5

Summary and Conclusions

The twelve major and mega cities examined in this study share, to varying degrees, features that render a significant threat to their populations from air pollution. These cities have extremely large population numbers and are extensive settlements encompassing areas of extremely high population density. Industrial activity, traffic volumes, the density of residential and commercial development, as well as specific prevailing geographical conditions, have led to an intensification of air pollution problems that have acute and chronic detrimental effects on human health through the degradation of both outdoor and indoor atmospheric environments. The management of these air pollution problems also poses huge financial, technical and logistical problems for urban and national authorities. Furthermore, current trends in urbanisation do not suggest that there will be any rapid abatement in the problems posed.

In order to arrive at conclusions from this study, a logical framework as the basis for further action is required. This will form the basis of any improvements in atmospheric conditions, and human health and well-being, through technical and managerial support and strengthened capacities to deal with the problems.

5.1 A Logical Framework for Urban Air Quality Management

A useful framework for management of urban air pollution is the classic *Driving force – Pressure – State – Impact – Response* (DPSIR) framework (EEA, 1999) (See Figure 5.1). Specifically targeted economic instruments have strong direct (e.g. environmental taxes and subsidies) and indirect (e.g. prices and costs of raw materials and products) effects on the pollution system, and its abatement. Those cities within the study with the highest level of economic development are those that appear to control air pollution most successfully through regulation and defensive expenditures.

The use of the DPSIR framework to examine air quality management (AQM) in Asian cities demonstrates the common problems and differences that the twelve cities examined in this study are currently experiencing. The *driving forces* are the same for nearly of all of the cities - the rapid growth in population accompanied by the expansion of the transport and industry sectors. These two sectors are the main catalysts of economic growth and development within Asia. However, the extent and intensity of the *pressure* of these sectors varies with each city and is dependent on the city's level of economic activity. The emissions of air pollutants from these sectors are similar but reflect the dominance of each sector within the city.

The main differences between the cities is in the *state* of current air quality and the *response* taken by national and local government in addressing urban air quality issues.

The *state* of air quality is reflected in the sophistication and coverage of air quality monitoring systems and the degree of exceedence of WHO air quality guidelines (WHO 2000; WHO 1987) or national standards. Those cities which have a relatively extensive air quality monitoring can measure the exceedence of air quality guidelines for up to three pollutants.

The *response* of national and local government to manage the air quality again vary from city to city and range from using CNG and LPG powered buses to banning 2-stroke 3-wheelers.

5.2 Stages of Urban Air Pollution in Asian Cities

Although air pollution problems in relation to levels of development is a continuous relationship, the cities in general can be divided into five broad groups based on the severity of their urban air pollution problem (see Chapter 3):

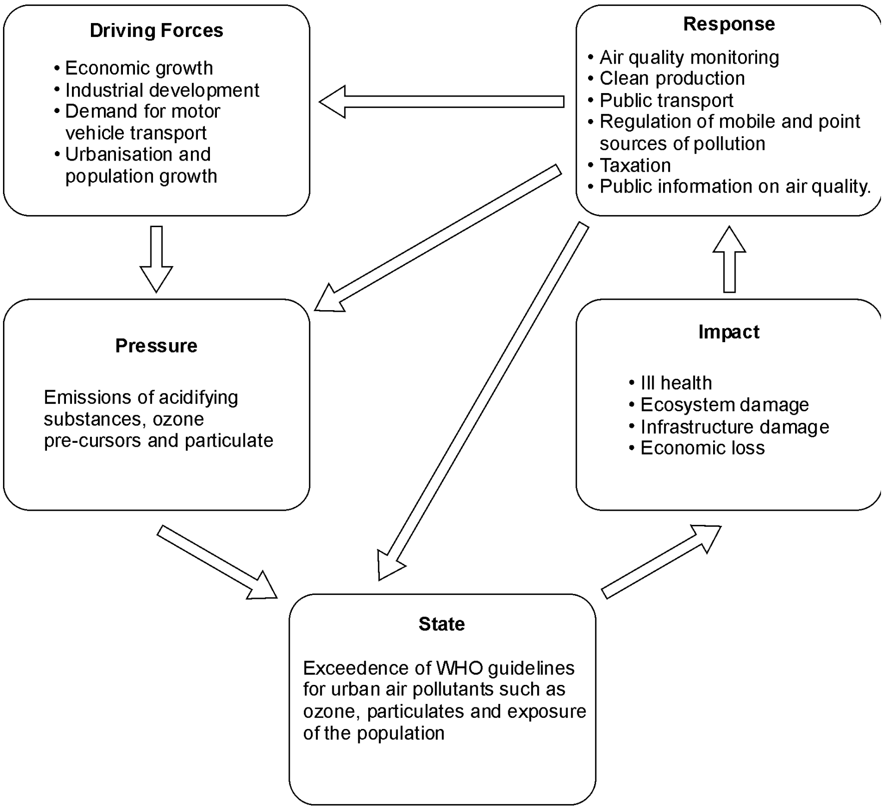

Figure 5.1 The DPSIR Framework

Stage 0 Pre-problem stage
Stage I Moderate and increasing levels of air pollution
Stage II High but stabilising levels of air pollution
Stage III High to moderate and decreasing levels of air pollution
Stage IV Low and decreasing levels of air pollution

Stage 0 – *Pre-problem stage*

Before industrial development, the main source of air pollution was from the domestic sector and light industry. None of the Asian cities examined in this study are currently at this stage.

Stage I – *Moderate and increasing levels of air pollution*

With increased industrialisation, urbanisation and demand for transport, air quality begins to worsen. The use of coal and other high-sulphur fuels is the norm and leaded gasoline is used in the transport sector. Management of air quality is rudimentary with little or no systematic air quality monitoring. Control of air emissions is minimal causing rising levels of pollutants such as SO_2, SPM and Pb. Some pollutants frequently exceed WHO guidelines. Impacts on the health and the environment are becoming apparent and worsening.

Stage II – *High but stabilising levels of air pollution*

Levels of air pollution are high due to emissions from heating facilities, electrical generators, vehicles (including two-stroke vehicles) and small, medium and large-scale industrial boilers. Concentrations of many pollutants (SO_2, TSP, CO, HC, NO_x and O_3) regularly exceed WHO guideline values (WHO 2000; WHO 1987 for TSP) and the *impacts* are widespread and severe. Rising concerns stimulate increasing efforts to manage air quality by monitoring air quality and controlling air pollutant emission sources.

Stage III – *High to moderate and decreasing levels of air pollution*

Concentrations of many air pollutants are decreasing as a result of efficient air quality management systems. Reduced emissions have been achieved through the implementation of various control measures (such as switching to cleaner fuels in industry and transport, and the testing and enforcement of stringent emission and fuel standards), public awareness campaigns and the development of more efficient public transport systems. However, adverse impacts are still evident due to photochemical smogs and concentrations of TSP, NO_x and O_3 still frequently exceeding standards.

Stage IV –*Low and decreasing levels of air pollution*
Levels of air pollution are low and decreasing, air quality is generally acceptable and acute adverse health episodes are seldom experience. This has been achieved by having comprehensive and efficient air quality management systems and vigorous implementation policies. Practices and standards commonly found in air pollution management regimes in the Europe and North America are in place (see Chapter 4).

5.3 Characterisation of Emissions for Major and Mega Cities of Asia According to the AMIS Database

Using the AMIS (Air Management Information System) database it possible to calculate the average concentrations for selected pollutants over a defined period. The data in AMIS are only available for 1990–1999 and only include eight out of the twelve cities covered in this benchmark report. Figure 5.2 shows that Beijing, Bangkok, Kolkata, Chongquing, Guangzhou, Mumbai, New Delhi and Shanghai experience high average concentrations of SPM with New Delhi experiencing the highest concentration of more than 400 µg/m[3]. In general, concentrations of SPM are approximately double the concentrations of $PM_{10.}$ PM_{10} is therefore relatively low in comparison with SPM, with Kolkata, Hong Kong, Mumbai, New Delhi, Seoul and Busan experiencing levels of PM_{10} above 50 µg/m[3]. However, not all cities have the capability to monitor PM_{10}.

The AMIS data are also presented in Table 5.1. Although the evolution of air pollution problems in relation to a city's level of development is on a continuous scale, cities can be clustered according to their stage in the development of urban air pollution problems (see Figure 3.2; Chapter 3). The concentration of PM_{10} provides a suitable indicator for the extent of air pollution problems in each city as this poses a significant threat to human health and usually reflects the general level of AQM within the city[1]. The cities have therefore been grouped according to the extent of their exceedence of the US EPA National Air Quality Standards for PM_{10} (50 µg/m[3]) (see note b below Table 5.1) and whether a city's PM_{10} or SPM levels reported in the AMIS database are increasing, stabilizing or decreasing. For the purposes of this analysis, where PM_{10} data are absent, PM_{10} concentrations were estimated as half the SPM concentrations.

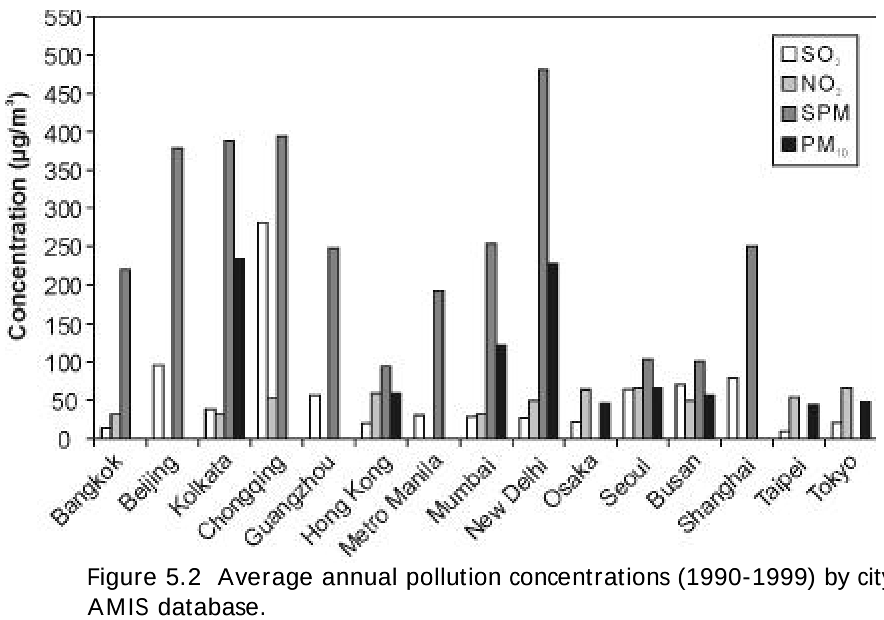

Figure 5.2 Average annual pollution concentrations (1990-1999) by city from the AMIS database.

Table 5.1 Annual average air pollutant concentrations [a] in selected Asian cities (1990–1999)

City	SO_2 µg/m^3	NO_2 µg/m^3	SPM µg/m^3	PM_{10} µg/m^3	Year of data	Air Quality trend for PM_{10}[b]	Stage of air pollution development
Bangkok	14	32	220	NA	1990–1995	High but stable	II
Beijing	96	NA	378	NA	1990–1994	High but stable	II
Kolkata	38	32	388	234	1990–1997	High but stable	II
Chongqing	281	53	394	NA	1990–1994	High but stable	II
Guangzhou	57	NA	248	NA	1990–1994	High but stable	II
Hong Kong	20	59	94	59	1990–1998	Medium and decreasing	III
Metro Manila	30	NA	192	NA	1990–1999	Medium but stable	II
Mumbai	29	32	254	122	1990–1997	High but stable	II
New Delhi	26	49	481	227	1990–1997	Very high but decreasing	III
Osaka	22	64	NA	46	1990–1994	Low and stable	IV
Seoul	64	66	103	66[c]	1990–1998	Medium and decreasing	III
Busan	71	49	101	57[c]	1990–1998	Medium and decreasing	III
Shanghai	79	NA	250	NA	1990–1994	High but stable	II
Taipei	9	54	NA	44	1999	Low	IV
Tokyo	21	66	NA	48	1990–1995	Low and decreasing	IV
Average concentration	57	51	258	100	-	-	-
WHO guidelines (annual average)	50	40	60-90	No specific guideline	-	-	-

Notes:
[a] The concentrations are annual averages for industrial, commercial and residential areas.
[b] Where there are no PM_{10} data, it is assumed that PM_{10} levels are half the SPM levels for the purposes of the classification as:
'High' = more than twice the US EPA standard for PM_{10} of 50 µg/m^3 .
'Medium' = average annual PM_{10} concentration exceeded US EPA standard by up to a factor of 2.
'Low' = average annual PM_{10} concentration less than the US EPA standard.
[c] The concentration of PM_{10} for Seoul and Busan is based on the data after 1995.
NA: data are not available.
Source: WHO AMIS D/B (2001).

Table 5.2 summarises the AQM, according to the DPSIR framework, for the eleven cities covered in this report.

Table 5.2 Summary of AQM in the eleven cities covered in this report according to the DPSIR framework

	Bangkok	Beijing	Busan
Driving force	Increasing demand for transportation – vehicle population increasing by an average of 300,000 vehicles per year since 1990.	Growth in economy of 10% per year from 1996–2000 leading to growth in industry and increasing demand for private vehicular transport	Increasing demand for transportation – vehicle population increasing by 22 per cent per year since 1989 and stood at 862,699 in 2001.
Pressure	Emissions of air pollutants from vehicles (especially PM_{10}, CO, NO_x and HC).	Emissions of air pollutants from vehicles (PM, CO, NO_x, SO_2, HC and Pb) and industry (SO_2)	Emissions of air pollutants from vehicles (PM, CO, NO_x and HC).
State	Some exceedence of air quality standards for TSP, CO and O_3, particularly at roadside sites.	Frequent exceedence of air quality standards for TSP, SO_2, NO_x and O_3	Some exceedence of air quality standards for PM_{10}, and O_3
Impact	Respiratory and cardiovascular diseases in the population especially those living or working near busy roads. Cases of throat irritation as high as 60% in the general Bangkok population.	Chronic obstructive pulmonary disease and chronic bronchitis. Blood-Pb levels in children 80% higher than levels considered dangerous.	No studies that have examined the impacts of air pollution in Busan were made available.
Response	Setting and enforcement of ambient air quality standards, fuel quality standards and stringent vehicle emissions standards (equivalent to EU standards for light duty vehicles and heavy duty diesel vehicles; and Taiwan's standards for motorcycles – the world's most stringent). Development of mass transit projects, particularly rail transport systems.	Regulation of stationary and mobile sources of air pollution including strict emission standards. Prohibition of leaded gasoline in 2000. Conversion of buses and taxis to LPG or CNG. Plans to reduce emissions (SO_2 by 40%, NO_x by 33% and PM by 34%) from 2002-2007 contained in recently passed "Prevention of Atmospheric Pollution of Beijing, 2002"	Assessment of air quality according to Republic of Korea national standards. Expansion of clean fuel supply; implementation of SO_2 control measures, mandatory installation of catalytic converters on cars and the operation of environment vigilante.

Table 5.2 contd.

	Chongqing	Dhaka	Hong Kong
Driving force	Continued coal combustion in industry. Recent rapid growth in transport and construction sectors.	High and increasing demand for transportation especially highly polluting 2-strokes (auto-rickshaws, auto-tempos, and motorcycles)	Increasing demand for transportation coupled with very high density of traffic (275 licensed vehicles for every kilometre of road).
Pressure	Emissions of SO_2 from coal-fired boilers, dust from construction industry, transport emissions such as PM and NO_x.	Emissions of air pollutants from vehicles (especially PM, SO_2, Pb, NO_x and HC)	Exhaust emissions from vehicles especially those from diesel engines (PM and NO_2) combined with inhibited pollutant dispersion resulting from the many high-rise buildings and surrounding hills.
State	Frequent exceedence of air quality standards for SO_2, TSP and NO_x in urban ambient air with much higher levels of TSP and NO_x by roads .	Monitoring information limited but ambient levels of SPM, Pb and SO_2 found to far exceed Bangladeshi and WHO air quality standards. Also evidence that ambient levels of NO_2 and VOC regularly exceed standards.	Exceedence of air quality standards for TSP and NO_x particularly at roadside sites. Increasing trend in O_3 concentrations - up by 80% over past decade.
Impact	Unknown	Estimated that Dhaka's air pollution annually causes 10,800 premature deaths and 6.5 million extra cases of sickness at an economic cost of US $200–800 million. Blood-Pb levels higher than maximum tolerable limit in all those sampled.	Correlations between levels of NO_x, SO_2, PM and O_3 and hospital admissions and mortalities for respiratory and cardiovascular diseases. Economic cost estimated at $HK 3,841 million per annum.
Response	Fuel switching from coal to natural gas and oil in industrial boilers. Promotion of clean vehicles (e.g. LPG and CNG-fuelled vehicles) through China's newly revised Air Law (2000) and Clean Vehicle Action Programme.	Development partners supporting projects to build capacity and address the deteriorating air quality. In a recent radical move by the government, all 2-stroke 3-wheelers in Dhaka have been banned and will be replaced by CNG-powered vehicles by the end of 2002.	Efficient and comprehensive air quality monitoring network. Use of an Air Pollution Index to inform public and raise awareness. Legislation to control emissions from stationary and mobile sources including stringent vehicle emission and fuel standards, inspection and enforcement. Over 75% of petrol cars have 3-way catalytic converters. Trial for full-scale introduction of LPG taxis being carried out. Efficient mass transit (subway) system in place.

Table 5.2 contd.

	Jakarta	Kathmandu	Mumbai
Driving force	Rapid economic growth, urbanisation and increased demand for transportation.	Rapid urbanisation and industrialisation coupled with poorly maintained vehic les (over half are highly polluting 2-strokes) and a general lack of public awareness.	Industrialisation and increasing demand for transportation - in 1997 the total number of registered motor vehicles in Mumbai was 800,000
Pressure	Emissions from power stations/industry (PM, SO_2 and NO_x), and the transport sector (SO_2, CO, HC, and NO_x).	Emissions of air pollutants from cement factory and over 300 brick kilns (mainly PM and SO_2) in Kathmandu Valley, and from vehicles and open-burning of refuse in Kathmandu urban zone.	Emissions of PM from industry, re-suspension of road dust, refuse burning, domestic fuel-wood combustion and diesel vehicle exhaust; SO_2 from power plants and industry; NOx from vehicles and power plants.
State	Total HCs exceed the Jakarta standard at all stations. Air concentrations occasionally exceedence the 24-hour average TSP standard and the annual PM_{10} standard.	Information limited. An URBAIR study in 1996 found 50% of the population is exposed to a TSP concentration above the WHO Air Quality Guideline (90 $\mu g/m^3$) and 4% are exposed to more than twice the WHO guideline. NO and SO_2 levels are below WHO guidelines and represent little risk at present	TSP approximately three time the WHO (1979) annual average guideline; occasional violations of national air quality standards for SO_2 and NO_2.
Impact	No information from the local or national government was given.	The number of urban children reporting respiratory-related cases was higher than the number of rural children. Respiratory infections increased from 10.9% of the total out-patient visits in 1996 to 11.6% in 1998.	Studies show relatively higher prevalence of most respiratory diseases in more highly polluted urban areas compared with less-polluted areas of Mumbai and rural areas.
Response	Jakarta's 'PRODASIH' Clean Air Programme includes controlling and checking the road worthiness of motor vehicles (including vehicle emissions), managing traffic to reduce traffic congestion, promoting the use of clean fuel (including LNP and CNG and lead-free gasoline), controlling industrial emissions, and managing land use.	A coherent legislative or policy framework is lacking. There are no ambient air quality standards and no systematic air quality monitoring is carried out. However recent initiatives, notably the banning of diesel-operated three-wheelers, signal a more positive move in the management of air quality within the Kathmandu urban zone.	Relocation of industries and increased stack heights; switching to cleaner fuels (natural gas, unleaded petrol); national legislation on air quality standards, stringent emission standards for new vehicles, stringent fuel standards for gasoline and diesel, inspection and maintenance system for in-use vehicles.

Table 5.2 contd.

	Seoul	Singapore	Taipei
Driving force	Rapid increase in the number of motor vehicles since the late 1980s. Now more than 2.2 million, one-third of which are diesel-fuelled.	One of the most rapidly growing economies of the 'Asian Tigers' leading to rapid urbanisation and industrialisation. Increased wealth has led to high aspirations to own cars.	Increase in GNP leading to increased demand for private transport - especially motorcycles. Also increasing frequency of sandstorms in mainland China
Pressure	Mainly motor vehicle exhaust emissions coupled with topographical conditions (encircled by high mountains) which make Seoul susceptible to lingering air pollutants.	Motor vehicle exhaust emissions and seasonal smoke/haze resulting from forest fires in Indonesia.	Exhaust emissions from motor vehicles (especially 2-stroke motorcycles) and PM from sandstorms in mainland China.
State	Over the last decade, large reductions in winter-time concentrations of SO_2, TSP and CO have been achieved. However, NO_x levels have not reduced due to the increased volume of traffic and so photochemical smog continues to reduce air quality throughout the year. Ozone levels, sometimes high enough to violate Seoul's ambient air standards, are on an increasing trend.	The ambient air quality in Singapore is generally good and during 2000, the levels of air pollutants were within the WHO long-term goals and the USEPA standards	Taipei measures ambient air pollution in terms of a pollutant standards index (PSI). The goal of 197 annual exceedences of PSI-100 was met in 2001. However, sandstorms from mainland China can cause episodic problems (e.g. 255 exceedences of the PSI between January and April 2000).
Impact	Problems mainly evident in the spring during the 'yellow dust storm' phenomena, when transboundary air pollution combines with dust storms from the deserts of northern China and Mongolia. These have serious health impacts on the citizens of Seoul. Deaths related to cardiovascular illnesses, asthma and other respiratory illnesses have been shown to increase by 4.1% on yellow sand days.	There have been no major studies conducted in Singapore on the health impacts of ambient air pollutants. However, the Singaporean government considers the health risks to be serious and bases its policies on general health impact data for ambient air quality.	Children in the urban Taipei had significantly more respiratory symptoms (day or night cough, chronic cough, shortness of breath, and nasal symptoms) and diseases (sinusitis, wheezing or asthma, allergic rhinitis and bronchitis) when compared with those living in the rural areas.
Response	Seoul has a very high air quality management capability. It has a sophisticated and comprehensive air pollution monitoring network and has enacted many policies and enforcement strategies in the transport and energy sectors. The Republic of Korea's new emission standards are comparable to those of Europe and North America. Seoul has taken various measures to reduce air pollution including switching to cleaner fuels, mandatory	Singapore monitors ambient air quality through the 'Telemetric Air Quality Monitoring and Management System' (TAQMMS) which comprises 18 remote air monitoring stations linked to a Central Control System via dial-up telephone lines. There are strictly enforced air pollutant emission standards for stationary and mobile sources. For mobile sources, there are also stringent emission standards and fuel quality standards, mandatory inspection of vehicle	Taipei has one of the most comprehensive air quality management systems in Asia. For the past few years, the Taipei EPB has implemented a programme to improve air quality and has succeeded in continuously reducing polluting emissions. Measures to improve air quality have included: inspection of point sources (and assisting them to control emissions), reducing sulphur content of diesel, promotion of low emission

5.4 Urban air quality trends

It is difficult to accurately assess air quality trends for cities in the early stages (0 – II) of their developing air pollution problems because of the lack of adequate monitoring data or because monitoring systems have been installed only recently. However, evidence that does exist suggests that rapid increases in industrial and particularly transport emissions in these cities, have caused a dramatic decline in air quality over the last ten years. For those cities at stage III (i.e. with 'moderate and decreasing levels of air pollution'), air quality over recent years has improved substantially in terms of the primary air pollutants (such as SO_2, NO_x, Pb, CO and SPM) although attention has now shifted to the increasing incidence of photochemical ozone and smog episodes and the effects of transboundary air pollution from neighbouring countries. Cities at stage IV generally experience good air quality although transboundary air pollution (e.g. of 'yellow sand' from China) may still cause occasional problems.

5.5 Air quality monitoring

There is a wide range of air quality monitoring capability across Asian cities from state-of –the-art computerised systems in cities such as Singapore, Seoul, Taipei and Hong Kong to very rudimentary capability in poorer cities such as Dhaka and Kathmandu. It is clear that an efficient, well-coordinated, properly-funded monitoring capability is an important pre-requisite for improving air quality in cities. Without such a capability, the magnitude and sources of the air pollution problems cannot be gauged; cost-effective and targeted responses are impossible and the success or otherwise of mitigation measures cannot be gauged.

5.6 Impacts of air pollution

The impacts of air pollution are not always well characterized especially for cities in the early stages of their developing air pollution problems. Blood-Pb levels are often found to be higher than maximum tolerable limit for cities at stage II because of the continued use, or only recent banning, of leaded petrol. Also, for cities at stage II, air pollution is estimated to cause thousands of premature deaths and millions of extra cases of sickness at huge economic cost. For cities at stage III, respiratory and cardiovascular diseases continue to adversely affect the population, especially those living or working near busy roads. For cities in group IV, there is still evidence that the urban population has significantly more respiratory symptoms compared with those living in the rural areas.

5.7 Enforcement and control strategies

In cities in the early stages of their developing air pollution problems a coherent legislative or policy framework is often lacking, there may be no ambient air quality standards and no systematic air quality monitoring. However, there may be *ad hoc* efforts in these cities to encourage or compel some switching to cleaner fuels (such as CNG and LPG) especially for buses, taxis and 3-wheeled vehicles, and the introduction of unleaded petrol. Conversely, in cities. with stabilising or decreasing air pollution levels, AQM is much more advanced with ambient air quality standards and comprehensive air quality monitoring systems. There will be legislation to control emissions from stationary and mobile sources including stringent vehicle emission standards (equivalent to EU standards in some cases), stringent fuel standards and efficient inspection and enforcement systems. There may also be schemes such as the 'Air Pollution Index' or 'Ozone Alert System' to inform the public about air quality and raise awareness, as well as strategies to develop and encourage the use of public transport.

5.8 Lessons to be learnt from air pollution control management in Europe and North America

The lessons to be learnt from AQM in Europe and North America (see Chapter 4), and in the more advanced cities of Asia, are that improvements in air quality can only be achieved through a co-ordinated strategy to address all aspects of the air pollution problem. Such a strategy would include the modification of industrial processes, traffic systems and commercial and residential fuel-use practice, or by the installation of appropriate control technologies. Also, the implementation of economic measures and of policies, laws and regulations, accompanied by monitoring and enforcement, need to proceed hand in hand. Obviously, technical and management capacity is required at every stage of the improvement process. The financial implications of any projected measure are substantial. It is probably here, and in the effectiveness of specific measures, in practice, that city co-operation has the greatest role to play.

Local air quality management is considered an effective way to address urban air pollution problems. City authorities are better positioned to develop local air quality strategies in cooperation with all stakeholders and to improve poor air quality hotspots and report the state of local air quality to the public. Local action and cooperation is the most effective way of addressing urban air quality problems. This involves cooperation between city authorities, industry, commerce, public transport providers and the public.

5.9 Recommendations

- A greater degree of sharing of successes and failures in a full range of air pollution control management initiatives should be continued and more vigorously promoted.

- More comprehensive and up-to-date documentation is required, covering all 22 of the major and mega cities in the region, in order to inform the consultation process.

- Cities might best improve their AQM by working together and exchanging experience on common practice with other Asian cities at similar or slightly more advanced stages of development.

- Local air quality management should be adopted as the preferred mode of AQM.

- Health impacts should be assessed on the basis of a viable health surveillance system.

Footnotes

[1] A limitation of this approach, which must be borne in mind, is that occasionally, short-term elevated levels of SPM may be due to long-range transboundary transport of, for example, 'yellow sand' from the Chinese mainland in the case of Taipei and Seoul.

6

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Annex 1

Management Capabilities Assessment Index

Please answer "yes" or "no" to the following questions.

Indicators of air quality measurement capacity

1. Indicator of capacity to measure chronic health effects

. At least one site in a residential area which has been monitoring for one year or more with a frequency of greater than one day in six for the following pollutants:

NO_2
SO_2
Particulate matter
CO
Pb
O_3

2. Indicator of the capacity to measure acute health effects

. At least one site in a residential area which has been monitoring for one year or more and provides daily or hourly mean values, each day for the following pollutants:

NO_2
SO_2
Particulate matter
CO
Pb
O_3

a Daily mean ozone levels are not a useful indicator since night-time levels are usually very low; therefore, daytime hourly maximum or eight-hour concentrations indicators should be used for acute health effects.

There are no acute effects of lead and, therefore, no indicator.

3. Indicator of the capacity to measure trends in pollutant concentrations

. At least one site in a residential area which has been monitoring for a minimum of five years capable of providing annual mean values for the following pollutants:

NO_2

SO_2
Particulate matter
CO
Pb
O_3[b]

b Annual mean ozone is not a useful indicator and maximum, 98th percentile, second highest value or some equivalent statistic should be used.

4. Indicator of the capacity to measure the spatial distribution of pollutants

. At least three sites, one site in each of a predominantly residential, commercial and industrial area of the city, which have been monitoring for at least one year using equivalent equipment and methodologies (or those for which inter-comparisons have been conducted), with a monitoring frequency greater than one day in six, for the following pollutants:

NO_2
SO_2
Particulate matter
CO
Pb
O_3[c]

c The ozone sites should be located upwind and downwind in the suburbs of the city, and in the city centre, due to the secondary nature of O_3 pollution.

If mapping of pollutants had been conducted using modelling and an emissions inventory, this would be considered as meeting the indicator's criteria.

5. Indicator of the capacity to measure kerbside concentrations.

. A site monitoring within 3 m of the roadside or kerb operating for one year or more at least one day in six, for the following pollutants:

NO_2
SO_2
Particulate matter
CO
Pb

There is no indicator for O_3 since concentrations are very low at the roadside due to depletion by reaction with NO.

6. Indicators of data quality

. Instruments calibrated at least monthly
. Calibrations and analysis conducted using certified solutions or gases
. Site audits conducted to compare measurements from different instruments in the network, (inter-comparisons)
. Auditing procedures conducted by an independent body
. Sample analysis and audits performed by a laboratory with an accreditation certificate
. Sites reviewed at least every five years to ensure they still meet the objectives of the network and hence are appropriate

. Data are validated (critically assessed) before they are finally ratified
. Inter-comparison exercises are conducted between different measurement techniques and /or instruments from other networks

Indicators of data assessment and availability

1. Indicators of the capacity to analyse data

. Statistics and data analysis determined from the raw data include:

Means (Daily, monthly, annual)
Maximum values (Daily, monthly, annual)
Percentiles
Exceedances of national or WHO air quality standards
Trends
Spatial distribution (mapping)
Exposure assessments
Epidemiological studies
Modelling with meteorological measurements
Prediction modelling

. Computers are used in data assessment

2. Indicators of data dissemination

. Air quality information about the city is available:

As raw data
In newspapers
On television and radio
On information boards in the city centre

. Data are accessed through (select one):

Published reports which are readily available
Internal reports and bulletins
Only when requested – no formal documents available

. Air quality warnings are issued to the public during episodes of pollution

Indicators of emissions estimates

1. Indicators of emission estimates

. Estimates of emissions from the following source categories are available:

Domestic emissions
Commercial emissions
Power-generating facilities emissions
Industrial emissions

Cars
Motor cycles
Others, e.g., ships, aircraft
HGV/buses

2. Indicators of pollutant emissions estimates

. Estimates of emissions from the following pollutants are available:

Nitrogen oxides
SO_2
Particulate matter/smoke
CO
Pb
Hydrocarbons

3. Indicators of the accuracy of emissions estimates

. The inventory is calculated using (either/or):

Estimates based upon some actual measurements

Estimates based upon fuel consumption statistics and emissions estimates only

. Emissions from non-combustion processes are included

. The inventory is cross-checked (validated)

. Inventories are conducted at least every two years

. Future inventories are planned

4. Indicators of the availability of the emissions estimates

. Details of the inventory are (either/or):

Published in full
Partially available

Indicators of air quality management capability tools

1. Indicators of the capacity to assess air quality acceptability

. Acute ambient air quality standards have been established for:

NO_2
SO_2
PM
O_3

CO

(Acute standards refer to those with an averaging time of one day or less.)

. Chronic ambient air quality standards have been established for:

NO_2
SO_2
PM
Pb

(Chronic standards refer to those with an averaging time longer than one day.)

. Regulations exist to enforce compliance with air quality standards

. Local air quality standards exist to take account of sensitive ecosystems

. Air quality standards or guidelines are being introduced and or amended in the future

2. Indicators of the capacity to use air quality information

. Emissions controls imposed upon:

Cars
Natural gas vehicles/buses
Domestic dwellings
Heavy industry
Light industry

. Penalties imposed for exceeding emissions limits from:

Cars
Natural gas vehicles/buses
Domestic dwellings
Heavy industry
Light industry

. Local air quality considered in development of new:

Roads
Industrial plant

. Unleaded petrol available in the city

. Additional emission controls are imposed during episodes of particularly poor air quality

A report of the
Air Pollution in the Megacities of Asia project
www.asiairnet.org