Air pollution control

Technologies in the transport sector

Manju Mohan, Renuka Saini and Shweta Bhati

Automobiles are a major source of air pollution in urban areas. This article explores technical and non-technical ways to control this pollution. It examines regulation of vehicular emission in relation to fuel characteristics, impact on air quality and standards enforcement in various Asian nations. In addition to the various technical and non-technical ways, vehicular pollution can also be mitigated by the development of an efficient public transport system. The article discusses the cases of two modes of public transport systems - Rapid Bus Transit and Metro rail - in Delhi, India. While growth in the number of vehicles cannot be contained, the right means can ensure that the air we breathe does not damage our health.

Prof. Manju Mohan
Ms.Renuka Saini
Ms. Shweta Bhati
Centre for Atmospheric Sciences
Indian Institute of Technology
Hauz Khas, New Delhi-110016, India
E-mail: mmohan65@yahoo.com
(Author for correspondence)

Introduction

Motorized road vehicles are the primary means of transporting passengers and freight because of their versatility, flexibility, and low initial cost as compared to other transport modes. In all but the poorest developing countries, economic growth, rising incomes and urbanization are contributing to a rapid increase in vehicle ownership and use.

Over the last two decades, motor vehicles have emerged as a critical source of urban air pollution in much of the developing world. For example, motor vehicles are the largest source of PM_{10} emissions in most Asian cities, exceeding the contributions from re-suspended road dust, heavy fuel oil and coal combustion, and refuse burning. The incidence of other transport-related pollutants (e.g. CO, NO_x, SO_2 and O_3) in developing countries also exceeds international and national norms. The associated human health and welfare costs run into hundreds of millions of dollars and far exceed the prevention costs.

With economic prosperity and urbanization, there has been an unabated increase in motor vehicles, bringing unprecedented mobility to the burgeoning middle class in many Asian countries. Although *per capita* vehicle ownership in most Asian countries is low compared to OECD countries (for example, in China there are about 8 vehicles per 1,000 persons and in India only 7 vehicles per 1,000 persons compared to 750 vehicles per 1,000 persons in the USA), vehicle growth in the region has been phenomenal. The growth of motor vehicles in China has averaged about 11 per cent annually in the last 30 years doubling every 5 years, and in India the growth has been around 7 per cent per year for the past 10 years.

Common air pollutants in urban areas from the transport sector include:

- Respirable particulate matter from smoky diesel vehicles, two-stroke motorcycles and 3-wheelers, burning of waste and firewood, entrained road dust, and stationary industrial sources;
- Carbon monoxide from petrol vehicles and burning of waste and firewood; and
- Photochemical smog (ozone), produced by the reaction of volatile organic compounds and nitrogen oxides in the presence of sunlight.

Motor vehicle emissions are a major source of nitrogen oxides and volatile organic compounds:

- Sulphur oxides from combustion of sulphur-containing fuels;
- Secondary particulate matter formed in the atmosphere by reactions involving ozone, sulphur and nitrogen oxides and volatile organic compounds; and
- Known or suspected carcinogens, such as benzene, 1, 3 butadiene, aldehydes, and polynuclear aromatic hydrocarbons, from motor vehicle exhaust and other sources.

Motor vehicle emissions - concepts and causes

The internal combustion engine

With few exceptions, motor vehicles are equipped with internal combustion engines. In such engines, a compressed mixture of air and fuel is ignited to provide the mechanical energy needed to drive the crankshaft. There are two common types of internal combustion engines in use. The most common is the Otto engine, which is a four-stroke-cycle, spark-ignited internal combustion engine, used primarily for passenger cars and light-duty trucks. The second most common is the four- and two-stroke-cycle, compression-ignition internal combustion engine, commonly referred to as a diesel engine. This engine is used for large trucks, buses, locomotives and ships.

The basic principle of the operating cycle of the spark-ignited internal combustion engine is that a piston moves up and down within a cylinder, transmitting its motion through a connecting rod to a crankshaft, which drives the vehicle. The four strokes of the spark-ignited internal combustion engine are:

- Intake - The descending piston draws a mixture of petrol and air in through the open intake valve.
- Compression - The rising piston compresses the fuel-air mixture. Near or at the top of the stroke the spark plug fires, igniting the mixture.
- Expansion - The burning mixture expands, driving the piston down and delivering power.
- Exhaust - The exhaust valve opens as the piston rises, expelling the burned gases from the cylinder.

The fuel-air mixture is prepared in the carburettor. This mixture is characterized by its air-fuel ratio, the weight of the air per weight of fuel. Ratios below 9 and above 20 are generally not combustible. Maximum power is obtained at a lower ratio than for minimum fuel consumption. Mixtures with low air-fuel ratios are referred to as rich, whereas those with high ratios are called lean. During acceleration, when power is needed, a richer mixture is required than during cruising. The spark during the compression stage propagates unevenly across the cylinder. As a consequence of the non-homogeneous temperature distribution, the combustion in an Otto engine is to a considerable extent incomplete. This is of paramount importance with respect to automotive exhaust.

In a diesel engine, air and fuel are not mixed prior to being passed into the cylinder. Air is drawn in through the intake valve, and while it is being compressed to a high temperature, fuel is injected into the chamber as a spray under high pressure in precise quantities. As the piston nears the top position, the high temperature and pressure of compression cause ignition of the fuel without the aid of a spark. Ignition timing is governed by timing the injection of the fuel, and the power delivered is controlled by the amount of fuel injected in each cycle. The air-fuel mixture in a diesel engine is generally much leaner than that in a spark-ignition engine.

Emissions from vehicles

Motor vehicle emissions occur during these various stages of the working of the internal combustion engines. Mainly they can be classified as:

- Crankcase emissions. Due to "blow-by" around the piston rings, gases may escape from the cylinder into the crankcase. The largest part of the resulting emissions corresponds to the unburnt air-fuel charge, and only a small part consists of exhaust products and lube vapour.
- Evaporative emissions. Fuel evaporation may occur in the tank as well as in the carburettor. In addition, fuel vapour is displaced during refuelling. Evaporative losses markedly increase with increasing air temperature. Besides, they depend on the fuel volatility.
- Tailpipe emissions: These are emitted from the vehicle's exhaust system. The major pollutants emitted include Hydrocarbons, Nitrogen oxides (NO_x), Carbon monoxide (CO), Carbon dioxide (CO_2), Particulates and Sulphur oxides (SO_x).

Factors influencing motor vehicle emissions

- Vehicle and fuel characteristics
  - Engine type and technology - two-stroke, four-stroke; Diesel, Otto, Wankel, others; fuel injection, turbo-charging, type of transmission system.
  - Exhaust, crankcase, and evaporative emission control systems in place - catalytic converters, exhaust gas recirculation, air injection.
  - Engine mechanical condition and adequacy of maintenance.
  - Air conditioning, trailer towing and other vehicle appurtenances.
  - Deterioration characteristics of emission control equipment.
  - Deployment and effectiveness of inspection/maintenance (I/M)

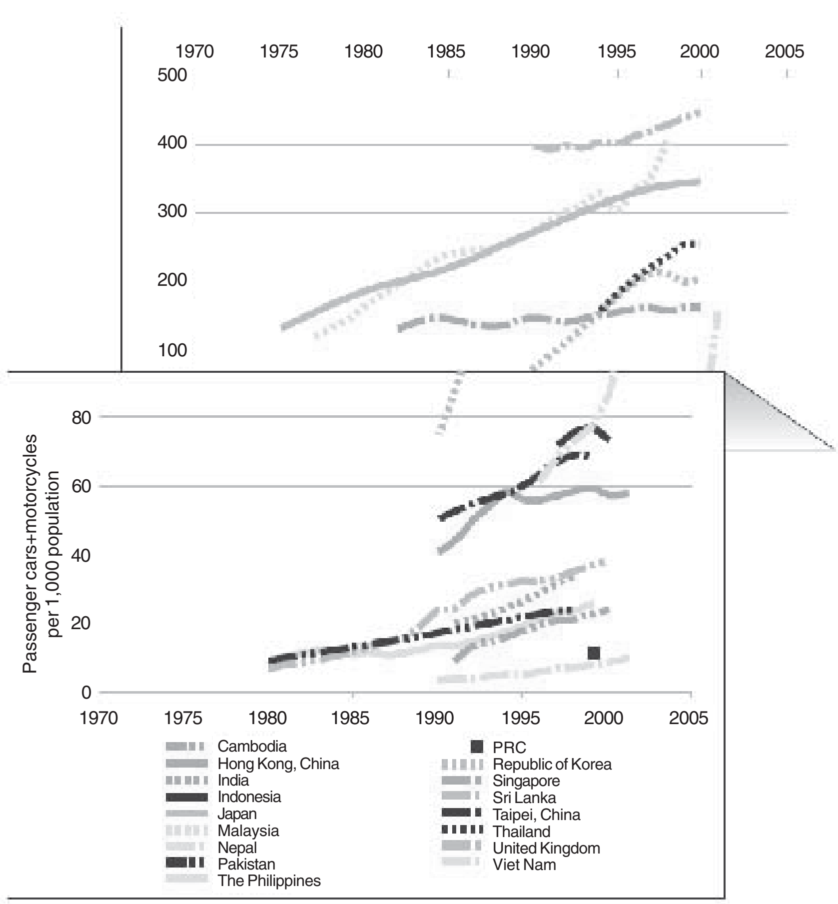
and anti-tampering (ATP) programme.

- Fleet characteristics
  - Vehicle mix (number and types of vehicles in use) and utilization (km per vehicle per year);
  - Age profile of vehicle fleet; and
  - Traffic mix and choice of mode for passenger/goods movements.
- Operating characteristics
  - Altitude, temperature, humidity (for NO_x emissions);
  - Vehicle use patterns: number and lengths of trips, number of cold starts, speed, loading, aggressive driving behaviour; and
  - Degree of traffic congestion, capacity and quality of road infrastructure, and traffic control systems.
- Fuel adulteration

Financial incentives arising from differential taxes are generally the primary cause of fuel adulteration. In South Asia, petrol carries a much higher tax than diesel, which, in turn, is taxed more than kerosene. Industrial solvents and recycled lubricants are other materials with little or no tax. Adulteration of petrol and diesel takes place primarily due to the significant price difference between these products and the adulterant. Petrol may also be adulterated with kerosene and some petrol boiling range solvent like toluene, xylene and other aromatics. Diesel is also adulterated with high sulphur content kerosene.

Adulteration of fuel can cause increased tailpipe emissions of hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x) and particulate matter (PM). Adulteration of fuels can also cause emissions of air toxins like benzene and polyaromatic hydrocarbons (PAHs), both known carcinogens.

Figure 1: Motorization trends in major Asian countries



Source ADB, 2002

Air quality and the transport sector

Levels of nitrogen dioxide, carbon monoxide, hydrocarbons and particulates are highest in towns and cities, where there is more traffic. Road transport is also the main cause of ozone. Ozone does not come directly from vehicles or factories but is created by chemical reactions between other nitrogen oxides and hydrocarbons.

Figure 1 shows the motorization trends in some major Asian countries, while Figure 2 depicts annual average concentration of various pollutants in some Asian cities. While considering both Figures 1 and 2 together, it can be seen that countries with steep growth in vehicle count from 2000 onwards such as Republic of Korea (Busan, Seoul), China (Hong Kong, Shanghai, Taipei), Indonesia (Jakarta) and India also have higher than prescribed standards of Nitrogen Oxides and Total Suspended Particulate (TSP) matter.

A similar observation is displayed in Figure 3 for Delhi, where an increasing vehicle count over the years corresponds to an increasing level of ambient nitrogen oxides.

Vehicle technology for controlling emissions

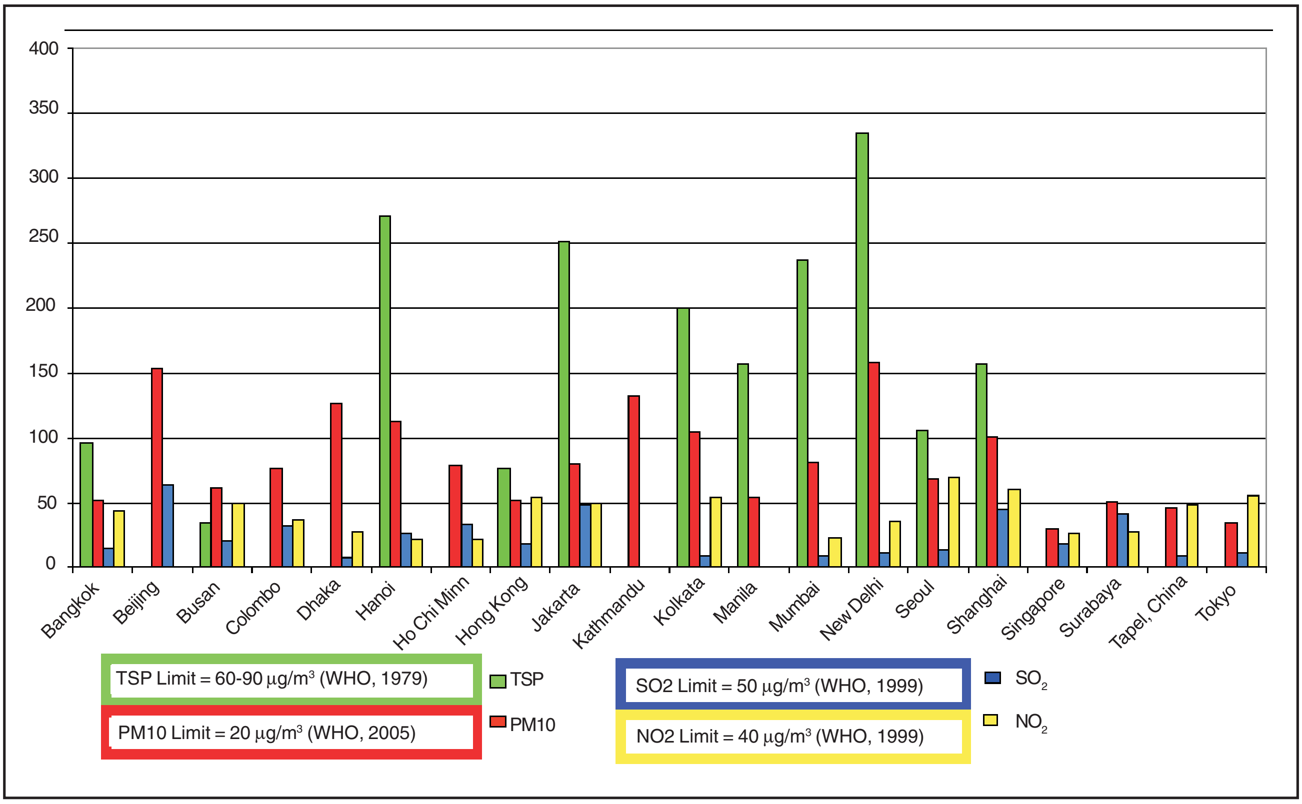
Petrol-fuelled vehicles

Emissions from spark-ignition engines can be reduced through changes in engine design, combustion conditions, and catalytic after treatment. Some of the engine and combustion variables that affect emissions are air-fuel ratio, ignition timing, turbulence in the combustion chamber, and exhaust gas recirculation. Of these, the most important is the air-fuel ratio.

Air-fuel ratio

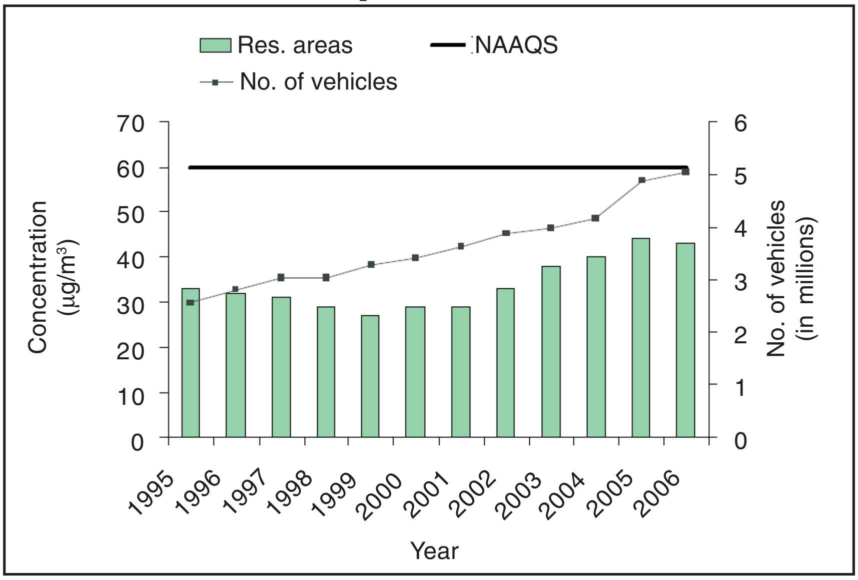
The ratio of air to fuel in the combustible mixture is a key design parameter for spark-ignition engines. An air-fuel mixture that has exactly enough air to burn the fuel, with neither air nor fuel left over, is stoichiometric, and has a normalized air-fuel ratio (ë) of 1.0. Mixtures with more air than fuel are lean, with ë higher than 1.0; those with more fuel are rich, with ë less than 1.0. A mixture with ë of 1.5 has 50 per cent more air than needed to burn all the fuel. Engines using lean mixtures are more efficient than those using stoichiometric mixtures. There are a num-

Figure 2: Average annual air pollution concentrations (2000 - 2004) in selected Asian cities



Source: CAI, 2005

Figure 3: Annual ambient NO_2 levels in Delhi, India



Source: CPCB Report, 2006-07

ber of reasons for this, including less heat loss, higher compression ratios (lean mixtures knock less readily), lower throttling losses at part load, and favourable thermodynamic properties in burnt gases.

Electronic control systems

Electronic control technology for stoichiometric engines using three-way catalysts has been extensively developed. These systems measure the air-fuel ratio in the exhaust and adjust the air-fuel mixture going into the engine to maintain stoichiometry. In addition to the air-fuel ratio, computer systems control features that were controlled by vacuum switches or other devices in earlier emission control systems. These include spark timing, exhaust gas recirculation, idle speed, air injection systems, and evaporative canister purging. The stringent air-fuel ratio requirements of three-way catalysts made advanced control systems necessary. But the precision and flexibility of the electronic control system can reduce emissions even in the absence of a catalytic converter. Many control systems can self-diagnose engine and control system problems. The ability to warn the driver of a malfunction and assist the mechanic in its diagnosis can improve maintenance quality. Self-diagnostic capabilities are becoming increasingly sophisticated and important as engine control systems become more complex. Computer-controlled engine systems are also more resistant to tampering and maladjustment than mechanical controls. The tendency for

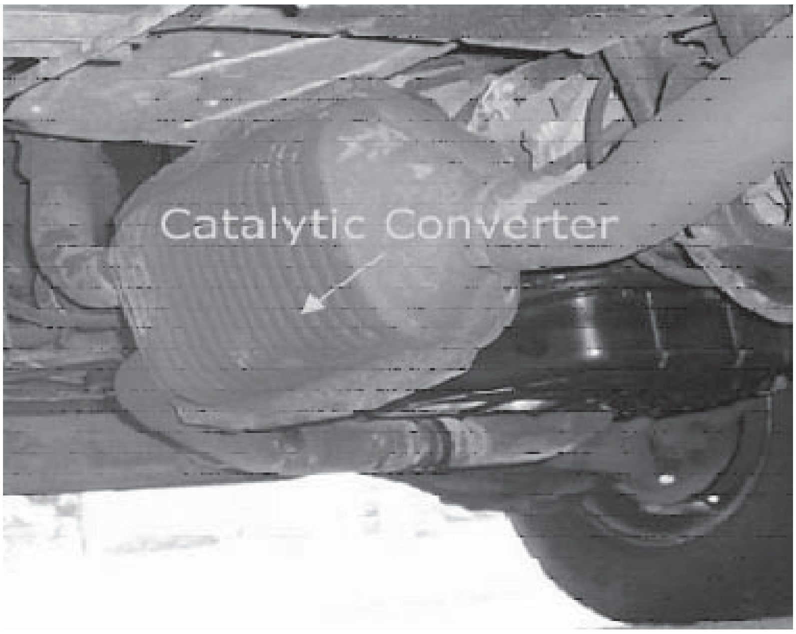


Figure 4: Catalytic converter

emissions to increase over time is thus reduced in computer-controlled vehicles.

Catalytic converters

The catalytic converter (Figure 4) is one of the most effective emission control devices available. The catalytic converter processes exhaust to remove pollutants, achieving considerably lower emissions than is possible with in-cylinder techniques. The catalytic converter comprises a ceramic support, a washcoat (usually aluminum oxide) to provide a very large surface area and a surface layer of precious metals (platinum, rhodium, and palladium are most commonly used) to perform the catalyst function. Two types of catalytic converters are commonly used in automotive engines: oxidation (*two-way*) catalysts control hydrocarbon and carbon monoxide emissions and oxidation–reduction (*three-way*) catalysts control hydrocarbons, carbon monoxide and nitrogen oxides. A new type of catalytic converter is the *lean nitrogen-oxide* catalyst, which reduces nitrogen oxide emissions in lean conditions, where a three-way catalyst is ineffective.

Evaporative emissions and control

Evaporative emissions are controlled by venting the fuel tank (and, in carburetted vehicles, the carburettor bowl) to the atmosphere through a canister of activated charcoal. Hydrocarbon vapours are adsorbed by the charcoal, so little vapour escapes to the air. The charcoal canister is regenerated or "purged" by drawing air through it into the intake manifold when the engine is running. Adsorbed hydrocarbons are stripped from the charcoal and burned in the engine.

Diesel-fuelled vehicles

The engine variables with the greatest effect on diesel emission rates are the combustion chamber design, air-fuel ratio, rate of air-fuel mixing, fuel injection timing, compression ratio, and the temperature and composition of the charge in the cylinder. A typical approach to reducing diesel emissions includes the following major elements:

- Reducing parasitic hydrocarbon and PM emissions (those not directly related to the combustion process) by minimizing injection nozzle sac volume and oil consumption;
- Reducing PM emissions and improving fuel efficiency and power output through turbocharging and by refining the match between the turbocharger and the engine;
- Reducing emissions of PM and nitrogen oxides by cooling the compressed-charge air with aftercoolers;
- Further reducing nitrogen oxides to meet regulatory targets by retarding fuel injection timing over most of the speed–load range. A flexible timing system minimizes the adverse effects of retarded timing on smoke, starting, and light-load hydrocarbon emissions;
- Further reducing nitrogen oxides in light-duty vehicles by recirculating exhaust gas under light-load conditions;
- Reducing the PM increase resulting from retarded timing by increasing the fuel injection pressure and injection rate;
- Improving air utilization (and reducing hydrocarbon and PM emissions) by minimizing parasitic volumes in the combustion chamber– such as the clearance between the piston and the cylinder head and the clearance between the piston and the walls of the cylinder;
- Optimizing in-cylinder air motion through changes in combustion chamber geometry and intake air swirl to provide adequate mixing at low speeds (to minimize smoke and PM) without over-rapid mixing at high speeds (which would increase hydrocarbons, nitrogen oxides and fuel consumption); and
- Controlling smoke and PM emissions in full-power operation and transient accelerations by improving the governor curve shape and limiting transient smoke (frequently through electronic governor controls).

In-use vehicles

Inspection and maintenance (I/M) measures to control emissions from in-use vehicles are an essential complement to emission standards for new vehicles. I/M programmes ensure that the benefits of new-vehicle control technologies are not lost through poor maintenance and tampering with emission controls.

Inspection and maintenance of high-technology, computer-controlled vehicles can be enhanced substantially with on-board diagnostic systems. For diesel vehicles, smoke opacity measurements in free acceleration are the most common inspection method. Opac-

Figure 5: Regular inspection and maintenance ensures reduced emissions

ity measurements can also be used to control white smoke emissions from two-stroke motorcycles.

Inspection and maintenance programmes help identify equipment defects and failures covered by vehicle warranty schemes. These programmes also discourage tampering with emission controls or misfuelling; the threat of failing inspection is considered a strong deterrent. Without effective I/M programmes, compliance with standards is significantly weakened.

Fuel modifications

A major advantage of fuel modifications for emissions control is that they often take effect quickly and begin reducing pollutant emissions immediately, whereas vehicle emission controls generally must be phased in with turnover in a vehicle fleet. Another advantage of fuel modifications is that they can be targeted geographically or seasonally by requiring the more expensive "clean" fuels only in highly polluted areas or during seasons with a high incidence of elevated pollution episodes. In addition, fuel modifications are usually easier to enforce, since fuel refining and distribution systems are highly centralized. Possible further changes to reduce emissions from petrol include reduced volatility, increased oxygen content, reduced aromatics and more widespread use of detergent additives. Conventional diesel fuel also can be improved by reducing the sulphur and aromatic content and by using detergent additives.

Emission standards

Emission standards vary from country to country depending on the technology availability and accessibility in that region. Normally emissions standards are prescribed in terms of European emission standards (Euro) and are progressively introduced with increasingly stringent standards. Table 1 lists the enforcement scenario in some major Asian countries.

In India, the first emission regulations were idle emission limits, which became effective in 1989. These idle emission regulations were soon replaced by mass emission limits for both petrol (1991) and diesel (1992) vehicles, which were gradually tightened during the 1990's. Since the year 2000, India started adopting European emission and fuel regulations for four-wheeled light-duty and for heavy-duty.

On 6 October 2003, a National Auto Fuel Policy was announced, which envisaged a phased programme for introducing Euro 2 - 4 emission and fuel regulations by 2010. The implementation schedule of EU emission standards in India is summarized below:

Overview

1991 - Idle CO limits for petrol vehicles and free acceleration smoke for diesel vehicles, mass emission norms for petrol vehicles.

1992 - Mass emission norms for diesel vehicles.

1996 - Revision of mass emission norms for petrol and diesel vehicles, mandatory fitment of catalytic converter for cars in metros on unleaded petrol.

1998 - Cold start norms introduced.

2000 - India 2000 (equivalent to Euro I) norms, modified IDC (Indian driving cycle), Bharat stage II norms for Delhi.

2001 - Bharat stage II (equivalent to Euro II) norms for all metros, emission norms for CNG and LPG vehicles.

2003 - Bharat stage II (equivalent to Euro II) norms for 11 major cities.

2005 - Bharat stage III (equivalent to Euro III) norms for 11 major cities.

2010 - Bharat stage III emission norms for 4-wheelers for the entire country, and Bharat stage IV (equivalent to Euro IV) for 11 major cities.

Recommendations and suggestions for mitigating vehicular pollution

Pollution control technology

For petrol vehicles, "three-way" catalysts, precise engine and fuel controls, and evaporative emission controls have been quite successful. More advanced versions of these technologies are in some cars and can reduce smog-forming emissions from new vehicles by a factor of ten. For diesel vehicles, "two-way" catalysts and engine controls have been able to reduce hydrocarbon and carbon monoxide emissions, but nitrogen oxide and toxic particulate-matter emissions remain very high.

Burning less fuel

The key to burning less fuel is making cars and trucks more efficient and putting that efficiency to work in improving fuel economy. This includes more efficient engines and transmissions, improved aerodynamics, better tyres and high strength steel and aluminum. More advanced technologies, such as hybrid-electric vehicles that use a petrol engine and an electric motor plus a battery, can cut fuel use even further. These technologies carry with them additional costs.

Zero-emission vehicles

Eliminating emissions from the tailpipe goes even further to cut down on harmful air pollutants. Hydrogen fuel-cell and electric vehicles move away from burning fuel and use electrochemical processes instead to produce the energy needed to drive a car down the road. Fuel-cell vehicles run on electricity that is produced directly from the reaction of hydrogen and oxygen. The only byproduct is water - which is why fuel-cell cars and trucks are called zero-emission vehicles. Electric vehicles store energy in an onboard battery, emitting nothing from the tailpipe.

Cleaner fuels

The petrol and diesel fuels in use today contain significant amounts of sulphur and other compounds that make it harder for existing control technology to keep vehicles clean. Removing the sulphur from the fuel and cutting down on the amount of light hydrocarbons helps pollution-control technology to work better and cuts down on evaporative and refuelling emissions.

Further large-scale reductions of other tailpipe pollution and CO_2 can be accomplished with a shift away from conventional fuels. Alternative fuels such as natural gas, methanol, ethanol, and hydrogen can deliver benefits to the environment while helping to move the world away from its dependence on oil. All of these fuels inherently burn cleaner than diesel and petrol and have lower carbon content - resulting in less CO_2. Most of these fuels are also more easily made from renewable resources, and fuels such as natural gas and methanol help provide a bridge to producing hydrogen for fuel-cell vehicles.

Table 1: Institutionalizing fuel quality standards

Country	Current status	Future directions
Bangladesh	Euro 1 under discussion	No dialogue or plans to move beyond Euro 1
Cambodia	No formal standards, still leaded	No road-map in place
China	Euro 3 - Beijing and Shanghai Euro 2 - Rest of the country	11th Five Year Plan laying out road-map for Euro 3 and Euro 4 for entire country
Hong Kong SAR (China)	Euro 4 in place	ULSD and Euro 5 (diesel) under consideration for 2007
Indonesia	Euro 2 (?)	Euro 3 gasoline by 2006 & Euro 3 diesel after 2010
Japan	Euro 4 Equipment (S 50 ppm)	Ultra-low sulphur gasoline and diesel 2007
Republic of Korea		Ultra-low sulphur gasoline and diesel by 2007?
Malaysia	Euro 2 by 2005	Euro 4 by 2009-2010
Nepal	Euro 1; still partly leaded	No structured discussion on how to move ahead
Philippines	Euro 1; 500 ppm sulphur diesel	Euro 2 mid 2005. Initial discussions on Euro 4 by 2010
Singapore	Euro 2 in place	Euro 4 diesel in 2006, no plans for petrol
Sri Lanka	Euro 1 in place	No roadmap in place
Thailand	Euro 3 petrol and Euro 2 for diesel	Euro 4 2006 with discussion ongoing on ULSD in some locations
Viet Nam	Euro 3 in 2009 announced and under discussion	Euro 2 in 2007 and Euro 4 in 2010 under discussion and tentatively scheduled for July 2005

Source: Clean Air Initiative-Asia, 2005, Brussels

Personal contributions

How we drive and how we take care of our vehicles affect fuel economy and pollution emissions. The following are several ways people can reduce the harmful environmental impact of cars:

- Driving as little as possible is the best way to reduce the harmful environmental impact of transportation needs. Car-pooling, mass transit and walking are ways to limit the number of miles we drive. Also, cycling for travelling shorter distances reduces vehicular emissions. However, this also calls for dedicated cyclist lanes on roads.
- Driving moderately and avoiding frequent stopping and starting.
- Keeping tyres properly inflated.
- During start-up, a car's engine burns extra petrol. However, letting an engine idle for more than a minute burns more fuel than turning off the engine and restarting it.
- During warm periods with strong sunlight, parking in the shade keeps a car cooler and can minimize the evaporation of fuel.

Efficient public transport and urban planning

The role of public transport varies widely in Asian cities. However, in most Asia's cities, public transport vehicles operating on fixed routes carry the majority of public transport trips. Policies for public transport to improve air quality can either consist of activities that clean the vehicles directly (e.g. engine upgrades, use of alternative fuels) or can consist of activities that seek to influence modal shift (i.e. increase switching to public transport). An example of the use of alternative fuel has been witnessed in Delhi, India, where the use of Compressed Natural Gas (CNG) was made compulsory for all public transport vehicles post year 2000. Similarly, the introduction of a metro rail system and a Bus Rapid Transit system (in Delhi) can be considered as an initiative for bringing about a change in transport means by people in general.

Figure 6: Adopting cycling requires dedicated lanes on road

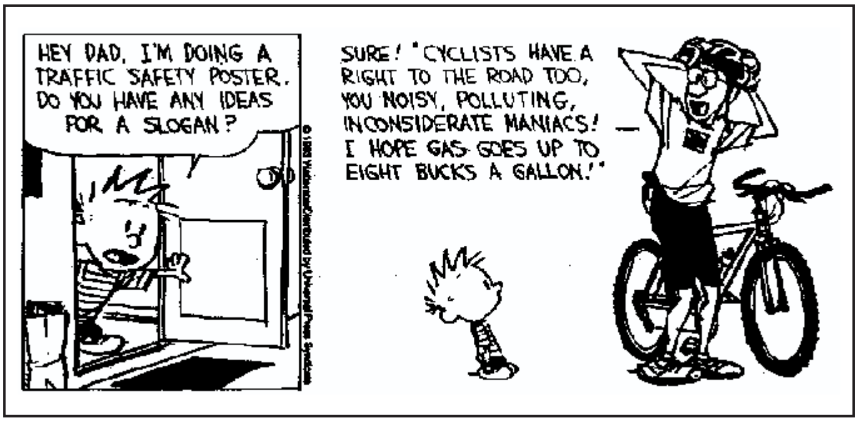


Figure 7: Implementing and adopting Public Transport is the need of hour

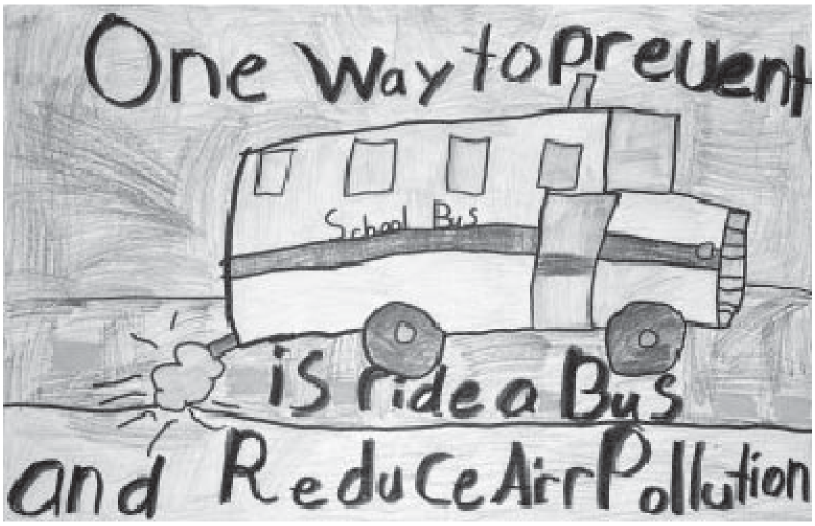


Figure 8: Delhi Metro Rail

Improvements to public transport proposed to reduce emissions, or other service quality enhancements should be implemented in an environment where the operations are efficient and financially sustainable.

Maintaining loyalty to public transport or attracting car and motorcycle drivers to switch to public transport is not easy in view of the status and convenience private vehicle usage confers. But high quality and fast and accessible public transport services, whether by rail or bus, combined with other measures, such as road pricing and parking restraints, have proven quite successful in attracting car drivers, especially when the road system is congested.

Delhi Metro

In developed countries, planning for mass transit systems such as the Metro Rail starts when the city population size exceeds 1 million; the system is in position by the time the city population is 2 to 3 million and once the population exceeds 4 million or so, planned extensions to the Mass Rapid Transit Systems are vigorously taken up. In developing countries like India, a Metro Rail has been proposed for all cities with more than five million population to start with, thereafter extending to cities with a population of more than three million.

Delhi's first metro rail system became a huge success when it carried over 1.2 million passengers on its first day, 25 December 2002. It is the first metro system in the world to obtain ISO 14001 certification for environment-friendly construction and operations at the construction stage itself, and the second after the New York Metro to achieve this standard. The benefits of this project are manifold as the Metro carries the same amount of traffic as nine lanes of buses or 33 lanes of private metro cars either way.

Bus Rapid Transit (BRT)

The Bus Rapid Transit (BRT), also known as the High Capacity Bus System, is one of the cost-effective mechanisms for cities to rapidly develop a public transport system. BRT is an effective option compared to other public transport systems, mainly due to low capital requirement, low infrastructure costs, ability to operate without subsidies and low gestation period. It can be easily adapted to a range of city conditions. Various versions of BRT are in existence in Brazil (Curitiba), Columbia (Bogota), USA (Miami, California), UK (London, West Sussex), and Australia (Brisbane). To meet the growing demand, the Government of the National Capital Territory of Delhi decided to build six BRT Corridors in Delhi, besides expanding the Metro rail in Delhi, by 2010.

The first pilot stretch of BRT has met with mixed responses. While private vehicle owners complain about lack of space availability on road, bus commuters feel uncomfortable with the location of bus stops in the middle of the road. However, people also feel that the BRT is a huge improvement for buses, giving them dedicated space to move on the road and thereby reducing their travel time to a great extent.

Nonetheless, it goes without saying that public transport projects like BRT are the need of the hour, provided they are implemented in a way comprehensible to the common man.

According to Delhi Integrated Multi Modal Transit System Ltd. (DIMTS), the correct measure to consider is not the number of vehicles but the number of people.

Buses move far greater numbers of people than cars and two-wheelers. While a car or a scooter on an average carries 2 passengers; a bus on an average carries over 80 passengers per trip. The central lane is the preferred location for the bus because it avoids coming into conflict with left turning traffic. The dedicated lane in the middle of the road ensures that the bus traffic does not interfere with the rest of the smaller vehicles on the road.

On the other hand, bus lanes towards the left of the road will provide convenience to commuters in terms of reaching the bus stops. DIMTS officials say that they are checking out “buses in the left lane models too. In many cities such as Bogota (Columbia) and Brisbane (Australia), each bus stop of such central lanes busways has access to an overhead bridge (or underpass) to facilitate movement of bus passengers to and fro each side of the road.

Figure 9: Overhead bridge for passengers in a Transmileneo (Bogota) Busway station (*left*) and a Busway station in Brisbane (*right*)

Conclusions

Technical emission control measures do not, by themselves, constitute an emission control strategy, nor are they sufficient to guarantee environmentally acceptable outcomes over the long run. Such measures can, however, reduce pollutant emissions per vehicle-kilometre travelled more than in-use uncontrolled vehicles.

Although technical measures alone are insufficient to ensure the desired reduction of urban air pollution, they are an indispensable component of any cost-effective strategy for limiting vehicular emissions. Employed as part of an integrated transport and environmental programme, these measures can buy the time necessary to bring about the needed behavioural changes in transport demand and the development of environmentally sustainable transport systems.

In addition, use of alternative fuels and effective public transport and management can ensure a substantial improvement in environmental conditions, despite continuing increases in vehicle fleets and their utilization.

References

1. “Air Pollution Control in the Transportation Sector: Third Phase Research Report of the Urban Environmental Management Project”, Institute for Global Environmental Strategies (IGES), 2007.
2. “Air Pollution from Motor Vehicles, Asif Faiz, Christopher S. Weaver, Michael P. Walsh”, World Bank Discussion Paper No. 349.
3. “Annual Report” 2006-07, Central Pollution Control Board, 2007.
4. “Bus Rapid Transit (BRT) System in Delhi, Delhi Integrated Multi Modal Transit System Ltd. (DIMTS)”, http://www.dimts.in/road.html.
5. “Delhi Metro Receives ISO 14001 for Eco-Friendly Systems”, Report, Date: 2003, USAID India, http://www.usaid.gov/in/about_usaid/success_stories/metro_eco.htm.
6. *Encyclopedia of Environmental Control Technology*, Paul N. Chereminisoff, Volume 2, Gulf Publishing, Houston, 1989.
7. “For a Breath of Fresh Air: Ten Years of Progress and Challenges in Urban Air Quality Management in India 1993-2002”, Environment and Social Development Unit, South Asia Region, The World Bank.
8. “From Busway to BRT, The City Fix”, July 14, 2008, http://thecityfix.com/from-busway-to-brt.
9. “Improving Urban Air Quality in South Asia by Reducing Emissions from Two-Stroke Engine Vehicles, Masami Kojima, Carter Brandon”, Jitendra Shah, December 2000, The International Bank for Reconstruction and Development, The World Bank.
10. “Introduction into Urban Air Quality in Asia: Status, Impact and its Management, Cornie Huizenga”, May Ajero and Herbert Fabian, *Clean Air Initiative*, June 2005, Brussels.
11. “Need for A Metro”, Delhi Metro Rail Corporation Ltd., http://www.delhimetrorail.com/corporates/needfor_mrts.html.
12. “New Directions: Air pollution and road traffic in developing countries”, *Atmospheric Environment*, Volume 34, Issue 27, 2000, pp 4745-4746.
13. “Vehicular Pollution”, http://www.pollutionissues.com/Ve-Z/Vehicular-Pollution.html. ❐