2

Understanding Urban Air Pollution in Asia

The United Nations estimates that by 2007 half of the world's population is expected to live in urban areas. Whereas 20 per cent of the world population lived in urban areas in 1950, the proportion of urban dwellers has been increasing and rose to 47 per cent in 2000 and is projected to reach 60 per cent by 2030 (UNPD, 2002).

Increased economic development in the Asian region has led to rapid and unplanned urbanisation with a large number of people being concentrated in cities. In the year 2000, 37 per cent of the population in Asia lived in urban areas. This number is expected to increase to 54 per cent by 2030. Tokyo (26.5 million) is the most populous urban agglomeration in the world, followed by México City (18.3), São Paulo (18.3), New York (16.8) and Mumbai (16.5).

Rapid urbanisation in developing countries has resulted in increased levels of air pollution and poor air quality in urban centres due to transportation, energy production and industrial activity all concentrated in densely populated areas.

It is estimated that currently twelve 'megacities' exist in the Asian region (Bangkok, Beijing, Delhi, Karachi, Kolkata, Metro Manila, Mumbai, Osaka, Seoul, Shanghai, Tianjin and Tokyo) (UNESCAP, 2000). By 2015, Tokyo will remain the largest urban agglomeration with 27.2 million inhabitants followed by Dhaka, Mumbai, São Paulo, Delhi and México City, which are all expected to have more than 20 million inhabitants. Figure 2.1 presents a number of Asian megacities which had a population of 10 million inhabitants or more for the year 2001 and their estimated populations in 2015.

2.1 Air Pollution Levels and Trends in Developing Countries

An analysis of the air pollution situation of 150 developing country cities using the Air Management Information System (AMIS) showed that the annual mean concentrations of SO_2 in residential areas did not exceed 50 µg/m^3 (Krzyzanowski and Schwela, 1999). Notable exceptions are several cities in China, India and Nepal, where SO_2 concentrations exceeding 100

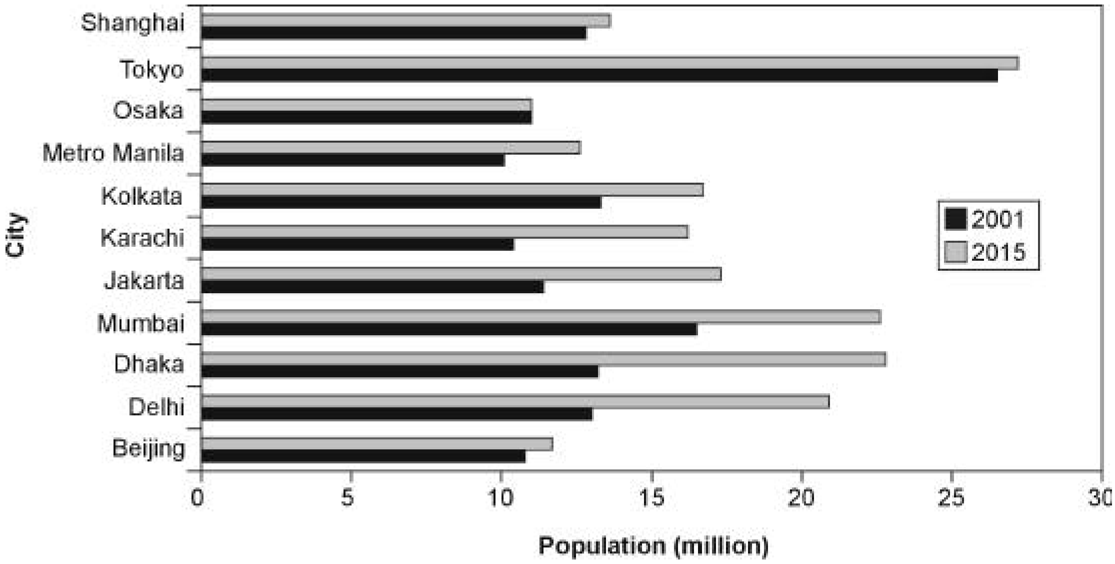

Figure 2.1 Population of selected Asian Megacities, 2001, 2015
Source: UNPD (2002)

µg/m^3. In most of the cities having data which allow trend assessment, a decline in mean annual SO_2 concentration was seen during the 1990s. In Chinese cities, an annual decline rate of between 1–10 per cent was observed (Schwela, 1999; WHO, 1998;. WHO, 2001a).

With respect to PM, the most commonly reported indicator is the mass of total suspended particles (TSP). In many cities, the TSP annual mean concentration exceeds 100 µg/m^3, with the levels exceeding 300 µg/m^3 in several cities of China and India. In a limited number of cities the mass concentration of particles with aerodynamic diameter less than 10 µm (PM_{10}) is also measured. In Asian cities, an increase in PM_{10} concentration was experienced in the 1990s. This increase has occurred even when a reduction in TSP was reported. An opposite trend and a reduction in PM_{10} level were seen in cities of Central and South America.

In most of the cities reporting to AMIS, the annual mean concentration of NO_2 remains moderate or low, not exceeding 40 µg/m^3. Trends vary between the cities but a 5–10 per cent annual increase was more common than a decrease in concentration of this pollutant. The highest NO_2 levels, and increasing trends, are observed in the cities with high and increasing car traffic. In South Asia and in Latin America, this high NO_2 concentration, combined with the intense ultra-violet radiation, results in photochemical smog with high ozone (O_3) concentrations.

The concentrations of air pollution in major and mega cities of developing countries often reach levels of concern for public health. Vehicle emissions are a major and increasing contributor to air pollution in developing as well as developed countries as a result of the continuing rise in vehicle numbers.

Outdoor air pollution is not the only evident problem related to air in developing countries. Indoor air pollution in developing countries plays a much more important role due to the fact that ovens and braziers used for cooking and heating in households lead to much higher air pollutant concentrations indoors than those observed in urban areas of developed or developing countries (WHO, 1992; Smith, 1996; Bruce et al., 2000). The resulting human exposures to suspended particulate matter, CO, and NO_x often exceed WHO guidelines by factors of 10, 20, or even more (WHO, 2000).

2.2 Sources of Urban Air Pollution

The main cause of urban air pollution is the burning of fossil fuels (coal, oil and natural gas) in domestic heating, power generation, industrial processes and in motor vehicles. In addition, the burning of biomass such as firewood, agricultural and animal waste in some cities contribute to the level of pollution. Many activities are undertaken in urban areas which result in polluting air emissions. The most typical urban pollutants include suspended particulate matter (SPM), sulphur dioxide (SO_2), volatile organic compounds (VOCs), lead (Pb), carbon monoxide (CO), carbon dioxide (CO_2) and nitrogen oxides (NO_x).

Urban air pollution not only has immediate localised impacts on human health and well-being but also contributes to regional and global air pollution. For example, regional acidification is increasingly experienced in East Asia and Southeast Asia. Pollutant emissions resulting from burning of agricultural waste and use of fossil fuels in the industrial and transportation sectors, not only contribute to global climate change but also the haze in South Asia known as the ‘Asian brown cloud’, which is a mass of ash, acids, aerosols and other particulates. The blanket of pollution stretches 3 kilometres high and is reducing solar energy reaching the earth surface by 10–15 per cent disrupting weather systems (including rainfall and wind patterns), triggering droughts in western parts of the Asian continent as well as impacting on health and agricultural productivity (UNEP, 2002b).

The air in Asian cities is amongst the most polluted in the world. The World Health Organization calculated that in the early 1990s, 12 of the 15 cities in the world with the highest levels of particulates, and 6 with the highest levels of SO_2 in the atmosphere were in Asia (WHO/UNEP, 1992).

The transport sector is a large contributor to urban air pollution in Asian megacities. In 1996, the total number of registered cars in the Asia and Pacific region totalled approximately 127 million - 4.2 per cent higher than the previous year (UNEP, 1999). In the cities of Delhi and Manila, the number of cars has doubled every seven years. In Southeast Asia the popularity of motorcycles and scooters, which have highly polluting two-stroke engines, together with high average vehicle age and poor maintenance, has led to more emissions per kilometre driven than in developed countries (Walsh, 1999).

2.3 Air Pollution Impacts

Air pollution has a number of impacts on the human health and the environment. It adversely affects human health through direct pathways such as inhalation but also indirectly via other exposure routes such as contamination of drinking water and food and via skin transfer. The direct human health effects of air pollution can vary according to both the intensity and duration of exposure as well as the health status of the population exposed.

People with a poor standard of living suffer from nutritional deficiencies, infectious diseases due to poor sanitation and overcrowding, and tend to be provided with a poor standard of medical care. Each of these factors may render individuals more susceptible to the effects of air pollution. The age structure of populations differs markedly from country to country. Old people tend to show increased susceptibility to air pollution. Very young children may also be at increased risk. Diseases which produce narrowing of the airways, a reduction in the area of the gas-exchange surface of the lung and an increased alteration of inhalation-perfusion ratios are likely to make the subject more susceptible to the effects of a range of air pollutants.

During the period 1991–1992, an estimated 40, 000 people died from air pollution caused by PM in the air in 36 Indian cities (Brandon and Hommann, 1995). Table 2.1 shows the number of premature deaths in selected Indian cities due to levels of suspended particulate matter (Agrawal and Narain, 1999).

In Dhaka (Bangladesh) the airborne lead concentration is one of the highest in the world and the mean blood lead concentrations in 93 randomly chosen rickhshaw-pullers was 53 µg/dl – five times higher than the acceptable limit in set by WHO (Tong *et al*, 2000; WHO, 2000).

Air pollution from increasing levels of energy production and road traffic in many urban areas can also result in the corrosion of buildings and infrastructure including historic and cultural monuments (e.g. the Taj Mahal monument in Agra, India). Many important materials are affected, such as metals, painted surfaces, calcareous stones, polymer materials and paper (Tidblad and Kucera, 1998).

Table 2.1 Estimates of annual premature deaths in selected Indian cities due to suspended particulate matter

City	1991–1992	1995
Ahmedabad	2,979	3,006
Kolkata	5,726	10,647
Chennai	863	1,291
Delhi	7,491	9,859
Hyderabad	768	1,961
Kanpur	1,894	3,639
Mumbai	4,477	7,023

Source: Agrawal and Narain (1999)

The emissions of pollutant gases such as SO_2, NO_2 and O_3 have direct impacts on crops and forests. High pollutant concentrations can affect crop plants and forest trees detrimentally through direct visible injury and/or effects on growth and yield (invisible). These impacts can have a direct economic consequences for farmers and the local economy (Ashmore and Marshall, 1998).

2.4 Urban Air Quality Management

The aim of air quality management (AQM) is to maintain the quality of air that protects human health and welfare but also provides protection of animals, plants (crops, forests and natural vegetation), ecosystems, materials and aesthetics, such as natural levels of visibility Figure 2.1 presents a systematic approach to AQM.

The development of an effective AQM strategy is dependent on a number of factors such as emission inventories, air quality monitoring networks, dispersion and air quality prediction models, exposure and damage assessments, health and environmental based standards together with a range of cost-effective pollution control measures and the legislative powers and resources to implement and enforce them (Elsom, 1996).

2.4.1 Air Quality Monitoring

Air quality monitoring is essential key step in the development of an AQM (see Table 2.1). It provides information on pollutant concentrations and assists decision makers in formulating the appropriate responses to reducing emissions of pollutants in a city. The formulation of emission control strategies requires detailed information on both the status of air quality and the principal sources of pollutants and their locations. This information is quantified in an emission inventory.

The 1996 MARC/UNEP/WHO study of air quality management capabilities in 20 major cities discovered that while most of the cities in the study had some capabilities few cities in the study possess all the required capabilities for effective air quality management strategies (MARC/UNEP/WHO, 1996). The study concluded that existing capabilities could be more effectively used in many cities in the development and implementation of air quality management strategies. The study highlighted five main reasons why many do not implement emission control plans despite adopting such plans:

1 Insufficient expertise and capabilities to formulate policies.

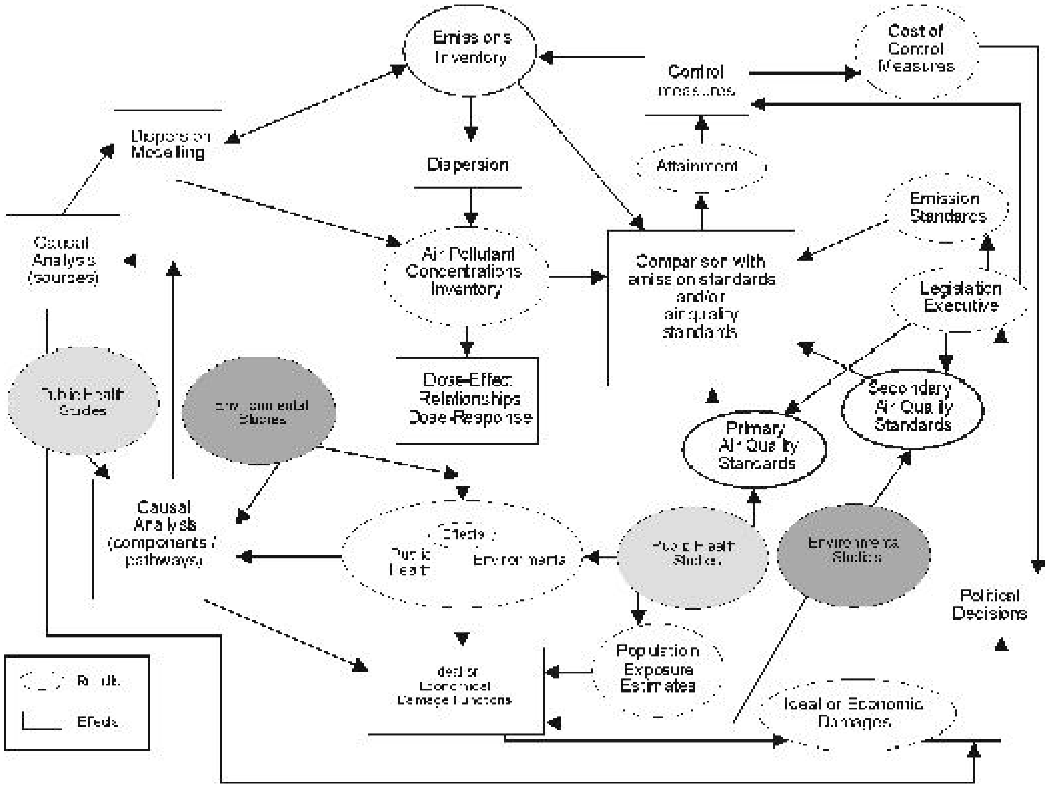

Figure 2.1 Systematic approach to air quality management

Table 2.2 outlines the key steps in the development of an AQM system.

Assessment	• identifying emission sources;
	• quantifying emission sources;
	• monitoring air pollution;
	• assessing the exposure conditions;
	• identifying-source exposure relationships;
	• estimating relative importance of pollution sources; and
	• assessing environmental and damage.
Analysis of Option	• investigating short-/long-term control options;
	• performing cost-benefit/cost-effectiveness analysis; and
	• implementing an investment plan.
Air Pollution Control	• developing institutions/regulations/enforcement mechanisms;
	• raising awareness and environmental education; and
	• implementing an investment plan.
Surveillance	• establishing an air quality information system.

Source: Shah *et al.* (1997)

2. Low priority given to air pollution control compared to other social and environmental issues.
3. Insufficient financial resources or concern over the economic impact of introducing pollution control policies.
4. Inadequate political will and dis-jointed administrative framework in which the responsibility for air quality is divided between a number of government of ministries and local administrations thus complicating policy making (MARC/UNEP/WHO, 1996).

2.4.2 Air Quality Standards

Air quality standards are another important aspect of AQM, for in areas where air quality standards are exceeded on a regular basis, measures need to be taken to reduce air pollution levels. The WHO Guidelines for Air Quality (GAQ) (WHO, 2000) are based on epidemiological studies that emerged in the late 1980s and 1990s (see Table 2.2). These studies were performed in the United States and later in Europe. Associations were demonstrated in these studies between daily average concentrations of PM, O_3, SO_2, airborne acidity, NO_2, and CO and the daily occurrence of events such as deaths or admissions to hospitals. Confounding factors such as season, temperature, day of the week, smoking behaviour, occupational exposure and drug use were carefully accounted for. Although the associations for each of these pollutants were not significant in all studies, taking the body of evidence as a whole, the consistency is striking. For PM and O_3 it has been generally accepted that the studies provide no indication of any threshold of effect.

The WHO GAQ were derived in the framework of air quality management and are globally applicable. Guideline values are derived for about 45 non-carcinogenic compounds and unit risks given for about 35 carcinogens. For SPM, exposure-response relationships were presented. Guideline values were derived in expert meetings, in which the Air Quality Guidelines for Europe (WHO, 1987) were updated. Information was also taken from the International Programme for Chemical Safety (IPCS) and the Concise International Chemical Assessment Documents (CICAD) of the Inter-Organization Programme for the Sound Management of Chemicals. The guidelines serve to give advice to Governments with respect to standard setting and developing clean air implementation plans to protect their populations from the adverse effects of ambient and indoor air pollution on health.

2.4.3 Air Pollution Prevention and Control Strategies

Many countries in Asia have developed their own air quality prevention and control strategies. These strategies have included air quality standards for main pollutants as well as emission standards for power plants, certain industries and motor vehicles.

Options for reducing emissions range from measures which address fuel quality (including switching to cleaner fuels and improving the quality of fuels to reduce emissions), rationalization of fuel prices to provide incentives for efficient fuel use, adoption of technologies that reduce emissions at source, and energy efficiency measures that reduce emissions through reduction in the quantities of fuel used. Control technologies have been generally based on the modification of fuel or the combustion technique or removal of flue gases.

Measures adopted to reduce motor vehicle pollution include diverting traffic away from heavily populated areas (e.g. by building ring roads around cities or restricting downtown traffic); converting high-use vehicles to cleaner fuels (e.g. converting buses to natural gas); improving vehicle maintenance; increasing the share of less polluting traffic modes; using more fuel-efficient vehicles; and installing catalytic control devices. Supply-side traffic management measures are aimed at reducing congestion (e.g. by improving road infrastructure). However, such measures rarely lead to significant overall emissions reductions because they may simply increase traffic flows (UNEP, 2002b).

Table 2.2 WHO Air Quality Guidelines

Pollutant	Annual ambient air concentration (µg/m^3)	Guideline value (µg/m^3)	Concentration at which effects on health start to be observed (µg/m^3)	Exposure Time
CO	500-7000	100,000		15 min
		60,000		30 min
		30,000		1 hour
		10,000		8 hours
Lead	0.01–2.0	0.5		1 year
NO_2	10–150	200	365–565	1 hour
		40		1 year
O_3	10–100	120		8 hour
SO_2	5–400	500	1000	10 min
		125	250	24 hour
		50	100	1 year

Source: WHO, 2000