



# Towards Cleaner Air

## A Case Study of Delhi

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# A Curtain Raiser

Not very long ago, when a visiting Cricket team from a developed country lost a match in the capital city of India, it attributed part of its defeat to air pollution in Delhi. Perhaps, they were bad losers but we must confess that emission levels in the city at that time were precariously high. Not only the emission measuring instruments, but everybody, from a school-going child to an elderly commuter spoke in tandem regarding the increased air pollution levels.

During the 70's and 80's Delhi, the national capital, saw an unprecedented growth in population, vehicles and small scale industries, which caused serious ecological imbalance and environmental degradation. The problem got further aggravated by increasing migration from neighbouring states as shown in **Figure 1**. The

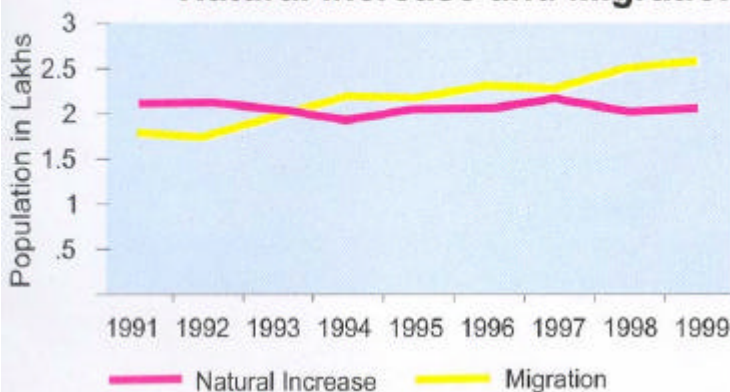
core of Delhi's growth problems lie in its rapid urbanization and its ability to offer opportunities for employment. What was essentially an administrative center with a population of 1.45 million in 1951 became a huge urban metropolis with a population of 13.78 million as per the 2001 Census. Compare this with a population of 9.42 million in 1991. Figure 2 shows an all time high decennial growth of 46.31% between 1991-2001. During the same period, the corresponding national level growth was 21.34%.

The total area of NCT of Delhi is 1483 sq. Km with an urban segment of 685.34 sq. Km in the year 1991. Urban population grew at 51.53% from 1991-2001 as compared to 46.89% during 1981-1991. Compare this with rural population growth of only 1.69% during 1991-2001.

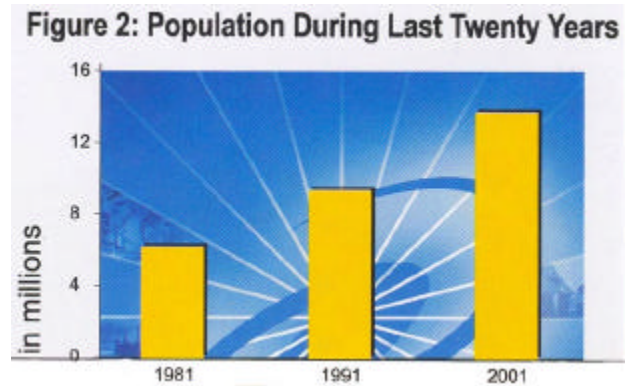
The density of the population also increased to 9294 persons per sq. Km (the highest in the country) in the year 2001 against 6352 persons per sq. Km in 1991 (Source : Economy Survey of Delhi, 2001).

Though the expansion of industry, trade and commerce have provided opportunities for economic development, but this in turn has transformed the character of Delhi from an

**Figure 1: Population growth through Natural Increase and Migration**



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administrative city to a multifunctional megapolis with a significant shift towards industry, commerce and services.

This rapid population growth alongwith the high rate of urbanization as also industrialization and an increase in motorised transport has resulted in an increase in the levels of various air pollutants, namely (1) Oxides of Sulphur, (2) Oxides of Nitrogen, (3) Suspended Particulate Matter, (4) Respirable Suspended Particulate Matter, (5) Carbon Monoxide, (6) Lead, (7) Ozone, (8) Benzene, (9) and Hydrocarbons.

## Oxides of Sulphur

Oxides of Sulphur (SO<sub>x</sub>) occur in ambient air in the form of Sulphur Dioxide (SO<sub>2</sub>) and Sulphur Trioxide(SO<sub>3</sub>). It has been observed that out of the SO<sub>x</sub> in the ambient air, the percentage of SO<sub>2</sub> may be more than 95 % while the remaining 5 % or less may be in the form of SO<sub>3</sub>. The major anthropogenic sources of SO<sub>2</sub> in the atmosphere are burning of fossil fuels for industrial and domestic purposes as well as their use in industrial processes, viz., petroleum, chemical, metallurgical and mineral based industries. Bacterial decomposition of organic matter, forest

fires, etc. also add to the presence of SO<sub>x</sub> in ambient air.

The harmful health effects of the SO<sub>2</sub> include irritation of eyes and respiratory system, increased mucous production, cough and shortness of breath.

## Oxides of Nitrogen

The Oxides of Nitrogen (NO<sub>x</sub>) are formed during the combustion processes mainly because of oxidation of atmospheric nitrogen and to a lesser degree by oxidation of organic nitrogen in fuels. The transport and industrial sectors are the major sources of NO<sub>x</sub> which causes irritation of the pulmonary tract and affect the functioning of lungs. Higher concentrations can even result in the narrowing of the air passage.

## Suspended Particulate Matter

These are fine particles of soot, dust etc. They are found in ambient air due to the combined effect of various natural factors. In the case of Delhi, presence of extensively large arid and semi arid regions in north-west, loss of moisture from top soil strata, etc. and anthropogenic factors, i.e., extensive urbanization and construction activities, increasing vehicular

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population, captive and domestic power generation are some of the major contributors to SPM in ambient air. High SPM levels cause respiratory diseases and reduce visibility. While the human nostrils filter out 99% of the inhaled large and medium sized particles, the rest may enter the wind pipe and lungs where some inhaled particles cling to the protective mucous.

## **Respirable Suspended Particulate Matter (RSPM)**

RSPM are the suspended particulates, which are less than 10 micrometers in diameter (PM10) and tend to pose a great health hazard as these particles can be easily inhaled and can get accumulated in the alveoli (tiny air sacs in the lungs) which slows down the exchange of Oxygen and Carbon Dioxide in the blood. The finer the particles, the longer is their propensity to remain air borne. The diverse sources of RSPM are fuel combustion in industries, power plants, industrial furnaces and boilers, diesel generating sets, and motor vehicles. The other sources are refuse and agricultural residue, refuse burning, solid waste disposal, construction activities, and traffic/road dusts.

## **Carbon Monoxide**

Carbon Monoxide is produced as a result of incomplete combustion of fuel. Vehicles and industries are major sources of CO emissions. Due to its high affinity for haemoglobin, Carbon Monoxide displaces Oxygen, leading to progressive Oxygen starvation and severe health effects. In greater concentration, the effect of Carbon Monoxide could sometimes even be fatal.

## **Lead**

Lead and some of its chemical compounds are virtually ubiquitous in the environment. Lead comes into the atmosphere, mostly through vehicular exhaust. Lead exposure is of great concern from the health point of view as it does not spare any organ in the body and can cause kidney damage in children as well as in adults.

## **Ozone**

Ozone at the ground level is a secondary pollutant, formed by reaction of Oxides of Nitrogen and Hydrocarbons in the presence of sunlight. The major harmful effects on human health include eye, nose & throat irritation and

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reduced resistance to colds. It can also aggravate asthma and bronchitis.

## Benzene

The major sources of benzene are anthropogenic. It exists in the environment in vapour form. The presence of benzene in petrol and industrial solvents results in wide spread emissions into the environment.

According to the reports, benzene is a known human carcinogen and can damage both bone marrow and the immune system.

## Hydrocarbons

Hydrocarbons are fine particles of unburnt liquid fuel. Hydrocarbons may be carcinogenic and some of the compounds are strong irritants of the eyes, nose and throat.

## Delhi's Pollution

Delhi, in terms of air pollution, was ranked fourth among the 41 most polluted cities in the world, in the 90's. The annual average levels of suspended particulate matter increased to 450  $\mu\text{g}/\text{m}^3$  during 1996, which is nearly three times the National Ambient Air Quality Standard of 140

$\mu\text{g}/\text{m}^3$  for residential areas as notified by the Ministry of Environment, Govt. of India. During this period, the annual average levels of CO also increased to 5587  $\mu\text{g}/\text{m}^3$  as against the National Ambient Air Quality Standard of 2000  $\mu\text{g}/\text{m}^3$  for the residential areas. Vehicles, thermal power plants and large as well as small-scale industrial units in Delhi were the major sources of these pollutants.



# The Problem

The period between 1989 – 1996 saw a rapid increase in pollution levels. Infact, 1996 is considered the peak year in terms of air pollution load. The transport, industrial and the domestic sectors were the major contributors towards the rising ambient air pollution levels, in addition to

the presence of natural dust due to meteorological conditions. Figure 3 indicates the contribution from various sectors to ambient air pollution. The contribution from the vehicular sector increased from 23% in the year 1970/71 to as much as 72% by the year 2001.

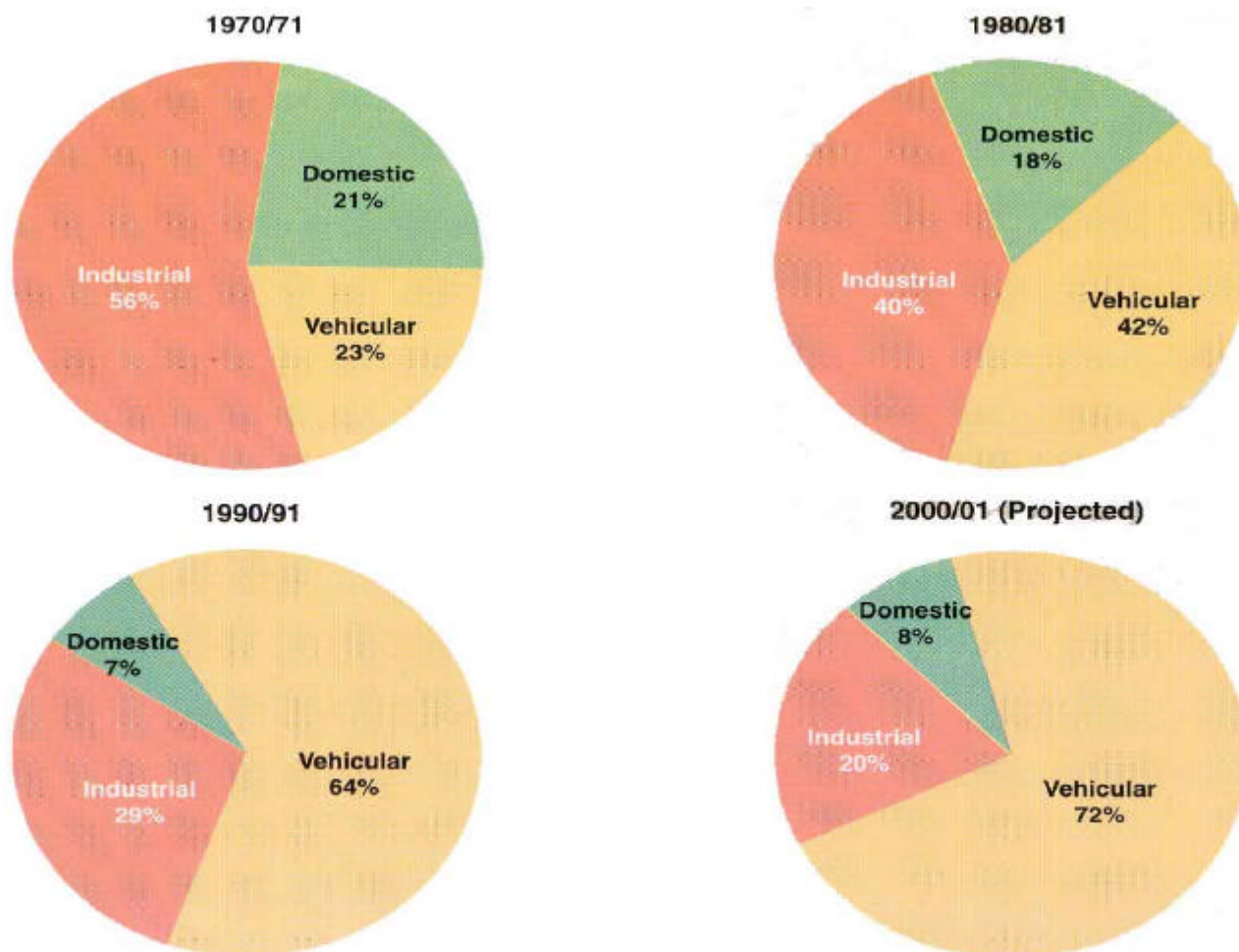


Figure 3 : Contribution of Various Sectors to Ambient Air Pollution (Source : MoEF)

# The Problem

## Meteorological Conditions

Besides anthropogenic sources, climate and natural sources too play an important role in the build-up of pollution levels. Delhi has a semi-arid climate, with an extremely hot summer, average rainfall and very cold winters. Mean monthly temperatures range from 14.3 °C in January (minimum 3 °C) to 34.5 °C in June (maximum 47 °C). The annual mean temperature is 25.3 °C (WMO 1971). Dust storms occur frequently during summer months leading to build-up of particulate matter in the atmosphere.

The monsoon season witnesses the least pollution due to frequent washout of pollutants along with rains. Mixing height is one of the important parameters that influences the dilution of pollutants. It follows diurnal and seasonal variations. During winter, ground-based temperature inversions are a regular feature that restrict mixing height to low levels. Lower temperatures, calm conditions, lower mixing height, and temperature inversions during winter is to restrict and confine pollutant dispersion and dispersal (CPCB 1993/94 and CPCB 2000). The monsoon rain scrubs the atmosphere regularly in a yearly cycle. Winter evenings, have higher pollution build-up because of frequent calm

conditions with temperature inversions resulting in poor natural ventilation and high emission loads due to evening traffic peaks. The situation in Delhi during winter is therefore more critical as compared to Mumbai, Chennai, and Kolkata as the effect of natural sea breeze is absent resulting in virtually no dilution of pollutants.

In the summer season, there are frequent pre-monsoon dust storms, when strong westerly winds from Rajasthan desert deposit large concentration of dust particles in Delhi's atmosphere.

## Vehicular Pollution

Delhi has experienced an exponential growth in the number of personalized vehicles over the last two decades. The rising trend in air pollution load from vehicular exhaust can also be noticed from the rise in the consumption of both major auto fuels i.e. petrol and diesel. By 1996, emission load in Delhi was much greater than the emission load in other metropolitan cities such as Kolkata, Mumbai and Chennai as illustrated in **Table 1**.

All this was happening in spite of widening of roads and an increased network of roads. The

# The Problem

city continued to grow, the number of vehicles on the roads kept increasing, traffic became more chaotic and congested. The poor road condition had also to cope with overloaded public transport vehicles since more and more people needed to commute for longer distances.

**Table 1 Estimated Pollution Load in the Cities**  
(Source : Auto Fuel Policy, 2002)

City	Pollution Load in metric tones per day			
	CO	NOx	HC	PM
Delhi	421.84	110.45	184.37	12.77
Mumbai	189.55	46.37	89.93	10.58
Kolkata	137.50	54.09	47.63	10.8
Chennai	177.00	27.30	95.64	7.29
Banglore	207.04	29.72	117.37	8.11
Hyderabad	163.95	36.89	90.09	8.0
Kanpur	28.75	7.25	11.7	1.91
Agra	17.93	3.30	10.28	0.91

As many as 500 vehicles exist for every Kilometre of the road stretch in Delhi whereas the figure for Mumbai and Kolkata is 350, and for Chennai, this figure is less than 100 vehicles.

The Delhi Transport Corporation, the only public utility managing public transport in the city, which had a fleet of over 5500 buses contributed heavily towards the air pollution load of the city as most of buses were old and poorly

maintained. More importantly, all public transport was based on diesel or petrol. Low average speeds, frequent stops at traffic intersections, long idling times, etc. were the order of the day.

Generally, petrol-driven vehicles (cars and those motorcycles, scooter etc. that use the more efficient four stroke engine) emit more of unburnt petrol and carbon monoxide whereas diesel-powered vehicles (buses and lorries) emit more of soot (the technical term for which is 'suspended particulate matter') and oxides of nitrogen. Autoricksaws, scooters, motorcycles, mopeds, and so on that run on two stroke engines use petrol mix with lubricant oil emit large quantities of unburnt oil and, as a result, emit large quantities of unburnt petrol besides Carbon Monoxide and soot.

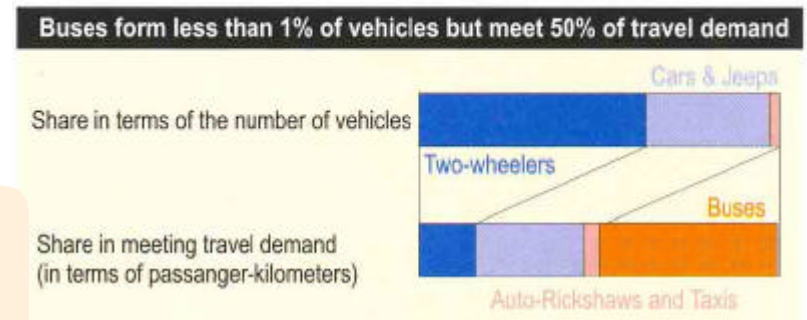
## Industrial Pollution

The other major source of air pollution load in Delhi was the fuel combustion by both large-scale and small-scale industries.

Among the large-scale industries, thermal power plants were the most prominent contributors to air pollution. Three coal based thermal power plants namely Rajghat, I. P. and Badarpur Power

# The Problem

Shares of different modes of transport in the total fleet strength and in meeting total travel demand (Source: TERI)



Plant, which have a total generation capacity of 1087 MW were responsible for as much as 10% (approx.) of the air pollution load in 2001.

These thermal power plants are located in the heart of the city. Particulate emissions from the I.P. Power Station (Unit no. 5) in 1998 reached an all-time high of 422 mg/Nm<sup>3</sup> as against the national standard of 150 mg/Nm<sup>3</sup>.

By 1996, the total number of small-scale industries in Delhi grew to a record number of 1,26,000 and unfortunately, most of the growth was witnessed in the pollution intensive areas and sectors.

In addition, significant pollution was also caused by a large number of Diesel Generating (DG) Sets, which were installed in various commercial and industrial establishments.

The erratic power supply was the *raison d'être* for the phenomenal increase in the number and use of DG sets.

# The Mitigation Measures

Compressed Natural Gas or CNG is dubbed as the fuel of the future. It is gaseous fuel consisting of a mixture of hydrocarbons mainly methane (89%-90%). Low-pressure natural gas is compressed to a pressure of 200-250 kg/cm<sup>2</sup> to enhance the storage capacity in a cylinder on board a vehicle; hence the name compressed natural gas.

It is a well known fact that polluted air is a symptom, not a cause – the cause is the absence of an efficient transport system, inefficient thermal power plants, greater emissions from non-point sources such as industries, diesel generators, etc.

## Vehicular Pollution

The main source of vehicular pollution is the fuel itself. The way it undergoes combustion inside the engine determines the amount of pollutant emissions from the engine. Any strategy then has to aim at the use of cleaner fuel, reduction in fuel consumption, adoption of efficient engines and installation of pollution control device at the tail end pipes of vehicles.

A part of mitigation measures started in 1996, with the introduction of reduced concentration of

Commonly referred to as the green fuel because of its lead-free character, CNG reduces harmful emissions and is non-corrosive, enhancing the longevity of spark plugs. Another practical advantage observed in countries where CNG is already in use is the increase in the life of lubricating oil as the fuel does not contaminate and dilute the crankcase oil.

lead in petrol from 0.56 g/l to 0.15 g/l, reduction of benzene to 5 % and reduction of sulphur from 1.0% to 0.5%. Over the next four years, the quality of fuel further improved as explained in **Table 2**

with further reduction in sulphur in diesel and lead in petrol.

On July 28, 1998, while hearing a Public Interest Litigation the Hon'ble Supreme Court directed, among other things, the replacement of all pre – 1990 auto-rickshaws and retrofitting all the post – 1990 auto-rickshaws and taxis with devices running on clean fuels. In addition to this, the Hon'ble Court also directed the withdrawal of buses which were more than eight years old and conversion of the rest of the city's bus fleet to CNG based vehicles and setting up of more CNG filling stations. This was based on the recommendations of Environment Pollution (Prevention & Control) Authority (EPCA), also known as Bhure Lal Committee, set up by the Ministry of Environment & Forests.



# The Mitigation Measures

Table 2 Vehicular Pollution Control Measures Taken in Delhi  
(Source : Auto Fuel Policy, 2002)

Measures Taken	1996	1998	2000	2001 (Jan-June)
<b>Emission Norms of Vehicles</b>	<ul style="list-style-type: none"> <li>Emission norms made stringent as compared to 1991</li> </ul>	<ul style="list-style-type: none"> <li>Emission norms for catalytic converter fitted vehicle made stringent</li> <li>Hot start replaced by Cold start test which gives less emissions</li> </ul>	<ul style="list-style-type: none"> <li>Euro-I equivalent norms for all types of vehicles except passenger vehicles which are EURO-II equivalent</li> </ul>	<ul style="list-style-type: none"> <li>CNG/LPG norms finalized</li> </ul>
<b>Fuel Quality improvement</b>	<ul style="list-style-type: none"> <li>Fuel quality specification notified under EPA for the first time.</li> </ul> <p>Lead content (g/l) = 0.15 Diesel Sulphur = 0.5% Gasoline Benzene = 5.0%</p>	<ul style="list-style-type: none"> <li>Diesel sulphur reduced to 0.25%.</li> <li>Gasoline Benzene reduced to 3.0%</li> <li>Gasoline Lead phased out</li> </ul>	<ul style="list-style-type: none"> <li>Diesel sulphur reduced to 0.05% in selected outlets</li> <li>Gasoline benzene reduced to 1.0%</li> <li>Gasoline sulphur with 0.05% maximum sulphur in all outlet.</li> <li>Low smoke 2-T oil introduced.</li> </ul>	<ul style="list-style-type: none"> <li>Diesel with 0.05% sulphur throughout retail outlets in NCT.</li> </ul>
<b>Other measures</b>	<ul style="list-style-type: none"> <li>Govt. vehicle to run CNG/Catalytic Converter</li> </ul>	<ul style="list-style-type: none"> <li>15 years old commercial vehicle banned.</li> <li>Pre-mix 2T oil in retail outlets.</li> </ul>	<ul style="list-style-type: none"> <li>Buses more than 8 years phased out.</li> <li>Replacement of pre-1990 autos/taxis with vehicle on clean fuels.</li> <li>Conversion of post 1990 autos to CNG initiated.</li> <li>Fuel testing laboratory established.</li> </ul>	<ul style="list-style-type: none"> <li>All taxis/autos and buses to run on CNG.</li> </ul>

In March, 2001, the Supreme Court asked the EPCA [Bhurelal committee] to examine as to which fuels can be regarded as clean fuel. Also, the other organization and association namely Tata Energy Research Institute, Indian Institute of Technology and Center for Science and Environment, were asked to give their views to this committee. In August 2001, the Bhurelal Committee recommended to the Supreme Court that CNG and LPG are environmentally acceptable auto fuels for Delhi. In April 2002, the Supreme Court rejected the plea of shortage of CNG and directed the phasing out of diesel buses.

The Govt of Delhi explored all possibilities for using CNG, by holding discussions with vehicle manufacturers and other public transport agencies. Vehicle manufacturers were asked to bring CNG technology into the country. The Gas Authority of India Ltd. was requested to lay underground pipelines for setting up of new CNG stations.

From 1999 onwards, the Govt. of NCT of Delhi persuaded the Govt. of India for bringing converted CNG vehicles under permit and tariff jurisdiction of the Govt., for which an amendment had to be made in the Motor Vehicles Act during September, 2001.

The co-ordinated measures for effecting the switchover were put in place by the Govt. of Delhi through multipronged action as different agencies were responsible for ensuring the environment



this was a challenging task, which was never undertaken on such a massive scale anywhere in the world.

Following the orders of the Hon'ble Supreme Court to move all public transport on CNG by March 31, 2001, the transporters went on strike and removed their buses from the road. Looking at the problem, Delhi Govt. approached the Court for extending the deadline but the Hon'ble Court did not accept the same. The problem became serious as neither the CNG vehicle manufacturers were forthcoming nor the owners of the buses were willing for the switchover to CNG as they had doubts about the technical and economical suitability of the CNG buses. It was in late 2001 that the Delhi Govt. prepared a phase out plan for diesel buses, which was

CNG being lead/sulphur free, its use substantially reduces harmful engine emissions. Besides, the operational cost of vehicles running on CNG, as compared to those running on other fuels, is amazingly low.

friendliness of public transportation namely Delhi Transport Corporation (DTC), Indraprasth Gas Ltd. (IGL), Dept. of Transport, and Dept. of Environment. Certainly,

# The Mitigation Measures

- December 2002: New 12-inch pipeline spanning 23.8 Kms in West Delhi marking 12 stations online commissioned
- April 2003: 110 CNG stations from 94 stations in march 2002

approved by the Hon'ble Supreme Court. Under this plan, 800 diesel buses per month were to be phased out every month between April, 2002 and November, 2002. Following this plan, the entire public city bus fleet was converted to CNG for which, Govt. of Delhi provided adequate funds.

Apart from buses, all pre-1990 auto-rickshaws were also to be replaced with new auto-rickshaws and post-1990 auto-rickshaws were to be retrofitted with CNG kits. In spite of the constraints like non-availability of CNG auto-rickshaws and retrofitment kits, Delhi Govt. was instrumental in getting 47000 auto-rickshaws replaced. This was done by giving incentives like Sales-Tax exemption and interest subsidy on loans to the auto rickhsaw owners. Besides this, 2.4 million vehicles were checked for pollution during the year 2002-03.

While there were around 1000 CNG vehicles in April 1998, by 2003, there were 70,249 vehicles including : taxis, auto-rickshaws and 9000 buses plying exclusively on CNG. Nowhere in the world, has any agency responsible for meeting the travel needs of an urban metropolis converted its entire fleet to run on CNG. DTC now has the distinction of being the world's largest eco-friendly CNG bus service.

With CNG accepted as an alternative fuel, the stage is now set for expanding the network to areas bordering Delhi, comprising the National Capital Region (NCR). CNG is also the cheapest of auto-fuels, as per the prevailing prices in May 2003, CNG compares favorably with diesel and petrol. However, use of clean fuels by the public transport system is only a part of the solution.

## Thermal Power Plants

Three Thermal Power Plants in NCT of Delhi contributed about 16% of the total air pollution in the year 1991. All the three thermal power plants have installed electrostatic precipitators in all their units to control particulate matter emissions. These plants were encouraged to adopt self monitoring systems to keep a constant check on the environmental quality parameters. Consistent efforts for environmental improvement have resulted in installation of new high efficiency Electrostatic Precipitator in unit no. 5 of I.P. Power Station. Besides this, the Power Plants are using beneficiated coal (ash content less than 34%) since 1999 as against the coal used earlier (ash content above 40%) to reduce pollution. Table 3 shows the trend of reduction in the air pollution from these power plants on annual average basis. DPCC has further



directed these power plants to achieve stricter norms of  $50 \text{ mg/Nm}^3$  as against the standards of  $150 \text{ mg/Nm}^3$  notified by the Ministry of Environment & Forests, Govt. of India earlier. These plants are in the process of taking necessary steps.

Two gas based power plants namely I.P. Gas Turbine Power Plant and Pragati Power Station have been commissioned to augment the power generation capacity from 1087 MW to 1700 MW. Since, these plants are based on natural gas, there is no significant addition to the existing air pollution levels as particulate emissions are virtually absent in gas based plants. In addition, low NOx burners have been installed at Pragati (gas based) power plant. Also in the last five years, the particulate matter emissions have decreased by about 20% & 10% at I.P. Power Station and Badarpur Thermal Power Plant respectively.

### **Small-Scale Industries**

The excessive increase in the number of small-scale industries in Delhi was also responsible for an increase in the pollution levels in Delhi.

In 1996, Hon'ble Supreme Court while hearing a Public Interest Litigation passed various orders to close down the 1328 'H' category units, i.e., Hot mix plants, lead smelting units, stone crushers,

pesticides, heavy foundries, steel rolling mills etc. Subsequently, DPCC also issued closure orders in respect of 118 industrial units which were engaged in 'H' category. In 2000, Hon'ble Supreme Court ordered the closure of polluting industrial units in non-conforming/industrial areas under the supervision of Ministry of Urban Development, Govt. of India as a Nodal Agency. Based on the criteria of polluting industries, evolved by the Nodal Agency and Expert Committee constituted by the Govt. of Delhi, 5046 units have been closed down by Govt. of Delhi. Acting on similar lines, Delhi Pollution Control Committee has also identified 557 such industries and ordered their closure.

Apart from above, Delhi Pollution Control Committee directed several industrial units to install pollution control devices, which were found polluting during the course of action of implementation of Air (Prevention & Control of Pollution) Act, 1981.

In order to check the pollution from D G Sets, Govt. of Delhi, on 10th December, 2001 authorised all Deputy Commissioners, SDMs and other Police Officers to implement the norms pertaining to DG Sets. These officers were asked to ensure that the D G Sets above 5 KVA capacity do not operate in residential areas, between 10.00 PM to 6.00 AM (except Group Housing Societies & Multi Storied Complexes) and ensure that these D G Sets meet the prescribed emission norms.

# The Mitigation Measures

**Table 3. Annual Average Emissions from Coal Based/Gas Based Thermal Power Plants Located in Delhi**

Year	Particulate Matter Emissions in coal based Thermal Power Plants (mg/Nm <sup>3</sup> )			NOx emissions in Gas based Thermal Power Plants (mg/Nm <sup>3</sup> )		Remarks	
	Rajghat Thermal Power Station	I.P. Thermal Power Station (247.5 MW)	Badarpur Thermal Power Station (705 MW)	I.P. Gas Turbine	Pragati Power Station		
1993-94	144	X	145	*	Pragati Power Station commissioned in the year 2002	ESP already installed in all coal based TPPs	
1994-95	139	X	140	*			
1995-96	142	210	137	*			
1996-97	144	275	135	*			
1997-98	145	166	132	*			
1998-99	149	210	130	*			
1999-00	127	190	127	*			1. Beneficiated coal introduced in the Thermal Power Plants. 2. High efficiency ESP retrofitted in unit no. V of I.P. Power Station
2000-01	125	180	125	*			Opacity meter installed in I.P. and Rajghat Power Station.
2001-02	127	135	120	1.68			
2002-03	124	125	115			13	

\* - Low pollution potential. Data not available.

X - Data not representative.



## Other Measures

Green areas like parks, forests, and gardens are more than just pastoral views or recreational spots. Vegetation cleans the air and acts as a climate moderator. One hectare of wood land (1000 trees) absorbs as much as 3.7 tonnes of CO<sub>2</sub> from the atmosphere and gives out 2.5 tonnes of life sustaining oxygen.

The city forests that are spread in various parts of the city, like the Ridge area, which are an extension of the Aravalli range of protected and reserve forests an admixture of both indigenous and exotic species of flora & fauna. Delhi's fast expanding forest cover however remains unrecognized for its role in reducing the level of air pollution, toxicity and ambient concentrations. The latest State of Forest Report 2001, released by the Ministry of Environment and Forests, Government of India, confirms what was otherwise becoming clearly visible:

Delhi's forest cover has increased to 111 sq. Kms in 2001 from 88 sq. Kms that existed two years back in 1999. Jumping from 5.9 per cent in 1999 to 7.5 per cent in 2001, the expansion of forest cover remains a remarkable achievement in afforestation. Add to this, the tree cover that

exists along the roadsides, streams, vacant lands falling outside the forest cover in Delhi which constitutes 40sq. Km. The total tree cover & forest cover is now 151 sq. Kms which is 10.2 percent of the total geographical area. Delhi is indeed getting greener.

## Mass awareness

No environment programme can succeed without mass awareness among the people. By launching various action programs and a number of public awareness activities, we can go a long way in the protection of the environment. Children are the future citizens of the country. Involvement of school children in environmental awareness programs was ensured by forming Eco-Clubs in schools of Delhi. So far, about 1500 Eco-Clubs have been set-up in various schools and colleges of Delhi. Under this programme, various campaigns like- "Say no to fire crackers", "Greening Delhi" were successfully conducted with the active involvement and co-operation of these Eco-Clubs and the citizens of Delhi.

# Present Scenario

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The fight against air pollution in the capital, which began in earnest in 1997, finally started yielding results. Statistics have shown that not only has the rising trend in pollution level been checked, but the level of various pollutants in the ambient air are also coming down. One of the renowned experts has stated, "what Britain took 30 years to accomplish, we have done in 5 years."

Though Delhi remains a polluted city, there is not much of chemical pollution. The period between 1989-96 saw a rapid increase in pollution levels. The Year 1996 may be considered as the peak year. But in the wake of use of CNG as an alternate fuel, the contribution of vehicular sector towards air pollution has been reduced in the

subsequent years. This is also supported by the fact that there is a significant improvement in the air quality. The best place to witness this change is the busy ITO traffic intersection, where toxic fumes no longer irritate the eyes as earlier. Carbon Monoxide, Nitrogen Dioxide, Lead and Sulphur Dioxide levels have all shown a declining trend. The annual average of  $42 \mu\text{g}/\text{m}^3$  of Sulphur Dioxide in the year 1996 came down to as much as  $18 \mu\text{g}/\text{m}^3$  during 2002 at ITO Intersection, whereas  $\text{NO}_2$  came down from  $75 \mu\text{g}/\text{m}^3$  in 1996 to  $59 \mu\text{g}/\text{m}^3$  in 2000. Further, there has been a marked decline in the annual Lead levels after introduction of unleaded petrol in 1998.

Also, the results show a significant improvement in the overall air quality of the city. The concentration of Carbon Monoxide has fallen by 32 per cent; Sulphur Dioxide levels have fallen by 39 per cent in 2002 as compared to 1997. The concentration of other pollutants like Lead and Benzene have also registered a marked decline. Despite the phenomenal growth in vehicular population, the levels of Nitrogen Dioxide have remained more or less constant, this can be attributed to the phasing out of old commercial vehicles and implementation of Euro-I and



### National Ambient Air Quality Standards

Pollutants	Time weighted average	Concentration in Ambient Air	
		Industrial Area	Residential & Rural Area
Sulphur Dioxide (SO <sub>2</sub> )	Annual Average	80 µg/m <sup>3</sup>	60 µg/m <sup>3</sup>
Nitrogen Dioxide (NO <sub>2</sub> )	Annual Average	80 µg/m <sup>3</sup>	60 µg/m <sup>3</sup>
Suspended Particulate Matter (SPM)	Annual Average	360 µg/m <sup>3</sup>	140 µg/m <sup>3</sup>
Respirable Particulate Matter (RPM) (Size less than 10 microns)	Annual Average	120 µg/m <sup>3</sup>	60 µg/m <sup>3</sup>
Carbon Monoxide (CO)	8 Hours	5000 µg/m <sup>3</sup>	2000 µg/m <sup>3</sup>
Lead	Annual Average	1.0 µg/m <sup>3</sup>	0.75 µg/m <sup>3</sup>

As can be seen from the above, although the word "standard" is used, it should not be looked up as a desirable value but be taken as a maximum limit beyond which levels should not exceed and if they do, adequate response measures like an "alert mechanism" or "emergency warning" need to be put in place.

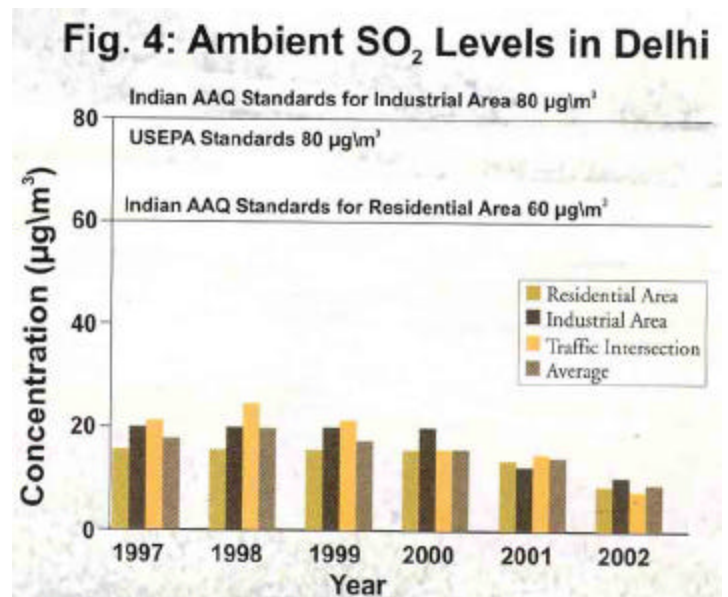
### USEPA Standards (Maximum acceptable outdoor exposures)

Pollutants	Time weighted average	Concentration in Ambient
Sulphur Dioxide (SO <sub>2</sub> )	Annual Average	80 µg/m <sup>3</sup>
Nitrogen Dioxide (NO <sub>2</sub> )	Annual Average	100 µg/m <sup>3</sup>
Respirable Suspended Particulate Matter (Size less than 10 microns)	24 hour average	150 µg/m <sup>3</sup>
Carbon Monoxide (CO)	8 Hours	10000 µg/m <sup>3</sup>
Lead	Annual Average	1.5 µg/m <sup>3</sup>
Ozone	8 Hour average	156 µg/m <sup>3</sup>

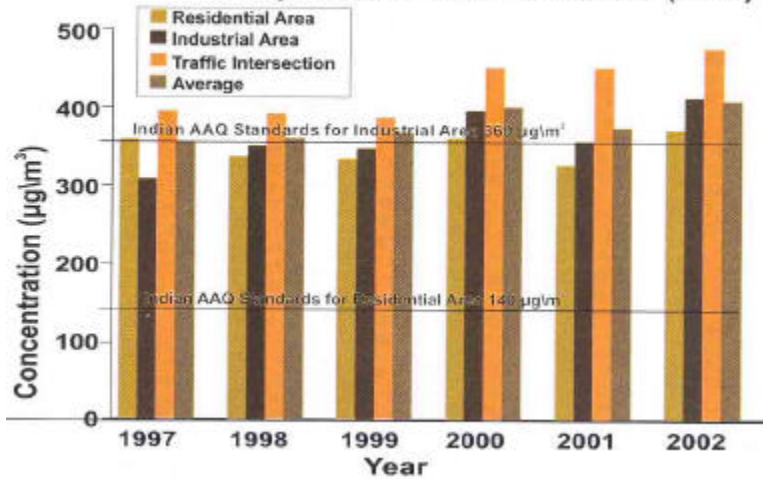
subsequently Euro-II norms for petrol and diesel driven private vehicles.

### Sulphur Dioxide

The figure 4 shows that over the last few years, the levels of SO<sub>2</sub> have drastically come down in the ambient air. Annual mean SO<sub>2</sub> levels were observed as 18.03 µg/m<sup>3</sup>, 14.1 µg/m<sup>3</sup>, 11.3 µg/m<sup>3</sup> in the year 2000, 2001 and 2002 respectively. SO<sub>2</sub> levels decreased by 21.8 % & 19.6 % in the year 2001 & 2002 respectively. The annual mean SO<sub>2</sub> levels in Delhi satisfy the annual average of National Ambient Air quality Standards for residential areas, which is 60 µg/m<sup>3</sup>.



**Fig. 6: Yearwise Annual Mean Variation of Suspended Particulate Matter (SPM)**



## Nitrogen Dioxide

Figure 5 shows the annual average values of NO<sub>2</sub> observed during last six years. Despite, an increase in the number of vehicles from 1997 to 2002, the NO<sub>2</sub> levels have shown an increase from 41.7 to 47.2 µg/m<sup>3</sup> which is not very significant. The annual mean of NO<sub>2</sub> levels in Delhi is well within the annual average of National Ambient Air Quality Standards for residential areas, which is 60 µg/m<sup>3</sup>.

## Suspended Particulate Matter (SPM)

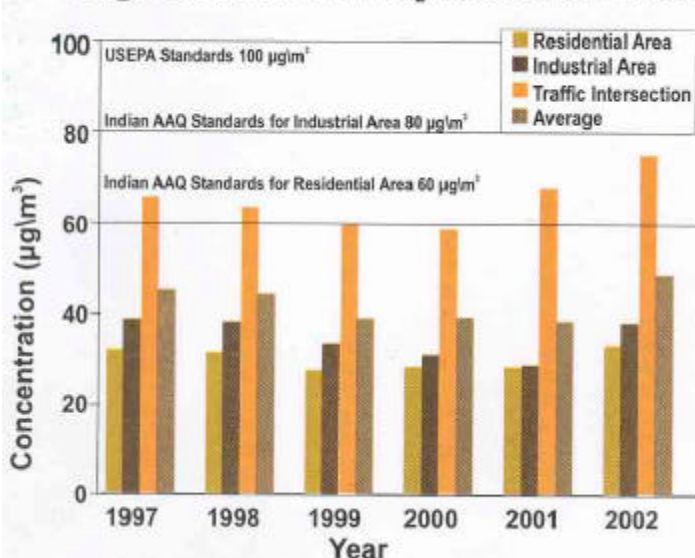
Figure 6 which shows that SPM levels have increased from 363 to 456 µg/m<sup>3</sup> between 1997

to 2002. But, SPM levels reduced by 11.4% in the year 2001 and increased again to 19.4 % in the year 2002. This could be attributed to the adverse meteorological conditions in 2002.

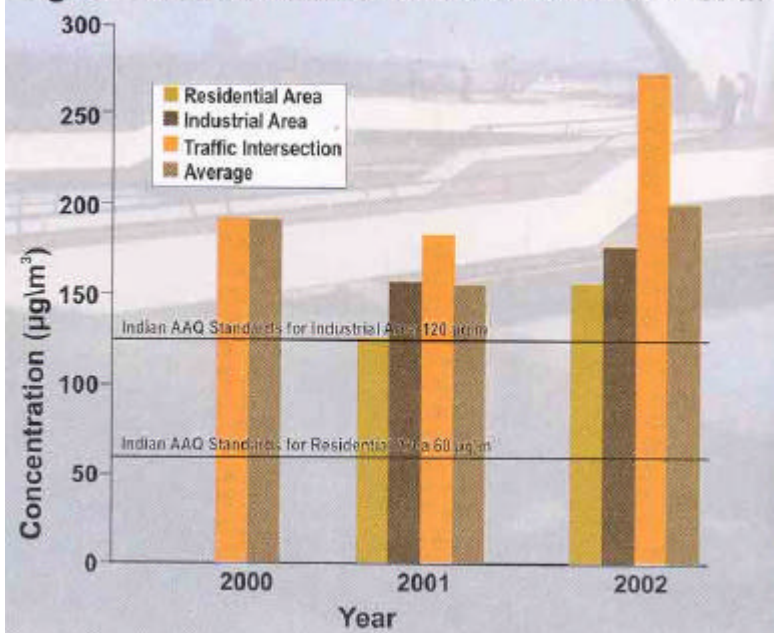
## Respirable particulate matter (RSPM) or PM10

Figure 7 shows the annual average of RSPM levels over the city. It is clear that RSPM levels have reduced to 21.4 % in the year 2001 and remained almost constant in the year 2002 as compared to year 2000. The increase could be due to adverse meteorological conditions in 2002.

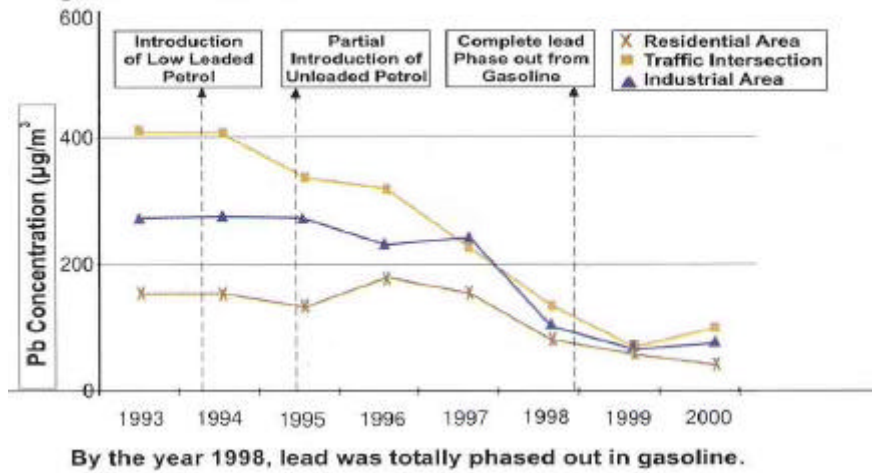
**Fig. 5: Ambient NO<sub>2</sub> Levels in Delhi**



**Fig. 7: Yearwise Annual Mean Variation of RSPM**



**Fig. 9: Decline in Ambient Lead Concentration in Delhi**



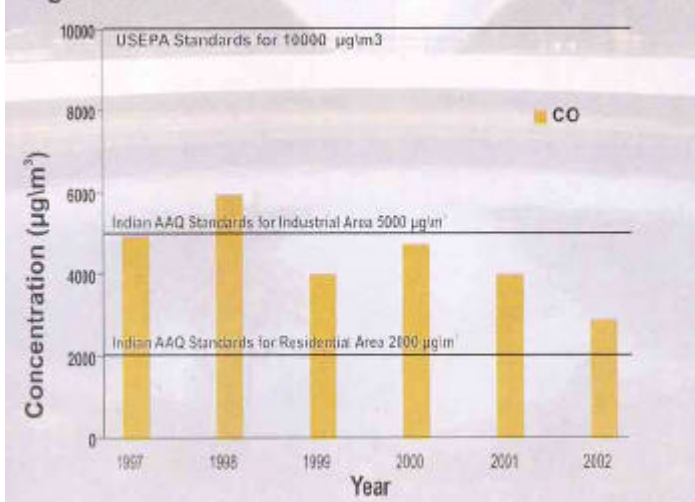
## Carbon Monoxide (CO)

The annual average CO levels as shown in Figure 8, indicate constant reduction of CO levels at ITO intersection. The observed concentration of CO came down from 4183  $\mu\text{g}/\text{m}^3$  in Year 2001 to 3258  $\mu\text{g}/\text{m}^3$  in Year 2002. This could be attributed to the stringent vehicular emission norms, fuel quality up-gradation and development of better engines. Though the annual average levels of Carbon Monoxide continue to be above the danger mark of 2,000  $\text{mg}/\text{m}^3$ , there has been a gradual decline.

## Lead

Figure 9 depicts that annual average levels of lead in the city which have substantially reduced after 1996. In 1996, the lead concentration in petrol was brought down from 0.56 g/l to 0.15 g/l. In 1998, lead was totally phased out from petrol. These measures resulted in the reduction of the lead levels in the ambient air.

**Fig. 8: Yearwise Annual Mean Variation of CO at ITO in Delhi**



# Air Pollution: its impacts on health



The people of Delhi still have memories of the Bhopal disaster. The Bhopal Gas Tragedy of 2nd-3rd December 1984, was caused by an acute exposure to methyl-isocyanate (MIC) leaking from the Union Carbide pesticide plant, and killed about 2000 people. This disaster is a tragic illustration of the impact of pollutants on human health.

The health effects of pollutants depend upon the concentration, exposure duration and the individual's susceptibility. In general, after an initial lag period the health effects become manifest and continue to rise, reaching a plateau thereafter.

There are important connections between air pollution and diseases, and the cost that they impose on the society. Carter Bradndon and Kirsten Hommann had conducted a study for World Bank in 1995 on valuing the economy wide cost of environmental degradation in India. According to the study, in India, the cost of health impacts on account of air pollution were estimated to be \$ 1,310 million. Further, the cost due to air pollution was estimated to be 14% of the total economy wide cost of environmental degradation.

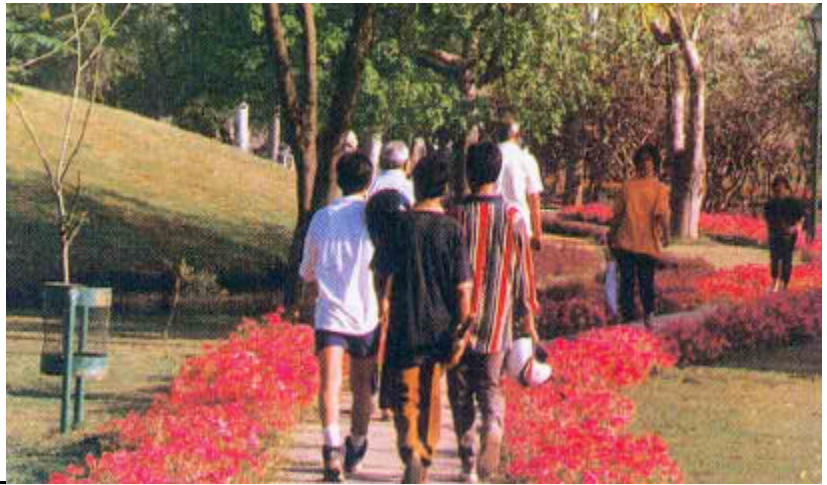


The World Bank presented the first authentic evidence of adverse impact of urban air pollution in Delhi through its report as prepared by Anna Alberini, Nathalie B. Simon, P. K. Sharma, and Maureen L. Cropper in 1997.

According to the study 'Particulate air pollution has less overall impact on non-traumatic deaths in Delhi, India, than in U.S. cities. But deaths occur earlier in life in Delhi, which could mean a larger loss in life-years.'

The important conclusions drawn from this time-series study of the impact of particulate air pollution on daily mortality in Delhi were as follows:

# Air Pollution: Its Impacts on health.



A positive, significant relationship between particulate pollution and daily non-traumatic deaths as well as deaths from certain causes (respiratory and cardiovascular problems) and for certain age groups.

In general, these impacts are smaller than those estimated for other countries, where on an average a 100-microgram increase in total suspended particulates (TSP) leads to a 6% increase in non-traumatic mortality. In Delhi, such an increase in TSP is associated with a 2.3% increase in deaths.

The differences in magnitudes of the effects are most likely explained by differences in distributions of age at death and cause of death, as most deaths in Delhi occur before the age of 65 and are not attributed to causes with a strong association with air pollution.

Although air pollution seems to have less impact on mortality counts in Delhi, the number of life-years saved per death avoided is greater in Delhi than in U.S. cities-because the age distribution of impacts in these two places varies. In the United States particulates have the greatest influence on daily deaths among persons 65 and older. In Delhi, they have the greatest impact in the 15 to

44 age group. That means that for each death associated with air pollution, on average more life-years would be saved in Delhi than in the United States.

Large differences in the magnitude of effects do call into question the validity of the "concentration-response transfer" procedure. In that procedure, concentration-response relationships found for industrial countries are applied to cities in developing countries with little or no adjustment, to estimate the effects of pollution on daily mortality.

Dr. J N Pande and his colleagues from the Department of Medicine, All India Institute of Medical Sciences, New Delhi studied the 'Outdoor air pollution and emergency room visits at a hospital in Delhi'.

The study was undertaken to correlate the daily levels of various pollutants with the number of patients visiting the All India Institute of Medical Sciences (AIIMS, New Delhi) suffering from cardio-respiratory disorders. Daily counts of patients visiting the emergency room of the AIIMS for acute asthma, acute exacerbation of chronic obstructive airway disease (COAD) and acute coronary event was obtained in

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prospective manner from January 1997 to December 1998. Daily mean levels of ambient CO, NO<sub>x</sub> and SO<sub>2</sub> were monitored along with temperature and humidity. It is concluded that there is a considerable burden of cardio respiratory diseases in Delhi due to high levels of ambient air pollution.

In Delhi, Vallabhai Patel Chest Institute conducted a study which concluded that the lungs of those living in more polluted areas functioned poorly when compared with those living in less polluted area.

Exposure to Carbon Monoxide even in small quantities can be fatal. However, long term exposure to Suspended Particulate Matter (SPM) can be dangerous.

The World Health Report 2002 attributes environmental risks especially the urban air pollution, indoor air pollution, lead exposure and climate change as some of the causes for the Disability Adjusted Life Year. (DALY).

With the multi pronged efforts taken by the Delhi Government in recent years as already mentioned, the concentration of both SO<sub>2</sub> and CO have declined. However, the impact of introduction of CNG on the levels of NO<sub>x</sub>, SPM

and RSPM needs to be studied in detail. No specific epidemiological study on impact of air pollution and its effects on human health has been done in Delhi. More importantly, cost effective solutions need also to be developed through advanced research and analysis and integrated into the policy framework in various sectors like transport, health and even the industrial policy. This has not happened so far.