_2 levels are low



Source: Anon, *National ambient air quality status,* Series of reports from 2000 to 2004, Central Pollution Control Board, Union ministry of environment and forests, New Delhi

8. PUNE

The city of 3.7 million (2001) has 0.9 million (2002) vehicles and adds close to 10,000 new vehicles every month.[1] The public transport services are very poor. The trip rate by bus (total passenger trips by bus divided by population) has been falling consistently. It has gone down from 0.35 in 1990-91 to 0.17 in 2000-2001.[2] Citizens are shifting from buses to other modes of transport.

EPCA is monitoring Pune

ACTION TAKEN

Transport sector

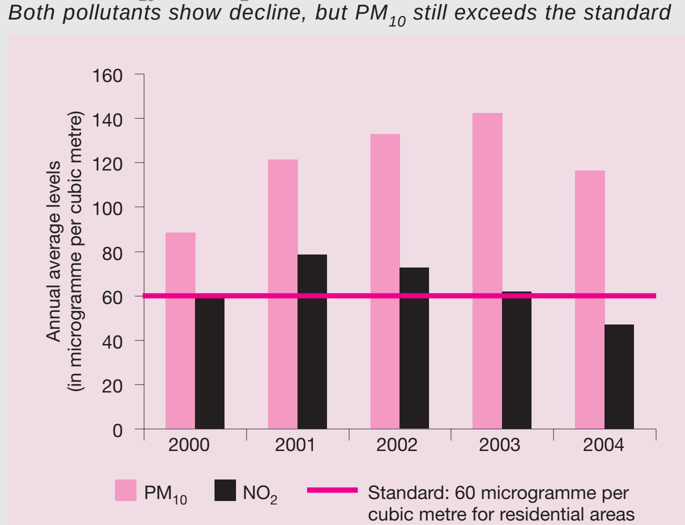
- In early January 2004, the MoPNG allocated 0.4 million metric standard cubic metre per day of CNG, but gas is expected to be available only in August 2007. Meanwhile, the city has initiated the LPG programme. Two auto-LPG outlets are run on a trial basis.[3]
- Euro II and III norms enforced from 2003 and 2005 respectively. Unleaded petrol mandatory. Supply of loose 2T oil is banned
- Plying of six-seater three-wheelers within the Pune Municipal Corporation (PMC) areas banned after December 2003[4]
- Only petrol rickshaws are permitted within PMC areas. Diesel rickshaws cannot be replaced with existing ones[5]
- Construction of bypasses around the city to promote flow of inter-city traffic[6]
- Heavy-duty vehicles banned from plying on 17 selected routes in the central area of the city during the day[7]
- Countdown timers installed in 23 traffic signals to reduce emissions from waiting vehicles[8]
- One hundred old municipal corporation buses replaced with new cleaner vehicles[9]

Industrial sector

- Pune has 12 large and medium-scale industries and 876 small-scale (service sector) units.[10] Industries have more or less taken measures for emissions controls

Graph 8: PM_{10} AND NO_2 TREND 2000-2004

Both pollutants show decline, but PM_{10} still exceeds the standard



Source: Anon, *National ambient air quality status,* Series of reports from 2000 to 2004, Central Pollution Control Board, Union ministry of environment and forests, New Delhi

9. KANPUR

The city's pollution gained notoriety after smog forced umpires to call off the India-South Africa cricket test match on November 24, 2004. A city of 2.69 million, Kanpur has 387,697 vehicles. Of these, 83 per cent are two-wheelers.[1] It also has a fertiliser plant, thermal power plant, textile mills and more than 5,000 small-scale units. Use of diesel gensets is also very high. The state government has told the SC that vehicles contribute 80 per cent of the air pollution load, industries six per cent and domestic sources 14 per cent. A study by NEERI in 2002 estimated that vehicles and diesel gensets contributed 22-39 per cent of total PM_{10}, while re-suspended dust contributed between 20 and 30 per cent.[2]

Kanpur came under the SC's surveillance in 2003.

ACTION TAKEN

Transport sector

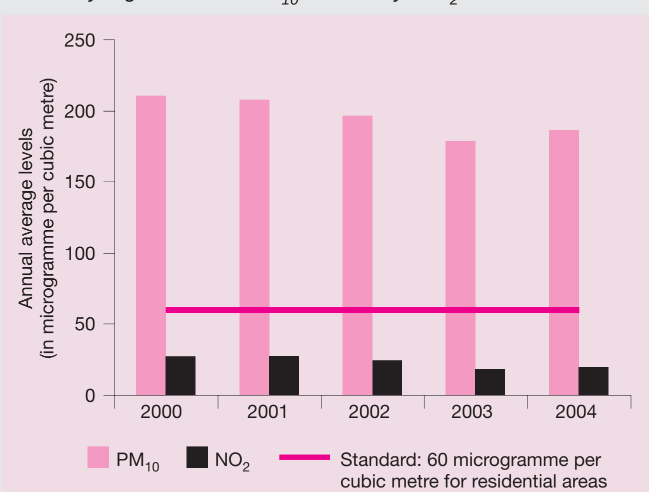
- Euro II and Euro III norms implemented in 2003 and 2005 respectively
- Benzene in petrol reduced, from 3-1 per cent from April 2005
- Age limit for phasing out vehicles has been fixed at: auto taxis — seven years, bus/minibus — nine years, 8-10-seater light commercial vehicles — seven years, tempos/taxis/auto-rickshaws — five years
- Some roads have been made one-way
- Department of transport and authorised pollution test centres are carrying out checks
- Entry of non-destined commercial vehicles is restricted

Industrial sector

- Guidelines and notification have been issued for compliance with emissions norms
- Emissions inventorisation being done for all polluting industries
- No new unit being issued no-objection certificate in non-conforming areas

Graph 9: PM_{10} AND NO_2 TREND 2000-2004

Extremely high levels of PM_{10} in the city. NO_2 levels are low



Source: Anon, *National ambient air quality status,* Series of reports from 2000 to 2004, Central Pollution Control Board, Union ministry of environment and forests, New Delhi

10. SOLAPUR

A small city with a population of 0.87 million (2001), Solapur is situated on the Pune-Hyderabad national highway. Two-wheelers are the predominant mode of transport and also the dominant source of air pollution. Solapur recorded very high PM_{10} levels during 2004, exceeding the standard by more than two times. For a small city, the particulate levels are significantly high. The city has a vehicle fleet of 276,768, of which two-wheelers constitute 78 per cent.[1] There has been a disproportionate increase in the number of private vehicles and informal transport. Public transport is inadequate, the number of buses reduced to 302 in 2002 from 698 in 1992.[2]

Solapur came under SC's surveillance in 2003.

ACTION TAKEN

Transport sector

- Euro I and II norms implemented in 2000 and 2004 respectively
- Six-seater auto-rickshaws banned in the Solapur municipal area
- No diesel-run auto-rickshaw can be registered as a replacement for an old auto-rickshaw
- In an effort to revive vehicle inspection, close monitoring of pollution testing centres is being done and action has been taken against defaulters

Industrial sector

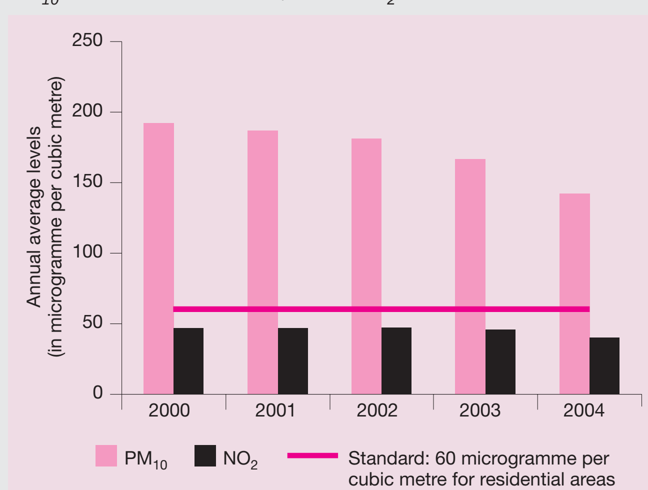
- Maharashtra Pollution Control Board (MPCB) has adopted a location policy for stone crushing units. They cannot be located near sensitive and residential areas
- The MPCB has undertaken a 'residential restricted zoning' policy for the siting of industries

Other measures

- Open burning of garbage has been banned by the MPCB under the Municipal Solid Waste (management and handling) Rules 2000

Graph 10: PM_{10} AND NO_2 TREND 2000-2004

PM_{10} levels show decrease, while NO_2 levels are stable



Source: Anon, *National ambient air quality status,* Series of reports from 2000 to 2004, Central Pollution Control Board, Union ministry of environment and forests, New Delhi