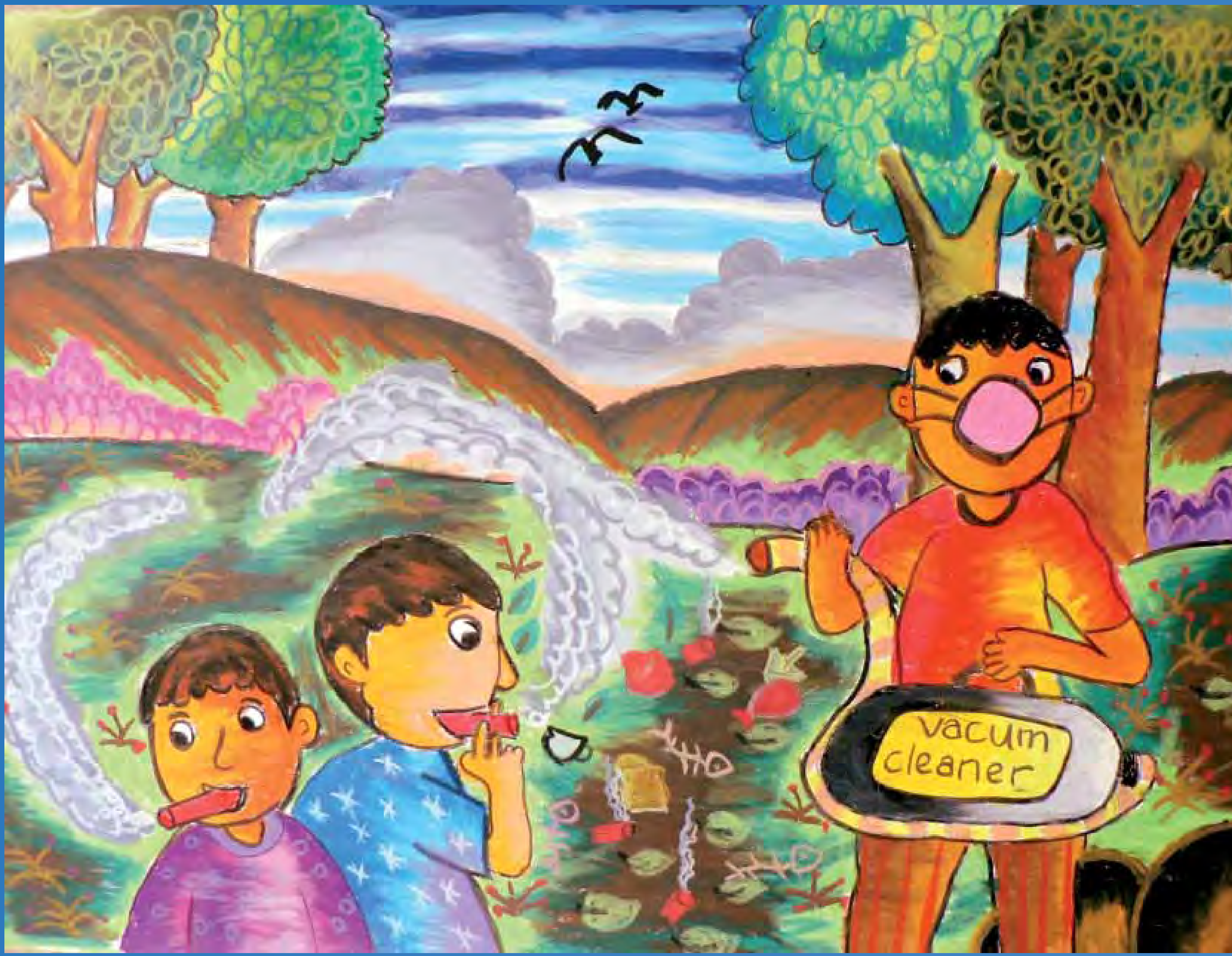
Urban Air Quality Management

Summary of Country/City Synthesis Reports Across Asia



Discussion Draft, December 2006

ADB

CLEAN AIR INITIATIVE for Asian Cities

Urban Air Quality Management

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

About the Cover Art

Cover Art is by Kirana Yosandra, six years old from Indonesia, awarded 1st prize Junior Category of Art for Air Contest organized by the Better Air Quality 2006 Organizing Committee

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Abbreviations

ADB	Asian Development Bank
AQ	air quality
AQM	air quality management
CAI-Asia	Clean Air Initiative for Asian Cities
CO	Carbon monoxide
EU	European Union
GDP	gross domestic product
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxide
PM	particulate matter
PM_{10}	particulate matter with diameter not more than 10 microns
$PM_{2.5}$	particulate matter with diameter not more than 2.5 microns
PRC	People's Republic of China
PRD	Pearl River Delta
SPM	suspended particulate matter
SO_2	Sulfur dioxide
TSP	total suspended particulate
UK	United Kingdom
US	United States
US EPA	United States Environment Protection Agency
WHO	World Health Organization
ug/m^3	microgram per cubic meter

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

Acknowledgments

The purpose of this summary synthesis report on urban air quality management in Asia is to review and highlight the key trends in pollution sources, concentrations and impacts, as well as policies to improve air quality in Asia, and point to some future directions.

This summary synthesis report draws together information from a series of 17 country reports and one city report on urban air quality management in Asia. This is the first time that a comprehensive overview of urban air quality management (AQM) at the country level has been prepared in the region. Research compilation for the series of country and city reports was led by the Clean Air Initiative for Asian Cities (CAI-Asia) Secretariat with inputs from a range of organizations and air quality experts from across Asia and elsewhere and facilitated by the Asian Development Bank (ADB) through its Regional Technical Assistance No. 6291: Rolling Out Air Quality Management in Asia. For the Summary Synthesis, the primary authors are Professor Frank Murray of Murdoch University and Mr. Cornie Huizenga, Ms. May Ajero, and Mr. Herbert Fabian of the CAI-Asia Secretariat.

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» Part One

Introduction

Indicators of air quality (AQ) in the largest cities of Asia show that although many of these cities are among the most polluted in the world, AQ in many cities has generally been improving over the past few years. To improve AQ further, Asian cities must respond to the combined pressures of rapid growth in urban population, transport, economic development, and energy consumption. Asia is expected to account for most of the growth in world economic activity to 2025. Asia currently has about one billion people living in urban areas, and this number is growing at an average of 4% per year.

The major sources of air pollution in cities in Asia are vehicles, large stationary sources such as power stations and other major industries, small stationary sources such as domestic sources and small industries, and area sources such as open burning.

Fine particulate matter (PM), or particles with diameter not more than 2.5 microns ($PM_{2.5}$), clearly presents the greatest health risk for air pollutants in ambient air—estimated to cause 520,000 premature deaths and more than 4 million years of lives lost annually in Asia (Cohen et al. 2005). The projected increases in ozone concentrations in East Asia may lead to substantial crop losses and damage to natural areas in the near future. Acid deposits and other pollutants also present health and environmental challenges in some countries.

Despite these challenges, the strong economic growth of many Asian economies is providing the resources necessary to meet the costs of effective air quality management (AQM), fuel changes, emissions control technologies, industrial restructuring, and modernization of transport systems.

» Part Two

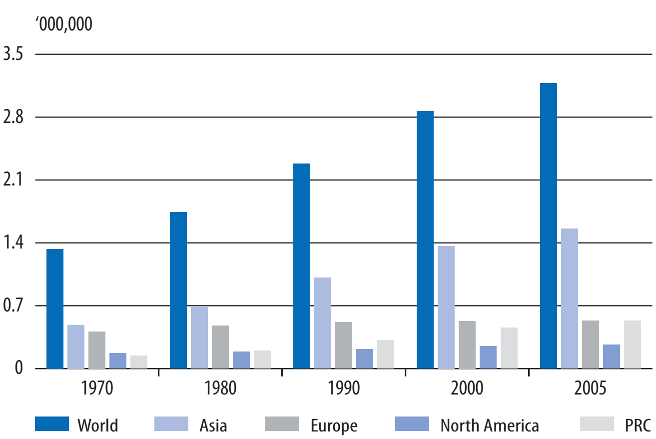
General Information

Urbanization and Population

Increasing urbanization presents considerable challenges in Asia (Figure 2.1). Growing numbers of people are being attracted from rural areas to towns and cities with growing populations, where emissions are concentrated and AQ is most degraded. One billion people are living in Asia's urban areas. This number is growing at an average of 4% per year. It is projected to grow to about three billion people by 2025, from about 35% in 2000 to about 55% of the total population by 2025 (World Bank 2000 and Health Effects Institute [HEI] 2004). From 2000 to 2015, about 700 million people will be added to Asia's population (Asian Development Bank [ADB] 2001). As the population grows, it will become increasingly urbanized, with particularly high growth in the largest cities. Of the 17 cities in the world with populations greater than 10 million in 2001, 12 are in Asia (ADB 2001). As the populations of large cities is rapidly growing, increased demand is placed on the capacity of the city to provide energy, housing, employment, resources, and transport—with potential to further increase emissions to the air.

FIGURE 2.1

Asia's Growing Urban Population



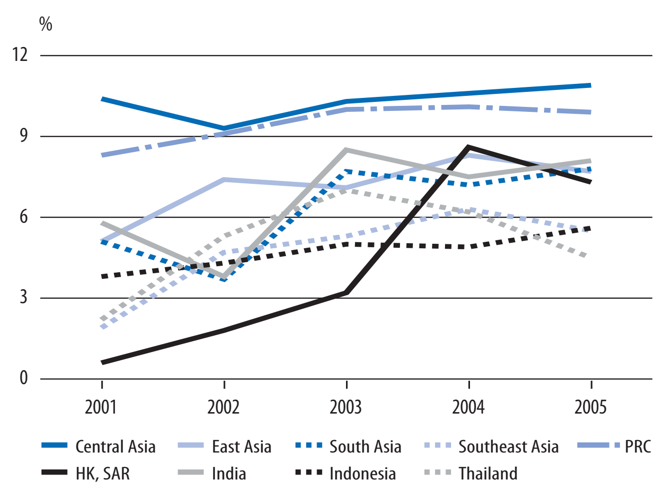
PRC = People's Republic of China
Source: United Nations, 2005.

Economic Growth and Industrialization

Much growth in the world's economic activity in 2025 is expected to be in Asia. The gross domestic product (GDP) in developing countries of Asia has increased at a rapid pace over the last years (Figure 2.2) and is expected to expand at an annual average rate of 5.1% compared with 3% per year for the world as a whole (Energy Information Administration [EIA] 2004).

FIGURE 2.2

Growth Rate of GDP in Selected Countries in Asia, % per year



GDP = gross domestic product; HK, SAR = Hong Kong Special Administrative Region; PRC = People's Republic of China; % = percent
Source: ADB, 2006.

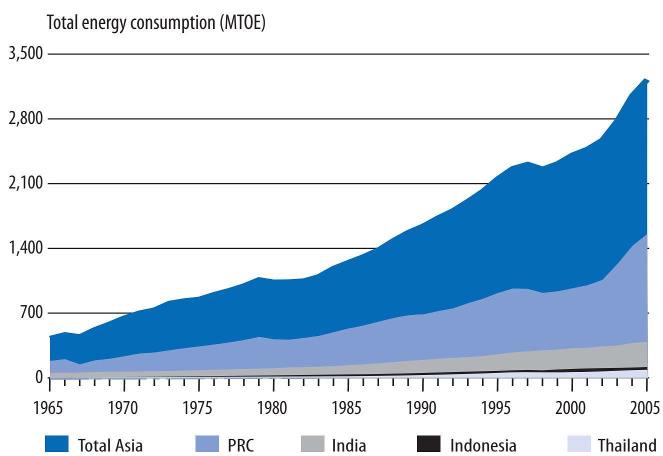
Population and economic growth have the potential to increase emissions in the absence of increasingly stringent measures to control emissions. However, the most rapidly growing economies are generating the economic wealth and specialized knowledge needed for effective AQM, fuel changes, emissions control technologies, industrial restructuring, and modernization, etc. This growing national wealth provides these nations with the opportunity to obtain leverage from the experience of developed nations. By the introduction and enforcement of suitable proven policies and technologies, the rapidly growing economies have the opportunity to achieve a cost-effective improvement in AQ in a decade to a level that it took the developed economies many decades to attain. Hong Kong SAR and Singapore are excellent examples of cities successfully addressing these challenges.

Energy

The growth in GDP is leading to even stronger growth in energy consumption, with the developing countries of Asia expected to account for 40% of the total projected increase in world energy consumption and 70 % of the increase in developing country consumption to 2025 (Figure 2.3). In contrast with Europe where coal use is rapidly declining, coal use in the People's Republic of China (PRC) and India is growing. Together, they are projected to account for 67% of the total increases in coal use worldwide (EIA 2004). Growing energy use in the PRC was, until recently, also associated with a more energy-efficient economy. But since 2002, the energy intensity of the PRC has started to display an upward trend.

FIGURE 2.3

The Growing Demand for Energy in Selected Countries in Asia

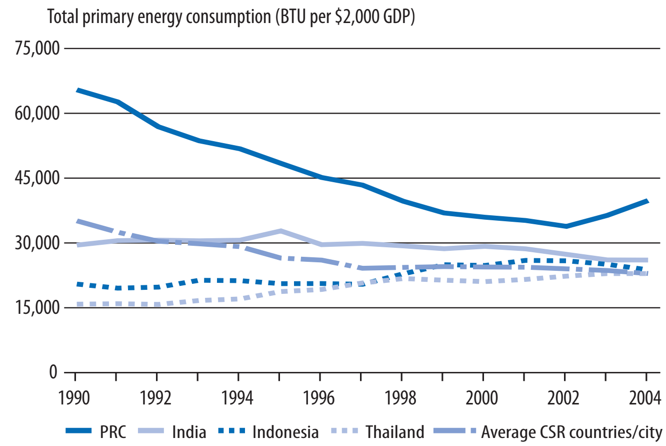


BP =British Petroleum; MTOE = million tons oil equivalent; PRC = People's Republic of China
Source: BP, 2006.

There is an emerging trend toward use of natural gas and renewable sources of energy. Pakistan and Bangladesh are making very impressive progress with fuelling their growing economies with natural gas. Several countries, including Thailand and Singapore, are developing major biodiesel and ethanol production facilities. Bhutan, Lao PDR, PRC, and Viet Nam have considerable existing or potential to exploit hydroelectric power.

FIGURE 2.4

Energy Intensity in Selected Asian Countries



BTU = British thermal units; CSR = country synthesis report; EIA = Energy Information Administration; GDP = gross domestic product; PRC = People's Republic of China; US = United States; $ = US dollar
Source: EIA 2006.

Transport

Public demand for motorization in Asian countries is growing at different rates. This will continue to increase with the possible exceptions of Singapore and Hong Kong SAR (where controls limit the number of vehicles and promote public transport). The types of motor vehicles in Asia are diverse, which affect the setting of emission standards. Figure 2.5 contains growth forms for four major countries in Asia—PRC, India, Indonesia and Thailand. It illustrates the projections for rapid growth in numbers of all vehicle types, but particularly for motorcycles in developing and transitional countries. Action to control emissions from vehicles has been impressive in many countries of Asia, but considerable challenges remain in some countries with the proliferation of old vehicles.

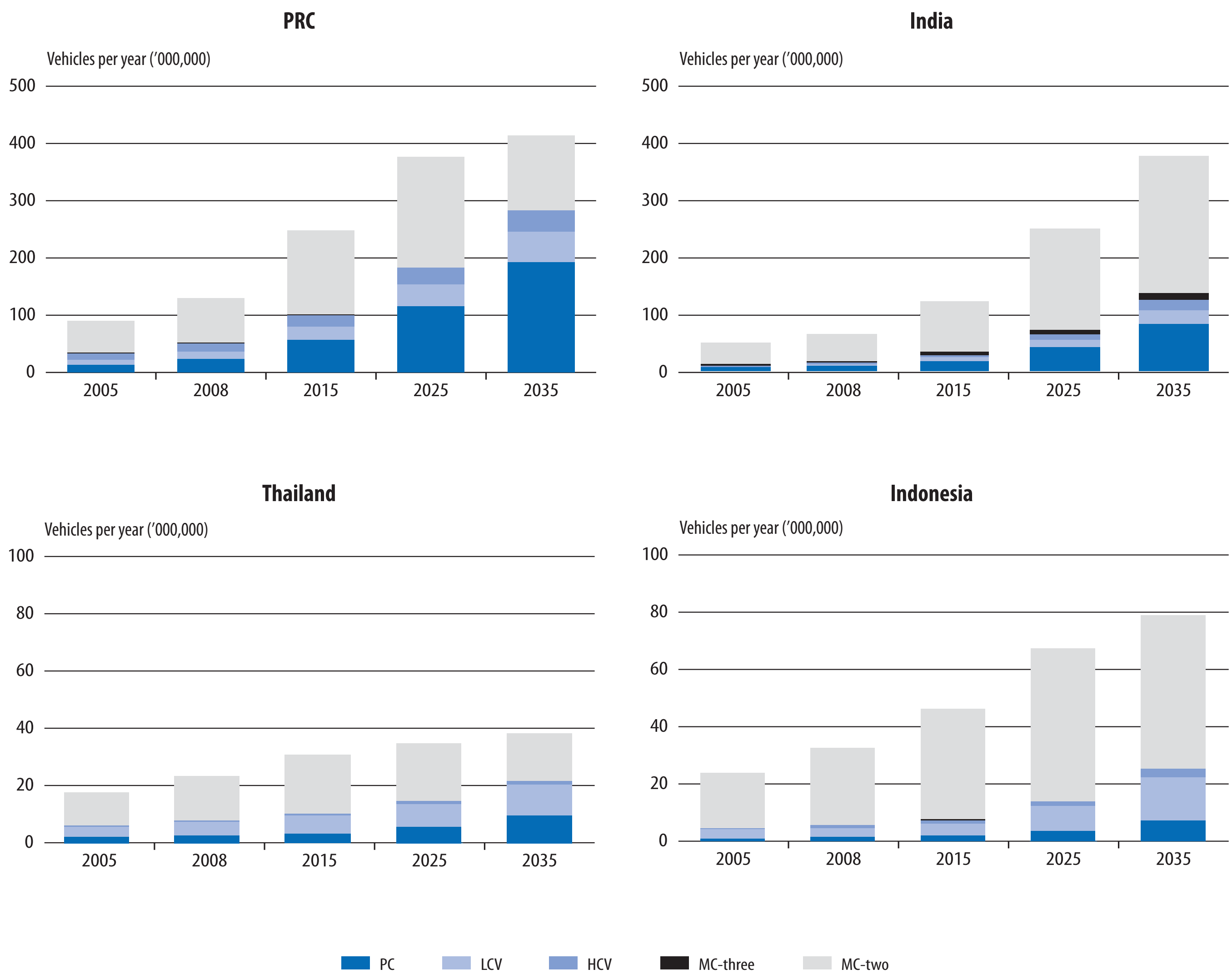
The growth in vehicle numbers and the relatively large emissions rates from some types of vehicles in Asia represent particular challenges. For example, India's motor vehicle fleet increased from only 665,000 in 1961 to about 40 million in

2000 and 67% of these motor vehicles are motorcycles, many of which have high-emission 2-stroke engines (Badami 2004). However, they play an important role in the mobility of millions of people who may have few other practical transport options. The development of sustainable urban transport systems supported by the community has a critical role in improving AQ in Asian cities.

The growth in motorization has the potential to increase emissions of hydrocarbons and Nitrogen oxides (NO_x) if not effectively controlled. This then can lead to the production of photochemical smog extending far beyond the boundaries of cities, with potentially severe effects on food security and biodiversity in agricultural and natural areas (Emberson et al. 2003).

FIGURE 2.5

Forecasts for Growth in the Number of Motor Vehicles in Some Asian Countries



HCV = heavy commercial vehicle; LCV = light commercial vehicle; MC-three = three-wheeled vehicle with a motorcycle engine; MC-two = two-wheeled motorcycle; PC = private car; PRC = People's Republic of China

Source: Segment Y Ltd. 2006.

» Part Three

Sources of Air Pollution

The major sources of air pollutants in Asia taken as a whole are vehicles, stationary sources such as power stations and other major industries, and area sources. Streets et al. (2003) estimated that the power generation sector dominated by coal-fired power plants in the PRC produced 45% of the total Asian Sulfur dioxide (SO_2) emissions in 2000 while the industrial sector produced 36%. The transportation sector produced 37% of NO_x emissions in Asia in 2000 followed by the power generation sources (27%). The residential sector was estimated to generate about 65% of carbon particulate emissions from the combustion of coal, kerosene, and biofuels (Streets et al. 2003). Emissions from stationary sources are closely related to the consumption of fossil fuels with coal combustion a substantial source of emissions of particulates, SO_2, and NO_x.

For many Asian cities, the main source of air pollution is vehicle emissions. In some cities, the sources may be diverse and include industrial emissions and area sources. The priority, however, in most cities is vehicle emissions. As Asian cities have developed and attention has been given to control emission sources, considerable success has been achieved with the control of SO_2 and coarse particulates (particle sizes larger than 10 microns), so the characteristics of emissions in some Asian cities are changing. Fuel use in vehicles is a major source of particles, Carbon monoxide (CO), and NO_x. With frequent traffic congestion, and large fleets of poorly maintained vehicles consuming fuel of poor quality, AQ in some cities in Asia is largely determined by vehicle emissions (ADB 2003).

Sound decision making about priorities to address emissions requires some knowledge of the relative importance of different emission sources. Choices must be made about the allocation of limited resources because it is important to target emissions sources where it can be expected that the maximum outcome can be achieved toward attaining the objectives. Emissions inventories are important to provide information to assist in making these decisions. However, they are not commonly conducted in Asian cities and are rarely used for regulatory purposes. When compiled, emissions inventories usually cover mobile sources but less often include stationary sources, and even more rarely include area sources (CAI-Asia 2006a).

As emissions inventories are not considered by many Asian regulatory agencies a priority, a wide range of organizations use World Health Organization (WHO) or US Environmental Protection Agency (US EPA) emission factors, but with different methodologies, outdated source inventories, no standardized source categorization, using poor quality source operating data, inappropriate emissions factors, and limited quality assurance. There are some nations that regularly update and use their emission inventories to target policy and management to improve AQ but these are exceptions. Emissions inventories remain a current weakness in AQM in Asia (CAI-Asia 2006a). An encouraging recent development is the generation of emissions inventories in the countries supporting the Malé Declaration on Control and Prevention of Air Pollution and its Likely Transboundary Effects for South Asia.

Most Asian countries do not conduct source apportionment on a regular basis and when they do, the studies are typically done by academic and other research organizations with limited involvement by the regulators. The results are rarely used by regulatory agencies in setting or evaluating AQM policies and programs. However, these techniques offer opportunities to identify important sources to validate and improve emissions inventories. The results of studies of particles usually show a large range of sources including mobile, stationary, area, biomass burning, natural marine, and land-based sources, and can often highlight important sources not adequately captured by the emissions inventory (CAI-Asia 2006a).

» Part Four

AQ Monitoring and Modelling

Most large Asian cities have some AQ monitoring and modelling in place, with varying levels of sophistication and quality assurance. Among other uses, AQ monitoring and modelling provide the data required to assess compliance with current ambient AQ standards, assess trends, decide on the priority pollutants, and assess the effectiveness of existing and proposed policies. Without adequate AQ monitoring and modelling, decision-making on AQ issues is operating in the dark. For any city serious about actions to improve AQ, adequate AQ monitoring and modelling is essential.

In recent years, many countries in Asia have substantially upgraded their AQ monitoring capacities, expanded monitoring to a larger number of cities, measuring more pollutants, and using more sophisticated equipment with improved quality assurance. For example, the PRC has been active in expanding and further developing its capacity to monitor air pollution. In 2004, it had 2,289 monitoring stations including 688 automated monitoring stations in 234 cities. Singapore, Hong Kong SAR, and Thailand have very sophisticated AQ monitoring systems providing data of high quality.

In contrast, some countries in the early stages of industrial development clearly need to develop an adequate system for measuring AQ. In almost all Asian countries, there is a need to expand AQ monitoring to secondary cities.

Across Asia, there is a trend to replace the monitoring of total suspended particulates (TSP) or suspended particulate matter (SPM) with the monitoring of PM_{10}. The trend in monitoring from TSP toward PM_{10} reflects the growing awareness of the high impact that PM is having on the health of Asians. Few cities currently monitor $PM_{2.5}$ although it is now accepted that the health impacts of $PM_{2.5}$ are even more severe than those of PM_{10}. Since there is no national standard for $PM_{2.5}$, there is no mandate for the country to monitor $PM_{2.5}$.

Most, but not all, cities in Asia report the results of AQ monitoring to the public. The amount, quality, and timeliness of the reporting are variable. Some cities, such as Singapore and Hong Kong SAR provide air pollution index information to the public on a daily basis, on websites, and through call centers. This provides the public with a timely summary of daily AQ, to be used and broadcasted by print and electronic media.

A greater degree of openness and transparency in the release of accurate information on AQ would be in the public interest, enabling the trends in the different criteria pollutants to be known, benchmarking of AQ status, and actions to address AQ to be understood by the interested public, scientists, and policy makers. In particular, the release of summary data on the trends in the number of excesses of AQ standards and guidelines by each of the criteria pollutants provides a useful indicator.

In addition, the publication of accurate information on assessments of AQ status in a language understandable to the public and the media, enhances public interest and knowledge.

» Part Five

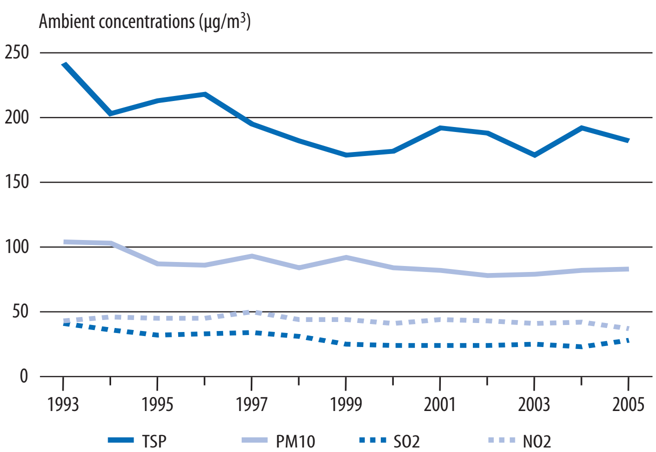
Status of Air Quality

Ambient AQ Concentrations

Ambient AQ data from Asian cities reveal a complex situation, with general AQ improving in many cities and deteriorating in some others. If the data from 20 large cities are brought together, they show a general situation of slow improvement in AQ, especially for TSP and SO_2 (Figure 5.1). The greatest area of improvement has been in reducing levels of TSP and SO_2, while the levels of PM_{10}—by far the most critical air pollutant—have shown a limited decline. PM_{10} average concentrations in many Asian cities still far exceed WHO guidelines, which for PM_{10} is an annual average of 20 µg/m^3

FIGURE 5.1

Aggregated Annual Ambient AQ Monitoring Data for 20 Selected Cities in Asia, 1993–2005 (µg/m^3)



AQ = air quality; CAI-Asia = Clean Air Initiative for Asian Cities; EU = European Union; NO_2 = Nitrogen dioxide; PM_{10} = particles with diameter not less than 10 microns; SO_2 = Sulfur dioxide; TSP = total suspended particulates; WHO = World Health Organization; US EPA = United States Environment Protection Agency; µg/m^3 = micrograms per cubic meter

[a] NO_2 annual guideline value from WHO (2006) = 40µg/m^3; annual limit from US EPA (2006) = 100µg/m^3; annual limit from EU (2005) = 40µg/m^3

[b] PM_{10} annual guideline value from WHO (2006) = 20µg/m^3; limit from EU (2005) = 40 µg/m^3

[c] SO_2 guideline value from WHO (2006) = 20µg/m^3 for 24-hr average; WHO (2006) has no annual SO2 guideline; annual limit from US EPA (2006) = 78µg/m^3; annual limit from EU (2005) = 20 µg/m^3

[d] TSP annual guideline value from WHO 1979 = 60-90µg/m^3

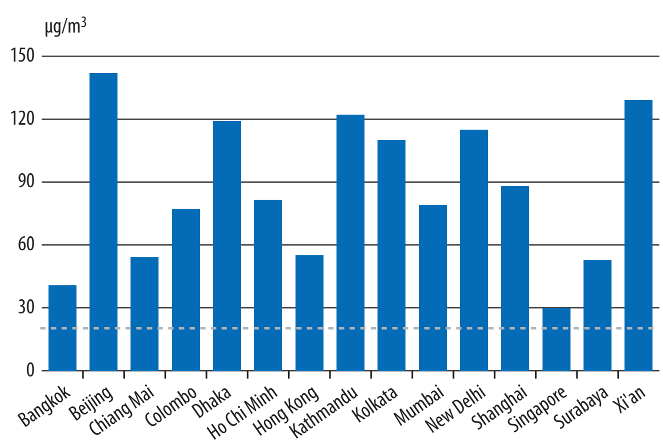
Source: CAI-Asia 2006a.

(Figure 5.2). None of the large Asian cities shown in Figure 5.2 meets the WHO guideline for PM_{10} although Singapore and Bangkok are the closest and the mean concentration for the 20 large cities shown in Figure 5.1 is about four times the WHO guideline. The average concentration of PM_{10} in these cities of about 80 µg/m^3 has changed little since 1995, illustrating the difficulty of probably the most important challenge in AQ in Asian cities—the reduction in PM_{10} levels. WHO interim guidelines for PM_{10} will provide interim targets for AQM in Asian cities, the achievement of which is critically important if the health of Asian city dwellers is to be protected.

Ambient concentrations of SO_2 in most Asian cities—but not all—are within WHO guidelines. The picture for NO_2 is variable, with some cities having ambient concentrations within WHO guidelines and some exceeding them. Data for ozone (O_3) are not comprehensive enough to make an assessment at this time.

FIGURE 5.2

Annual Average Ambient Concentrations of PM_{10} in Selected Asian Cities



Note: WHO annual PM_{10} guideline value is 20 µg/m^3

CAI–Asia = Clean Air Initiative for Asian Cities; PM_{10} = particulate matter with diameter not more than 10 microns; WHO = World Health Organization; µg/m^3 = micrograms per cubic meter

Source: CAI- Asia, 2006a.

The relocation of major industrial facilities out of large cities and the growth in small- and medium-scale manufacturing in peri-urban and rural areas has led to a broader scale increase in concentrations of fine particulates and photochemical smog, well beyond the boundaries of cities. For example, the relative success of actions to reduce emissions in Hong Kong SAR has been partially offset by increases in emissions from sources in the Pearl River Delta (PRD) region of neighboring Guangdong Province.

Transboundary Pollution and Long Range Transport of Air Pollutants

The magnitude of emissions of particles, acid gases, and O_3 precursors presents serious problems of AQ on local and—more important—regional scales due to long-range transport of air pollutants across national and continental boundaries. Recent research on emissions and regional scale dispersion suggests that industrial and transport emissions, biogenic emissions, and biomass burning provide considerable potential for future growth in long-range transport of carbon, sulfur, and nitrogen compounds in the Asian region (Streets et al. 2003) with intercontinental transport associated with the atmospheric brown cloud. The atmospheric brown cloud is a brown haze in the atmosphere over parts of Asia and Africa consisting of soil particles, combustion particles, sulfates, and nitrates, with the scale and intensity to reduce solar radiation at the surface of the earth and alter monsoon and other climatic patterns, changing rainfall, plant photosynthesis, and crop production (United Nations Environment Protection [UNEP] and Center for Clouds, Chemistry and Climate [C4] 2002).

A number of countries are concerned about impacts of acid deposition such as the PRC, which surveyed rainfall in 527 cities in 2005 and measured acid rain in 298 of them. Indications suggest that acid rain in the PRC is intensifying (SEPA 2005).

Smoke from periodic seasonal forest fires in Indonesia spread downwind throughout the region causing low visibility in Kuala Lumpur, Singapore, and other smaller cities in Southeast Asia. Adverse health impacts on people in the region were reported (Emmanuel 2000). Although the fires eventually abate, they highlight the contribution of regional, cross-border issues associated with air pollution. All members of the Association of Southeast Asian Nations (ASEAN) have signed an agreement on transboundary haze, except Indonesia. An action plan for the control of fires responsible for the transboundary haze has been developed by ASEAN countries affected by the haze.

BOX 5.1

Collaboration on Regional Air Pollution

As local sources of air pollution are controlled, regional-scale issues such as fine particulates, ozone (O_3), and acid deposition can grow, requiring regional collaborations. Hong Kong SAR and the adjacent Guangdong Province share the airshed of the Pearl River Delta (PRD). Emissions from sources from both the regions contribute to the issue of air pollution, and the people of both regions experience the effects on human health and the environment. Both governments have agreed to contribute to the operation of the PRD Regional Air Quality Monitoring Network and the daily release of the regional air quality index to the public.

The two sides will release details of the Emission Trading Pilot Scheme for Thermal Power Plants in the PRD region in 2006 so that prospective participants can identify trading partners and draw up emission trading agreements.

The environmental protection authorities of both sides will review the progress and effectiveness of the enhanced control measures in the PRD Regional AQM Plan, evaluate the trend of regional emissions, and draw up strategies and follow up actions to achieve the agreed emissions reduction targets by 2010.

Source: Newsgd.com, 2006.

» Part Six

Impacts ofAir Pollution

The adverse health effects of air pollution in the region are increasingly well documented. Numerous studies across the region have reported that air pollution is associated with increased chronic respiratory symptoms, lung cancer, premature mortality, and admission to hospital for diseases of the cardiorespiratory system (HEI 2004). Robust data indicate the relationships between exposure to air pollution and health effects in Asia.

Particulate air pollution is related consistently and independently to the most serious effects of air pollution, including lung cancer and other cardiopulmonary mortality. Fine particulate air pollution ($PM_{2.5}$) causes about 3% of mortality from cardiopulmonary diseases; about 5% of mortality from cancer of the trachea, bronchus, and lung; and about 1% of mortality from acute respiratory infections in children under 5 yrs worldwide. This amounts to about 0.8 million (1.2%) premature deaths and 6.4 million (0.5%) years of life lost. About 65% of this burden occurs in Asia alone (Cohen et al 2005).

The costs to the community of health effects of air pollution have also been determined in numerous studies and are generally much lower than the costs of pollution control. Studies have been conducted in most countries in Asia to assess the health costs of air pollution for the residents of the capital city and, in some cases, other cities. Estimates of the projected rates of sulfur deposition to ecosystems and their critical loads in Asia—the levels of acid deposition beyond which they are threatened—suggest that 73 million hectares of ecosystems will receive levels of sulfur deposition in excess of their critical loads (Cofala et al. 2004). The Chinese State Environmental Protection Agency has estimated that economic losses due to acid rain damage to forestry and agriculture are $13.25 billion annually (Carmichael et al. 2002).

The projected increases in O_3 concentrations in East Asia may lead to substantial crop losses in the near future. Wang and Mauzerall (2004) estimated that assuming there will be no change in agricultural production practices, grain losses in East Asia due to O_3 in 2020 will be 2–16% of the production of wheat, rice, and corn, and 28–35% for soybeans. Effects of current levels of air pollutants on crops and forests in Asia have been reported by Emberson et al. (2003).

» Part Seven

Air Quality Management

Policy Approaches at National and City Levels

Urban air pollution can have damaging effects on human health, natural and agricultural ecosystems, cultural objects, and buildings. In recent years, considerable improvements in the understanding of the relationship between exposure to air pollution and adverse effects, especially health effects, have been made. This has resulted in major advances in the analysis of the costs and benefits of prevention or control of air pollution, and the understanding of which sectors of the community bear the costs and benefits.

In most cities of the world, attempts have been made to arrest the growth in emissions of air pollutants, with varying levels of success. Improvements in AQ have been achieved because of annual expenditure on the prevention or control of air pollution with costs equivalent to about 0.8–1.5% of GDP since the 1970s. About half of this investment was public expenditure (ADB 2001).

Many cities have found that some air pollutants are more readily controlled than others. Experience has shown that emissions of Lead (Pb), SO_2, and coarse particles have been more amenable to AQM than emissions of NO_X, fine particulates, and hydrocarbons (McGranahan and Murray 2003). For a range of technical, economic, social, and political reasons, industrial sources of emissions have often been found to be more easily controlled than area and mobile sources of emissions. For this reason, combined with the increasing use of transport, transport emissions are commonly the major cause of air pollution in many cities of Asia (McGranahan and Murray 2003).

The stage of development of a city is also a critical factor in the capacity to prevent or control emissions. As economic development proceeds, a range of essential components of a system to control pollution become more readily assembled and put into place. These include an effective and efficient legal framework and regulatory system, a trained and skilled workforce, a mature and robust political and administrative system, a mature taxation system, an economy able to meet the public and private costs, an education and communications system, and public support for the measures required to improve AQ (Schwela et al. 2006).

The widespread acceptance among policy makers in recent years of the need to address climate change also provides opportunities for the achievement of co-benefits from the reduction of emissions of air pollutants and greenhouse gases. Many actions to prevent or reduce emissions of air pollutants also reduce emissions of greenhouse gases. There is an emerging trend to view actions to address climate change and air pollution, such as increased energy efficiency, cleaner coal technologies, use of renewable energy sources, substitution of coal with natural gas, promotion of public transport, etc. as closely linked, with many greater benefits than previously considered. It is very likely that Asian countries will increasingly view actions to address air pollution within the policy context of climate change.

Legislation and Institutional Mandates

The environmental protection regime of a country produces a set of agreed principles, norms, rules, decision-making procedures, and programs that govern interactions of stakeholders in addressing specific issues. It is clear that different countries in Asia give different priorities to the underlying principles behind AQ policy and management, such as user-pays, full-cost pricing, pollution prevention, precautionary approaches, etc. The policy instruments and approaches vary widely, according to attitudes and values, legal traditions, government structure and style, cultural factors, and enforcement practices. At a more pragmatic level, the necessary financial resources, and the required quantity and quality of human resources are critical to effective AQM. Globalization of information transfer is leading to a greater common understanding of both the issues and the options for addressing them. This is resulting in some measures being adopted through international agreements and greater transfer of information leading to less formal ways of resolving mutual environmental problems.

The backbone of policies to improve AQ in Asia is command and control regulations. Regulations are used by most countries in Asia and they have resulted in considerable successes in improving AQ. Some nations have comprehensive legislation to support such regulatory approaches or market based incentives—including the Philippines and Thailand. Others are developing important clean air legislation, including Viet Nam, Pakistan, and Indonesia. Across Asia, the trend is toward the introduction and implementation of comprehensive clean air legislation and a gradual shift from regulatory to market-based policies.

Many large stationary sources of emissions have been controlled by the effective enforcement of regulations, and vehicles emissions have been reduced through the enforcement of regulations requiring cleaner fuels and vehicle emissions standards despite rapid growth in vehicle numbers. In many cases, these gains have been much cheaper for society than the adverse health and environmental impacts of the emissions. Often, the benefits have exceeded the costs by an order of magnitude or more. Particularly, at the early stages of industrial development when capacities are highly limited, regulatory approaches to introduce cleaner fuels, lower emissions vehicles, etc. are generally preferred.

The main weakness in regulatory approaches in Asia is enforcement. This is closely linked to a complex suite of factors including financial and technical resources, legislation, political leadership, multi-agency coordination, and other factors. A weak institutional capacity for environmental monitoring and implementation of regulations is very common in most countries of Asia. In addition there is a lack in political leadership and institutional capacity for all aspects of AQM at various levels.

A combination of pressures has led to a shift toward the adoption of more innovative and flexible regulatory and market-based instruments in many nations, as part of a tool kit of available instruments. A mixture of policy instruments to prevent or control air pollution is increasingly being used where the machinery of government is able to manage this process. Regulations tend to provide a more direct control of pollution sources than economic instruments, and hence, reduce the uncertainty of the policy result. But economic instruments such as cap-and-trade and load-based licensing can bring about emissions reductions in a more cost-effective manner than regulations. The PRC, Hong Kong SAR, and Thailand are conducting limited trials of cap-and-trade economic instruments as tools to reduce SO_2 emissions from large stationary sources, while numerous other nations are using other economic instruments. There is no doubt that as regulatory environments in countries continue to develop, there will be an increased interest in the use of economic and other instruments to achieve improved AQ in Asia.

Ambient AQ Standards

Although AQ standards are variable in Asian countries, in many cases they lag behind international developments in AQ standards designed to protect human health and the environment. As new scientific information becomes available, WHO, EU, and some countries amend their AQ standards or guidelines on a regular basis to protect human health. For example, as new knowledge about the dose-response relationship between particulate and human health have become available, new standards such as standards for $PM_{2.5}$ and amendments to existing standards (such as for PM_{10}) have been introduced. Most Asian nations have not kept pace with these developments. Most do not have AQ standards for $PM_{2.5}$, and have standards for PM_{10} that are outdated and do not provide an adequate margin of protection for human health according to current scientific knowledge (Figure 7.1). Such standards also are needed to form the basis for cap-and-trade and other market-based policies.

WHO has recently introduced new AQ guidelines to protect human health. However, few large Asian cities are able to meet the guidelines for PM_{10}. WHO has also provided interim targets for AQM in cities (Table 7.1). These can be useful for policy makers in Asian countries as they provide attainable interim targets for actions to reduce PM concentrations in urban air.

TABLE 7.1

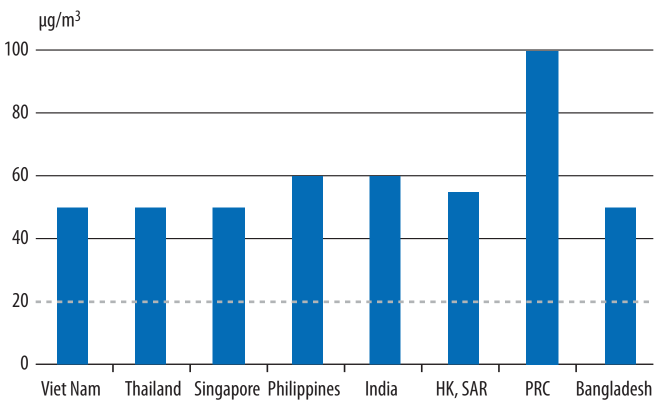
WHO Air Quality Guideline Values and Interim Targets for Particulate Matter as Annual Means

Annual Mean Level	PM_{10} (μg/m³)	$PM_{2.5}$ (μg/m³)	Basis for the Selected Level
WHO interim target (IT-1)	70	35	These levels are estimated to be associated with about 15% higher long-term mortality than at AQG
WHO interim target (IT-1)	50	25	In addition to other health benefits, these levels lower risk of premature mortality by approximately 6% [2-11%] compared to WHO-IT1
WHO interim target (IT-1)	30	15	In addition to other health benefits, these levels reduce mortality risk by another approximately 6% [2-11%] compared to WHO-IT2 levels
WHO Air quality guidelines (AQG)	20	10	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to $PM_{2.5}$. The use of $PM_{2.5}$ guideline is preferred.

AQG = air quality guidelines; IT = interim target; $PM_{2.5}$ = particulate matter with diameter not more than 2.5 microns; PM_{10} = particulate matter with diameter not more than 10 microns; WHO = World Health Organization; μg/m³ = micrograms per cubic meter
Source: WHO, 2006.

FIGURE 7.1

Annual Average Ambient AQ Standards for PM_{10} in Selected Countries of Asia, in Relation to the WHO Guideline Value for PM_{10}



CAI-Asia = Clean Air Initiative for Asian Cities; PM_{10} = particulate matter with diameter not less than 10 microns; PRC = People's Republic of China; SAR = Special Administrative Region; WHO = World Health Organization; μg/m³ = micrograms per cubic meter
Note: Annual PM10 standard presented here for PRC is based on Grade II category (100 μg/m³) applied for residential areas, mixed commercial residential areas, cultural, industrial and rural areas.
Source: CAI-Asia, 2006.

Management of Mobile Sources

In recognition of the major importance of vehicle emissions in determining the quality of air in a city, numerous Asian countries have implemented legislation to reduce vehicle emissions, and there is a trend toward the introduction of increasingly tight standards. Regulations have been developed and enforced to require that new vehicles must satisfy increasingly strict emissions standards in most Asian nations and the lag time with European standards has been considerably reduced since the mid-1990s when Asian countries started to formulate vehicle emission standards (Figure 7.2). To support the introduction of stricter vehicle emissions standards, fuel quality is required to meet tighter standards. With the exception of a limited number of countries, Afghanistan, Cambodia, Lao PDR, Mongolia, and Myanmar—all Asian countries—have phased out Pb. An issue following the phaseout of leaded gasoline is the use of octane enhancing fuel additives. Many countries have introduced inspection and maintenance requirements for in-use vehicles, but the success of efforts to implement these requirements have been mixed. Many countries are still struggling to develop effective inspection and maintenance systems.

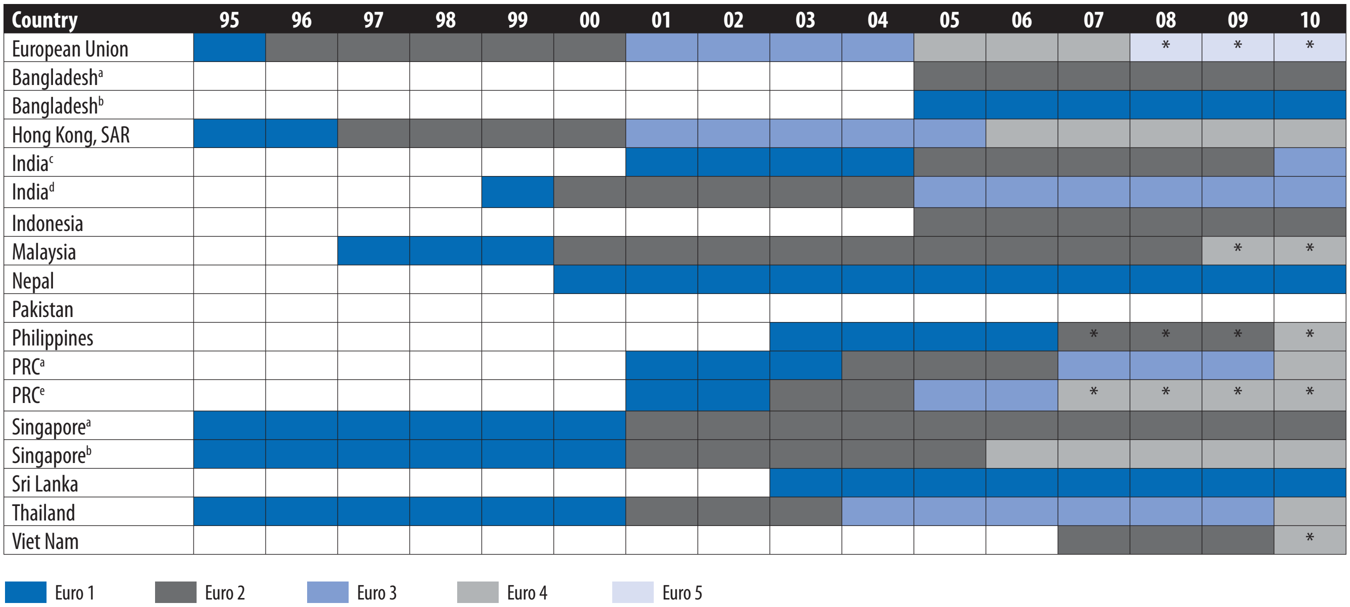
The removal from roads of high-emission vehicles (such as motorcycles using old 2-stroke technology) and the conversion of vehicles from high-emission fuels (such as old buses using diesel) to cleaner fuels (such as compressed natural gas and liquefied petroleum gas) has also contributed to the improvement of AQ in many cities. For example, the banning of baby taxis in Dhaka and other cities in Bangladesh; the conversion of Delhi's buses, taxis, and auto-rickshaws; and auto-rickshaws in some of Pakistan's cities to compressed natural gas have greatly reduced emissions. The very rapid growth in numbers of motorcycles has not been matched by effective regulation of their emissions in many countries.

CAI-Asia has been working with representatives of the oil industry and other experts to develop a fuel quality road map for Asia. This has been discussed with representatives from the oil industry, vehicle manufacturers, Asian governments, and development institutions to examine how Asian countries could move forward in establishing cleaner fuels to reduce emissions (CAI-Asia 2006b).

A complementary approach to address growing vehicle emissions from growing numbers of vehicles is to provide

FIGURE 7.2

Vehicle Emissions Standards in Asia and the EU



CAI-Asia = Clean Air Initiative for Asian Cities; EU = European Union; PRC = People's Republic of China; SAR = Special Administrative Region; ULEV = Ultra Low Emission Vehicle

* Under discussion

[a] gasoline; [b] diesel; [c] Entire country; [d] Delhi and other cities; Euro 2 introduced in Mumbai, Kolkata, and Chennai in 2001; Euro 2 in Bangalore, Hyderabad, Khampur, Pune, and Ahmedabad in 2003, Euro 3 to be introduced; [e] Beijing and Guangzhou (as of 01 September 2006) have adopted Euro 3 standards; Shanghai has requested the approval of the State Council for implementation of Euro 3; [f] Euro 4 for gasoline vehicles and California ULEV standards for diesel vehicles

Source: CAI-Asia 2006b.

reasonable alternatives to private transport. Most countries in Asia have committed to major improvements in mass transport in the largest cities including the PRC, India, Malaysia, and Singapore. A notable trend is the introduction of bus rapid transit systems that allow the establishment of a low–cost, high-quality mass transport system, thereby, slowing down the growth of private motorization.

Management of Stationary Sources

Most Asian countries have introduced standards to control industrial emissions. However, for these regulations to be successful, they will require more effective implementation in many countries. The implementation and enforcement issues often relate to the lack of availability of the necessary financial and trained human resources in both the public and private sectors. In addition, there are large numbers of small- and medium-sized industries in the formal and informal sectors of many developing Asian countries that are difficult to identify, inspect, and regulate. The regulation of fuel quality at a national scale (such as mandatory low sulfur diesel) offers some opportunity to address industrial emissions; and further investment in the policing, licensing, regulation, and enforcement of these sources is necessary if these emissions are to be controlled.

The PRC and India provide particularly powerful examples of nations facing enormous challenges in managing growing emissions from stationary sources with some success. The rapid economic growth of both countries is requiring increasing electricity supplies to meet demand. In both countries, much increase in electricity supplies will be met by coal-fired power stations, with potentially enormous increases in emissions of SO_2, particulates, NO_x and other air pollutants. Both countries are encouraging or mandating the use of cleaner coal technologies, other technologies (including renewable), and energy efficiencies to reduce emissions while managing electricity demand in their economies.

A number of Asian countries have introduced measures to control emissions from old technology brick kilns. Examples include Bangladesh, India, Nepal, and Pakistan where, in some cases, outstanding improvements in AQ have been achieved because of decisive government action.

Management of Area Sources

Significant contributors to air pollution in Asia are the burning of biomass fuels and low quality coal for heating and cooking, and area sources such as road and soil dust. The Asian region accounts for 44% of consumption of wood fuels worldwide (ADB 2001) and Streets et al. (2003) estimated that biofuels provide 70% of domestic consumption of fuels in Asia, resulting in high levels of PM and other pollutants in outdoor air. In urban residential areas of the PRC, coal burning is the dominant source of particulates arising primarily from coal-fired boilers and stoves used for residential heating and cooking (Florig et al. 2002). The open burning of vegetation and garbage is being increasingly controlled in large cities, including cities in India, Pakistan, PRC, and Thailand.

Beijing and other northern Asian cities are periodically affected by soil-derived particles during dust and sandstorms. PRC, Japan, Korea and Mongolia are taking actions to combat desertification to prevent dust and sandstorms. Resuspended road dust is a major source of particle emissions in urban areas of many of the Asian countries with extended dry seasons.

Public Participation

Public understanding and support is an important factor in achieving sustainable improvements in AQ. If adequate information is available to the public in a form that it can understand, the public can exert considerable pressure for change if it considers AQ a priority. Developments in interactive communications technology have enabled greater access to specialized information by the community, and events such as the forest fires in Southeast Asia, have increased public awareness of health impacts of air pollution in parts of Asia. Increased awareness often leads to public pressure. An example includes the Lead-Free Coalition in Manila which raised public awareness of the phasing out of Pb from gasoline in the Philippines, leading to the introduction of cleaner diesel, and the anti-smoke belching campaign (Lumbao 2002). Another example is the action of civil society in bringing matters to the Supreme Court of India that led to emissions control being implemented (Harashima 2000). Public interest litigation forced government agencies to address deteriorating AQ in cities in Pakistan, and resulted in a strong determination of the City of Lahore to improve AQ in the city.

Information and education instruments can also be powerful tools in some circumstances to mobilize public opinion, communities, civil society, and markets to achieve environmental goals. They can be very effective where government regulations are weak or not implemented. They are usually most successful when supported by other instruments, including regulations and economic instruments, to make selected high-emission activities both expensive and well-known to the community. The successful phaseout of high-emission 2-stroke three-wheeled vehicles in Dhaka proved that socially difficult environmental decisions could be effectively implemented if there is strong public support and political leadership.

Private Sector

Self-regulation instruments are increasingly being used by large corporations as tools to improve the environmental performance of their operations wherever they are located (Gunningham and Graboski 1998 and ICCA 2006)). Environmental management systems such as the ISO 14000 series and industry codes such as Responsible Care are being used by the private sector as voluntary tools, often going beyond simple compliance with government regulations to reduce impacts of operations on the environment and to protect corporate brands. The impact of the need of large corporations to protect their brands worldwide and to ensure compliance with laws and regulations wherever they operate is that they use and amend high-quality environmental management systems in countries wherein they operate and collaborate with regulators to ensure compliance with local laws and regulations. An example of a co-regulation based on the 3Ps approach (People, Public, and Private) is Singapore, which has a program including an Environmental Champions Programme (National Environment Agency [NEA] 2006) and a Voluntary Code of Practice on Pollution Control. (NEA 2004). Singapore is evolving its predominantly regulatory programs increasingly toward co-regulation and self-regulation programs underpinned by regulations (Ministry of Environment and Water Resources [MEWR] 2006).

Industry codes such as Responsible Care are global in effect. They facilitate and provide a global framework for responsible environmental performance in the industries to which they apply, including in countries with minimal laws and enforcement (ICCA 2006).

» Part Eight

Conclusions

AQM in Asia now faces several critical challenges, including identifying the major sources of air pollution emissions, enhancing the quality and scope of AQ monitoring, documenting population exposure and health effects throughout the region, selecting the most effective and efficient methods of control within the local context, and implementing them in a cost-effective and socially acceptable manner. Meeting these challenges will require the concerted and collaborative efforts of scientists from multiple disciplines working with policy makers.

Action to prevent or control air pollution in a number of countries is resulting in decreases in ambient concentrations of some pollutants concurrent with substantial economic growth. Increased public awareness, stronger implementation of regulations, use of higher quality fuels, changes in patterns of energy use, and other measures have improved AQ in many parts of Asia.

Public and government concerns about the growing impacts of air pollution in Asia are increasing, particularly in response to a growing awareness of the health impacts of air pollution. The extensive evidence from developed countries in North America and Europe is being augmented by high-quality health effects studies in Asian cities providing strong local incentives for policy action to improve AQ. In response to these growing concerns, the instruments that have been used in high-income countries to improve AQ are attracting considerable interest in low- and middle-income countries in Asia. Networking and benchmarking have been particularly important in the transfer of information and experience with AQM among nations in Asia. The emerging pattern is that the selection and implementation of policy instruments are locally driven but internationally informed. Some measures used internationally have been widely adopted throughout Asia in recent years, such as the replacement of leaded petrol with unleaded fuels. Other measures developed outside Asia are the subject of experimentation in some Asian countries, such as "cap-and-trade" instruments to reduce emissions of SO_2. Uniquely, Asia solutions to Asian issues have also been developed and implemented, such as the replacement of highly polluting 2-stroke rickshaws with cleaner engines. Clearly, the social context of measures to reduce emissions differs in Asia from many other parts of the world and needs to be addressed in their implementation. The building of community awareness of the issues and public participation and support for measures to improve AQ in Asia is critical to the effective implementation of these measures.

Prominent among the major challenges facing the achievement of better AQ for Asia are:

- The need to reduce ambient concentrations of PM to reduce impacts on human health;
- Political leadership and institutional capacity for all aspects of AQM at various levels;
- Strengthening monitoring, modelling, and emission inventories;
- Improved understanding of effects of air pollution on health and vegetation;
- Controlling regional air pollution, such as O_3, fine particulates, and acid rain;
- Strengthening AQ policy and improving implementation of management initiatives;
- The development of sustainable urban transport as a tool to reduce emissions from mobile sources; and
- Integration of climate change mitigation and urban AQM

References

Asian Development Bank (ADB). 2001. Asian Environmental Outlook. 2001. ADB: Manila, Philippines.

———. 2003. Reducing Vehicle Emissions in Asia. ADB: Manila, Philippines.

———. 2006. Asian Development Outlook 2006. Available at: www.adb.org/Documents/Books/ADO/2006/default.asp.

Badami, M.G. 2004. Environmental policy making in a difficult context: motorised two-wheeled vehicle emissions in India. Energy Policy, 1861–1877.

Clean Air Initiative (CAI)-Asia. 2006a. Urban air quality and its management in Asia. Status Report 2006. Presented at the Regional Dialogue of Air Quality Management Initiatives and Programs in Asia. 12 October. Bangkok, Thailand.

———. 2006b. Developing Fuel Quality Road maps for Conventional Fuels in Asia. 22–23 May. ADB Headquarters: Manila, Philippines. Available at: www.cleanairnet.org/caiasia/1412/article-70655.html.

Carmichael G.R., G. Calori, H. Hayami, I. Uno, S.Y. Cho, et al. 2002. The MICS-Asia study: model intercomparison of long-range transport and sulphur deposition in East Asia. *Atmospheric Environment,* 36, 175–199.

Cofala, J., M. Amann, F. Gyarfas, W. Schoepp, J.C. Boudri, et al. 2004. Cost-effective control of SO_2 emissions in Asia. *Journal of Environmental Management*, 72, 149–161.

Cohen, A., et al. 2005. The Global Burden of Disease Due to Outdoor Air Pollution.

Journal of Toxicology and Environmental Health Part A, 68, 1301–1307.

Energy Information Administration (EIA). 2004. International Energy Outlook 2004. EIA, US Department of Energy: Washington DC, USA.

———. 2006. www.eia.doe.gov/emeu/international/contents.html.

Emberson, L., M. Ashmore, and F. Murray. (editors). 2003. Air Pollution Impacts on Crops and Forests. Imperial College Press: London, UK.

Emmanuel, S.C. 2000. Impact to lung health of haze from forest fires: the Singapore experience. *Respirology*, 5, 175–182.

Florig, H.K. 1997. China's air pollution risks. Environmental Science and Technology, 31, 274A–279A.

Florig, H.K., G. Sun, and G. Song. 2002. Evolution of particulate regulation in China – prospects and challenges of exposure-based control. Chemosphere 49, 1163–1174.

Forbes, D., and M. Lindfield. 1997. Urbanisation in Asia: Lessons learned and innovative responses. AusAID:Canberra.

Harashima, Y. 2000. Environmental governance in selected Asian developing countries. *International Review for Environmental Strategies*, 1, 193–207.

Health Effects Institute (HEI). 2004. International Scientific Oversight Committee. Health Effects of Outdoor Air Pollution in Developing Countries of Asia: A Literature Review. Special Report 15. HEI: Boston, MA.

International Council of Chemical Associations (ICCA). 2006. Responsible Care. ICCA. www.responsiblecare.org.

International Energy Agency (IEA). 2004. World Energy Outlook 2004. IEA: Vienna.

Lumbao, L.K. 2002. Public awareness to save the air. Better Air Quality in Asian and Pacific Rim Cities. 16–18 Dec. Hong Kong SAR.

McGranahan, G., and F. Murray. (editors) 2003. Air Pollution and Health in Rapidly Developing Countries. *Earthscan*. London, UK.

Ministry of Environment and Water Resources (MEWR). 2006. The Singapore Green Plan, 2012: 2006 Edition. MEWR. Available at: www.mewr.gov.sg/sgp2012/index.html.

National Environment Agency (NEA). 2004. Code of practice on pollution control. NEA. Available at: www.nea.gov.sg/cms/pcd/coppc_2002.pdf.

———. 2004. Environmental Champions Programme (Industry). National Environment Agency. Available at : http://app.nea.gov.sg/cms/htdocs/article.asp?pid=2667.

Newsgd.com. 2006. Guangdong, Hong Kong step up cooperation. 7 July. Available: www.newsgd.com/prdcorner/newsspeeches/2006070600500.htm.

Schwela, D.S., G. Haq, C. Huizenga, W. Han, H. Fabian, and M. Ajero. Urban Air Pollution in Asian Cities. Status, Challenges, and Management. *Earthscan.* London, UK.

Segment Y. Ltd. 2006. Vehicle Population Projection. In ADB. 2006. Energy Efficiency and Climate Change Considerations for On-Road Transport in Asia. Manila, Philippines. May. Available at: www.cleanairnet.org/caiasia/1412/article-70656.html.

State Environmental Protection Authority (SEPA). 2005. Report on the State of the Environment in China. Environmental Information Center, SEPA. Beijing, People's Republic of China.

Smith KR, Mehta S. 2003. The Burden of Disease from Indoor Air Pollution in Developing Countries: Comparison of Estimates. *International Journal of Hygiene and Environmental Health*. 206, 279-289.

Streets, G.G., Bond, T.C., Carmichael G.R., Fernandes, S.D., Fu, Q., et al. 2003. An inventory of gaseous and primary aerosol emissions in Asia in the year 2000. Journal of Geophysical Research108, 8819, doi:10.1029/2002JD003093.

UNEP and Center for Clouds, Chemistry and Climate. 2002. The Asian Brown Cloud: Climate and Other Environmental Impacts UNEP, Nairobi.

United Nations. 2005. World Population Prospects. The 2004 Revision Population Database. Available: http://esa.un.org/unpp.

Wang, X., and D.L. Mauzerall. 2004. Characterizing distributions of surface ozone and its impact on grain production in China, Japan, and South Korea: 1990 and 2020. *Atmospheric Environment*, 38, 4383–4402.

World Health Organization (WHO). 2002. The World Health Report 2002: Reducing Risks, Promoting Healthy Life. WHO. Geneva.

———. 2006. WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulphur dioxide. Global update 2005. Summary of Risk Assessment.

World Bank. 1998. Pollution Prevention and Abatement Handbook. The World Bank: Washington DC, USA.

———. 2000. World Development Indicators. The World Bank: Washington DC, USA.