CLEARING THE AIR IN DELHI

DELHI, COVERING A SPRAWLING METROPOLITAN AREA OF SOME 17 MILLION PEOPLE, IS ONE OF INDIA'S PRIMARY ENGINES OF GROWTH. BUT THE CITY'S GROWTH HAS COME AT A COST. SARATH GUTTIKUNDA, A RESEARCHER AT URBAN EMISSIONS.INFO IN DELHI, EXPLAINS WHAT DELHI IS DOING TO IMPROVE ITS AIR QUALITY.

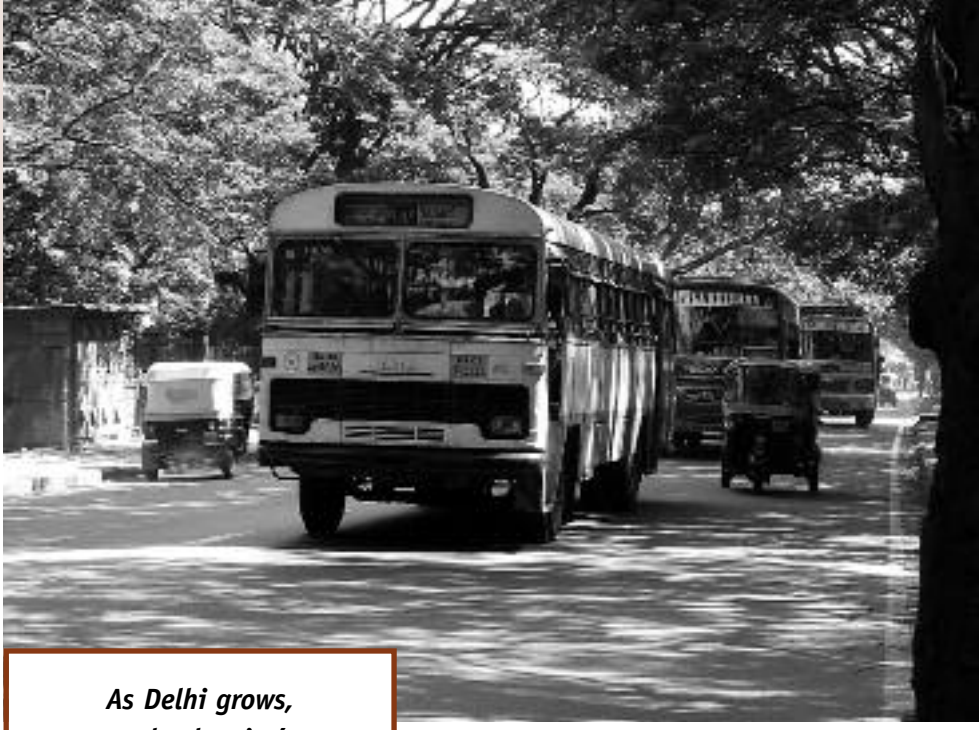
"India's Asthma Capital". That's the dubious honour the Indian Central Pollution Board (CPCB) gave to Delhi, the nation's capital city and second largest city (only Mumbai is larger), in March 2009.

Such rankings aside, Delhi is emerging as a world class city. But its growth has been accompanied by a relentless expansion of roads, industry, commerce and housing that has spurred a dangerous increase in the levels of air pollution. That, in turn, has led to rising health risks, reflected most notably by an increase in respiratory ailments.

In 1985, the National Capital Region (NCR) of Delhi covered just over 30,000 square kilometres. Today, the region covers more than 33,500 square kilometers and includes the neighbouring states of Haryana, Uttar Pradesh and Rajasthan.

Geographic expansion, of course, has been driven by population growth. In 1990, the population of Delhi's metropolitan area stood at 8.6 million. Today, it exceeds 17 million, and by 2025 it is expected to climb to 22.5 million. Yet, you don't need to be a mathematician to realize that the 10% increase in city size has failed to keep pace with a 50% increase in population.

Over the past decade, India's governments – at the city, regional and national levels – have introduced a number of 'green' initiatives to address the city's air pollution problems. While these measures deserve support, they have nevertheless fallen short in addressing the daunting challenges posed by air pollution. As a result, there is still a tremendous amount of work that needs to be done to provide clean air for the city's growing number of residents.



As Delhi grows, so do the city's transportation needs.

SEASONS AND SOURCES

No single sector – neither housing nor industry nor transportation – is solely responsible for Delhi's air pollution problems. Rather, a combination of factors, including outdated power plants, inefficient industries, widespread household burning of coal and biomass for cooking and heating, rising levels of vehicle emissions and road dust, all contribute to the city's dirty air.

Moreover, seasonal fluctuations in demand for fuel and such natural phenomenon as temperature inversions and dust storms create wide month-to-month variations in pollution sources and levels. All of this complexity must be taken into account when trying to maximize the effectiveness of pollution-mitigation initiatives.

In summer, dust storms that originate in the Thar Desert, southwest of Delhi, add to the levels of air-borne particulate matter and dust in the city. Scorching summer temperatures, moreover, cook the air and reduce its moisture content, causing high levels of dust to kick-up from the roadbed and waft into the air. Indeed some 40% of the particulate air pollution in summer is due to road dust, compared to less than 5% in winter. By way of contrast, in winter up to 30% of the particulate air pollution is due to the burning of biomass to heat homes and other structures. In summer, biomass accounts for less than 10% of particulate pollution as the burning of biomass is used solely for cooking.

Agricultural clearing is another factor that contributes to Delhi's rising air pollution levels. Again, this is a seasonal phenomenon that occurs in late fall and early winter as farmers in the not-so-distant agricultural districts that surround the city burn post-harvest plant residue – stems, leaves and upended roots – in preparation for next year's planting. The slithering smoke eventually sweeps over Delhi causing smog levels to rise.

STOP AND GO

As New Delhi grows, so do the city's transportation needs, fuelling a dramatic increase in scooters and motorcycles, automobiles and trucks, buses and taxis, and even auto-rickshaws. In 1991, New Delhi had an estimated 2 million registered vehicles plying its roads. Today, that figure stands at 4.5 million. Traffic speeds have slowed and idling times have increased, causing air pollution levels to skyrocket.

Efforts to unclog the traffic have prompted major road construction projects throughout the city. But the new highways, flyovers and bypasses have failed to yield the desired results. The reason, as most transportation experts will tell you, is that road construction only addresses the supply side of the transportation equation and thus fails to reign in the demand for vehicles. Indeed most experts agree that such efforts spur demand.

In fact, Delhi's experience with road construction has been replicated in cities throughout the world: More roads have led to more vehicles. This, in turn, has reversed the hoped-for improvements in traffic flow that the road construction projects were designed to achieve. In 2005, the number of car registrations rose to 1,000 a day in Delhi, marking a doubling of daily registrations in just five years. No amount of road construction can keep pace with such a dramatic increase in the number of drivers.

Industry, the other major source, accounts for about one-fifth of air pollution. Major culprits include the city's three major coal-fired electric power plants at Indraprastha, Badarpur and Raj Ghat, and about 200 brick kilns that also use coal to power much of the city's industry.

WHAT WORKS

In 1998, India's Supreme Court ruled that Delhi should take a number of concrete steps to combat air pollution in the transportation and industrial sectors. Most notably, it issued an order mandating the conversion of all diesel-powered buses in Delhi to compressed natural gas (CNG).

AIR BEIJING

Air pollution problems in Beijing, China, received a great deal of attention in 2008, primarily because the city served as the host of the summer Olympics. While stationary sources (industrial facilities and electric power plants) have historically been the main contributors to the city's pollution, Beijing's transportation sector – personal, public, and freight – has become an increasingly important factor.

The growing number of automobiles and trucks is not only exacerbating the city's air pollution problems, but it is also generating unprecedented levels of traffic. In 2009, according to the Beijing Traffic Management Bureau, the city registered nearly 1,500 motor vehicles a day, compared to 1,350 a day in 2008, a 10% increase in one year.

In 2003, the World Bank estimated that air pollution costs the Chinese economy some 520 billion Yuan (USD76 billion) per year, which represents about 3.2% of the nation's total gross domestic product (GDP).

During the 2008 Olympic Games, a series of measures were introduced to improve the number of "blue sky" (low pollution) days in Beijing (and the other participating cities in China). Two measures with the greatest impact were: shutting down the industries not only within the city limits, but also in cities within 100 kilometres of the centre of Beijing; and prohibiting 50% of the city's passenger vehicles from operating each day by instituting an even-odd permission system based on the vehicles' license numbers.

According to a report by the United Nations Environment Programme (UNEP), these measures led to a 50% decline in nitrogen dioxide levels and a 20% decline in carbon dioxide and particulate matter. The full impact of these initiatives, both for the environment and economy, have yet to be completely quantified. Meanwhile, government officials recently decided to reinstitute a less stringent version of the driving restrictions, requiring most cars to stay off the road at least one day every week. Clearly, shutting down the factories was only a temporary measure, designed to clear the air for the Olympics, and could not be continued beyond the closing ceremonies.

In addition to improvements in Beijing's air quality, these short-term measures also helped to enhance our understanding of the 'footprint' of various sectors and the potential that 'command and control' measures can have on efforts to reduce air pollution levels. We can only hope that Beijing (and other cities in China) do not need the incentives of Olympic games to make things happen in the future.



The compressed natural gas ruling marked the high point of Delhi's strategy.

In the transportation sector, this ruling led to more than 100,000 vehicles, including buses, taxis and auto-rickshaws, being converted to run on compressed natural gas (CNG).

The change-over, which occurred over a five-year period beginning in 1998, marked the world's largest switch to CNG for publicly owned and operated gas-driven vehicles to date. More importantly, it resulted in a dramatic reduction in the level of air pollution, with the greatest improvement coming from the conversion of some 3,000 diesel buses to CNG. As a result, Delhi has been able to enforce Euro II emission standards since 2000 – five years ahead of schedule. And since 2005, the city has been able to enforce Euro III for all passenger vehicles.

The court ruling also had a welcomed impact on mitigating industrial air pollution. About 500 heavy industries were shuttered and moved to areas beyond the city's administrative boundaries. This not only stirred a significant drop in air pollution within the city, but also prompted significant energy efficiency measures to be put in place as industries took advantage of the opportunity afforded by the relocation to upgrade their energy systems.

In 2003, the Indian Supreme Court issued another rule that required India's 14 fastest growing cities to conduct comprehensive analyses of their air pollution problems and then to submit an air pollution control action plan, based on their analyses, to effectively address the challenges.

As one of the 14 cities subject to this rule, Delhi's pollution control board is currently conducting the required comprehensive analysis, which includes a top-down monitoring of data and a bottom-up assessment of city-wide energy consumption and emission levels. The assessment, in addition to being a legal requirement, will also serve as the basis for the allocation of funds from the government-sponsored Jawaharlal Nehru National Urban Renewal Mission (JNNURM) for cities, which provides financial support for such urban development projects as the purchase of clean and efficient buses and road improvements for better traffic management.

DELHI ON THE GO

The CNG ruling marked the high point of the city's strategy to address rising air pollution problems. Early results following the conversion to CNG, especially for buses, were so dramatic that citizens could easily observe the improvement in air quality.

However, in the decade since the CNG conversion, air pollution levels in the city have edged back up. Some pollutants, including respirable particulate matter (RSPM) and nitrogen oxides, have climbed 40%.

The reasons are many. First, there is the sheer number of new vehicles on the road. As noted earlier, in 2000, some 500 vehicles were registered each day; in 2005, this figure doubled to 1,000. Consequently, the total number of vehicles in Delhi increased from 3.6 million in 2001 to 4.8 million in 2006. A survey conducted in February 2009 indicated that about 7% of vehicle exhaust emissions in Delhi are due to the idling of gas-driven vehicles stuck in traffic.

In 1998, India's Supreme Court ruled that Delhi should take steps to combat air pollution.

Then there is a lack of proper care and maintenance of gas-driven vehicles – both private and public. Here's one example. Buses operated by the publicly owned Delhi Transport Corporation were retrofitted to burn CNG in 2000. Over the past 8 years, maintenance has been spotty at best. As a result, many of these same buses have become less fuel efficient.

There is an urgent need to update Delhi's bus fleet. But efforts to purchase new buses have been hampered with delays. India's two largest bus manufacturers – Tata and Ashok Leyland – manufacture nearly 90% of the country's buses. At the current rate of production, only about 100 buses a month roll off the assembly line – a rate of supply that falls far short of the demand. The JNNURM fund alone has enough money to purchase 70,000 buses. It would take nearly 60 years to expend these funds at the current rate of bus production.

Exhaust fumes from poorly maintained trucks are also a problem. Emission controls are weak. Moreover, adulteration of diesel fuel, in which the fuel is contaminated by various products such as kerosene, is a chronic problem that only adds to the pollution that these trucks produce. In 2001, the city passed legislation prohibiting heavy duty trucks from entering the city during the day and enforced bypass regulations for trucks not destined for business locations in Delhi. Nevertheless, nighttime truck deliveries have an adverse environmental impact that is as perceptible as visibility-reducing smog during the day. This is especially true during the morning hours.

TAKE THE BUS

Delhi will host the 2010 Commonwealth Games. The government is using this high-profile event to enact measures that are designed to improve the quality of the city's air by easing traffic flows and increasing access to mass transport. Steps taken include expanding the public transportation network and streamlining traffic flows.

Among the most significant measures is an initiative to develop a Bus Rapid Transit (BRT) system characterized by dedicated bus lanes, train-like bus stations and wider bus doors.

In 2006, the TransMilenio BRT system in Bogotà, Colombia, became the world's first mass transport project approved for participation in the Kyoto Protocol's Clean Development Mechanism (CDM). TransMilenio has inspired other countries, including India, to institute the same system in their cities.

But results in Delhi have been mixed. After a two-year planning effort, only a five-kilometre 'pilot' lane has been built. The lane has been labeled the "corridor of chaos". While the road has yet to prove its mettle, it remains too early to declare the initiative a failure.

As experience elsewhere shows, a rapid bus transportation system can only succeed if it is built at a large enough scale to take people to where they need and want to go. Clearly, a bus lane that is less than 5 kilometres is inadequate to prompt significant changes in bus usage.

Despite the limited scale of this project, the start-up problems it experienced during the early months of operation and unfavorable media coverage, Delhi's BRT

system has recently elicited more positive approval, reflected not only in surveys but increased ridership.

The government should continue its efforts to improve the BRT by purchasing additional buses, upgrading the system's information centres and signage, and rigorously enforcing the restrictions placed on BRT lanes.

Without proper lane monitoring and enforcement, the BRT will not meet its objectives. For example, special lanes were set aside for pedestrians and other non-motorized transport in the initial plan. However, at one major junction, the lane that had been dedicated to cycling and walking has been converted to a 'left-turn only' lane for automobiles. Meanwhile,

AIR ULAANBAATAR

Ulaanbaatar, the capital city of Mongolia, is facing deteriorating urban air quality due to increased and inefficient combustion of coal, the primary source of energy. Also, efforts to curb air pollution in Ulaanbaatar have been thwarted by a number of natural constraints, including the fact that the city is encircled by mountains, which often trap the air, and it experiences very low temperatures during the winter months that cause the pollutants to mix and remain at low heights in the atmosphere. This increases the pollutants' ambient concentrations.

An analysis prepared for the World Bank in 2007 concluded that for particulate pollution, the largest emitters are power plants, domestic stoves and industrial boilers. The transport sector, which comprises fewer than 100,000 vehicles (including public transport), is small. But that doesn't mean Ulaanbaatar is free of traffic. Indeed limited infrastructure and inadequate planning causes traffic tie-ups despite the limited number of vehicles.

Gers *(traditional Mongolian dwellings comprised of wooden frames draped with several layers of wool felt), as well as the numerous food kiosks that line the city streets, burn coal during the winter months for heating and fuel wood all year round for cooking. The city's three combined heating and power plants and nearly 900 heat-only boilers generate heat for the apartments and commercial buildings.*

Although the power plants are responsible for most of the emissions, cooking stoves and small boilers in winter, and road dust in summer, add to the city's air pollution levels.

Local authorities have implemented a multi-pronged approach to control air pollution. Key programmes include improving monitoring capacity (through the efforts of a variety of government agencies), the introduction of innovative stove designs (aided by funds from the World Bank/Global Environment Fund), insulation of the gers *(with assistance from the Asian Development Bank), improving energy efficiency among small-scale industries and the power plants (again with funds from the World Bank), utilization of the fly-ash to reduce fugitive emissions (supported by the Xia Bank), the use of clean coal briquettes (which has been supported by the European Bank for Reconstruction and Development), and increasing the capacity of public transport (largely undertaken by government agencies in Mongolia).*



AIR DHAKA

Dhaka, Bangladesh's capital city and home to 12 million people, is the world's most densely populated city. Air pollution problems are on the rise due to the relentless increase in population and rising demand for energy. A 2008 study conducted by the Bangladesh Department of Energy attributed 15,000 premature deaths and several million cases of pulmonary, respiratory and neurological illnesses to poor air quality.

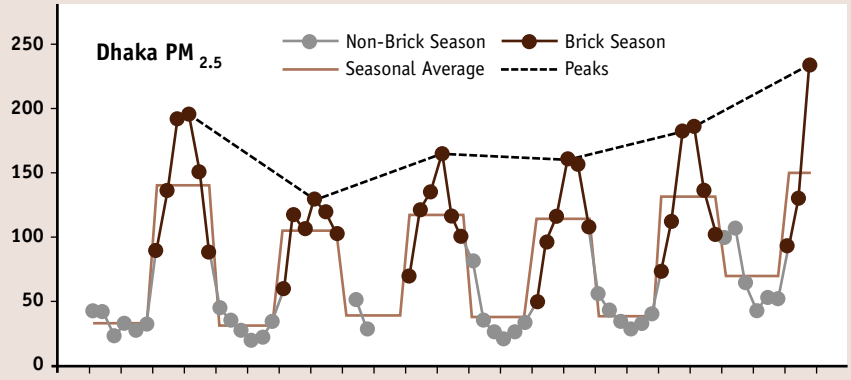
Transport emissions – direct exhaust from the vehicles and dust due to re-suspension – are the primary sources of Dhaka's air pollution. In the industrial sector, brick kilns are the major culprit, especially during periods of heavy manufacturing, which generally run from October to March depending on the behaviour of the monsoons. Seasonal averages have shifted over the years, but during peak brick manufacturing, pollution peaks measure 230 microgrammes per cubic metre ($\mu g/m^3$), compared to 100 $\mu g/m^3$ during off-peak manufacturing periods.

Growing construction activity has increased demand for brick, and that, in turn, is increasing the city's air pollution levels. A study by the Bangladesh University of Engineering and Technology of some 700 brick kilns shows that some 40% of the pollution in Dhaka originates from brick kilns burning biomass and low-quality coal. An additional 40 $\mu g/m^3$ during peak brick manufacturing periods leads to an estimated 5,000 premature deaths annually.

Pollution control measures for the transport sector range from better emission standards for passenger cars and cleaner buses to banning two-stroke vehicles and restricting bicycle rickshaws in central Dhaka to ease traffic.

Major efforts are now underway to mitigate pollution caused by the brick kiln industry. These measures, which include the use of advanced combustion technologies and filtering systems as well as public education to increase public awareness of the cost-savings derived from increased energy efficiency, are expected to quickly improve the city's air quality.

Monthly average $PM_{2.5}$ measurements in Dhaka City



Rapid bus transport and urban rail systems can help alleviate traffic congestion.

lanes that had been designated for non-motorized transport lanes are now dominated by motorcycles.

In 2002, Delhi opened a much awaited (and much delayed) 65-kilometre metro rail system. Construction on the next phase of the system – running 128 kilometres and reaching into a large number of Delhi's neighbourhoods – is underway.

The metro rail system has proven popular with the public. Indeed, it currently carries about 650,000 passengers a day. Air pollution experts project that when the second phase of the rail system is completed, it could help reduce emissions of RSPM and nitrogen oxides by nearly 10%.

The rapid bus transport and urban rail systems can help alleviate traffic congestion and encourage people to shift from private to public transportation. Yet, two completely 'zero emission' sources of transportation – bicycling and walking – should not be overlooked. Both help promote personal health, nurture a sense of community and enhance the quality of urban life.

BREATHING EASY

Delhi faces daunting air pollution challenges. Continuous growth, moreover, means that these challenges are likely to become even more daunting in the future. Yet, as the experience of other cities (for example, London, New York and, more recently, Beijing) shows, air pollution is an environmental problem that can be mitigated. The technology for providing cleaner air is already in place. What is most needed are innovative regulations, planning and incentives that allow growth to continue – but not at the expense of the air we breathe. ■

BIOVISION IN LYON AND ALEXANDRIA

This article is based, in part, on a presentation given by the author at the BioVision, The World Life Science Forum*, held in Lyon, France in March 2009 (see www.biovision.org). The conference session, organized by TWAS, also included presentations by Claudia Sheinbaum, researcher at the Institute of Engineering,* Universidad Nacional Autónoma de México *and former environment minister of Mexico City, and Robert Vaugard, director,* Laboratoire des Sciences du Climat et de l'Environnement*, France. It was moderated by Peter Wrobel, editorial director of Science Business Publishing, UK, and former managing editor of* Nature.

BioVision *is an international platform for dialogue, debates and proposals concerning major issues in the life sciences. The signature event is a conference held in alternating years in Lyon, France, and Alexandria, Egypt. The Lyon meeting is organized by the* Fondation Scientifique de Lyon *in collaboration with the French Academy of Sciences.* BioVison Alexandria *is held at the* Bibliotheca Alexandrina *(see www.bibalex.org). The next meeting of* BioVision Alexandrina *will take place on 11–14 April 2010.*