3.1 Bangkok

Situational Analysis and Urban Air Quality Trends

Bangkok is the capital city and main port of Thailand with an area of 1569 km^2 and an estimated population of 7.3 million full-time inhabitants and over 10 million day-time inhabitants (UN, BMA 2001). The tropical climate of Bangkok and its proximity to neighbouring flat plains and the Gulf of Thailand lend to free air movements and land-sea breezes. (Most pollution from industrial zones near Bangkok by-pass the city due to prevailing winds and the Bangkrajao forest greenbelt (BMA, 2001). Despite these geographical buffers, the pollutant concentrations and frequency of exceedence of Bangkok's ambient air quality standards for total suspended particulates (TSP), particulate matter with diameters less than 10 micrometres (PM_{10}), and carbon monoxide (CO) are high enough to result in significant adverse health impacts on the local population.

The World Bank cites transport, industry, construction, power generation, indoor air pollutants and refuse burning as the main causes of air pollution in Bangkok, with most air pollutants being emitted by the transport sector. The construction industry also causes high level of dust pollution. Lack of proper planning and zoning of housing areas has also aggravated the seriousness of air pollution.

Bangkok's transport system and resulting pollution problems are unique as Bangkok has 1,357 km of canals and 4,075 km of road with a total area of 58.45 km^2. The increase in the number of vehicles in Bangkok has not been matched by a proportional increase in road construction leading to traffic congestion, transportation delays and added pollution. It is reported that smoke from traffic is so severe that reductions in visibility have become a safety hazard on the road.

Although vehicle population in Bangkok has increased by an average of 300,000 vehicles per year since 1990, roadside CO, sulphur dioxide (SO_2) and oxides of nitrogen (NO_x) concentrations in Bangkok have been decreasing since 1993. In 2000, no violations of SO_2 and nitrogen dioxide (NO_2) standards were observed both in the general areas and at roadside sites in Bangkok. This coincides with the enforcement of emission standards for new light-duty gasoline vehicles in 1992 which require vehicles to have catalytic converters in order to reduce emissions to meet the standards. Additionally, gasoline quality was also improved to give an oxygen content of between 1-2 per cent by weight thus allowing more complete combustion of gasoline, especially in the existing vehicle fleet. Air concentrations of lead (Pb) have also been reduced significantly due to measures by the government to limit the use of leaded gasoline.

Particulate matter is a major air pollution problem in Bangkok, especially along streets with very congested traffic producing start-stops cycles of vehicles with very low speeds. In 2000, approximately 5.9 per cent of 24-hour average concentrations of roadside TSP and the annual mean concentration of TSP exceeded the standard. By weight, approximately 40 per cent of TSP in Bangkok is from diesel vehicles, 40 per cent from road dust and the remaining 20 per cent from sea salt particles and industries. It is estimated that 60 percent of TSP in Bangkok is PM_{10}, whose annual average and roadside levels also consistently exceed the standard. Levels of ozone (O_3) have also exceeded the WHO guideline. It was observed in 2000 that 0.3 per cent of hourly ambient O_3 concentrations exceeded the air quality standard of 100 ppb, mostly in the areas downwind from the centre of Bangkok which might indicate that Bangkok may be experiencing a photochemical smog problem (PCD Thailand, 2001).

A mobile source emission inventory for Bangkok was developed for the first time in 1994. In 1997, the inventory had been improved to encompass the area of Bangkok Metropolitan Region (BMR). The emission factors for pollutants emitted from vehicles driven at different speeds for given vehicle types and characteristics were calculated by using the USEPA MOBILE 5 emission factor model.

Table 3.1.1 Air quality in the general areas of Bangkok in 2000 (PCD Thailand, 2001)

	Concentrations				
Pollutants	Range	95 percentile	Average	Standard	Frequency of exceedence of standard
TSP (24-hr), µg/m^3	20 – 330	190	90	330	0/351 (0%)
PM_{10} (24-hr), µg/m^3	18.6 – 169.4	102.7	56.1	120	37/1,725 (2.1%)
CO (1-hr), ppm	0.0 – 12.50	2.6	0.96	30	0/70,186 (0%)
CO (8-hr), ppm	0.0 – 8.20	2.31	0.97	9	0/71,609 (0%)
O_3 (1-hr), ppb	0.0 - 203	54	15.6	100	161/54,415 (0.3%)
NO_2 (1-hr), ppb	0.0 - 136	22.8	22.8	170	0/67,094 (0%)
SO_2 (1-hr), ppb	0.0 - 161	20	6.7	300	0/72,750 (0%)
Pb (1-month), µg/m^3	0.02 - 0.33	0.21	0.09	1.5	0/93 (0%)

Table 3.1.2 Air quality at the roadside sites in Bangkok in 2000 (PCD Thailand, 2001)

	Concentrations				
Pollutants	Range	95 percentile	Average	Standard	Frequency of exceedence of standard
TSP (24-hr), µg/m^3	50 – 480	350	190	330	25/424 (5.9%)
PM_{10} (24-hr), µg/m^3	27.0 – 244.4	146.6	82.6	120	206/1,613 (12.8%)
CO (1-hr), ppm	0.0 – 18.5	5.6	2.20	30	0/41,879 (0%)
CO (8-hr), ppm	0.0 – 13.13	5.17	2.19	9	34/42,452 (0.1%)
O_3 (1-hr), ppb	0 - 136	31.0	7.6	100	5/23,615 (0.02%)
NO_2 (1-hr), ppb	0 - 169	81.0	35.4	170	0/22,962 (0%)
SO_2 (1-hr), ppb	0 - 12	24.0	9.2	300	0/22,988 (0%)
Pb (1-month), µg/m^3	0.03- 0.24	0.16	0.09	1.5	0/62 (0%)

Air Quality Monitoring

The central government of Thailand, including the Pollution Control Department, and the Ministry of Science, Technology and Environment, has played a vital role in air quality monitoring. At present, the Pollution Control Department is operating a comprehensive automated ambient air quality monitoring network consisting of 53 monitoring stations throughout Thailand. Different air pollutants are measured such as CO, NO_x, SO_2, O_3, TSP, PM_{10}, Pb, hydrocarbons (HC) and hydrogen sulphide (H_2S).

Monitoring of outdorr air quality in Bangkok has been carried out for more than 10 years. The network has been improved, upgraded, and expanded from time to time. Currently, monitoring of air quality in Bangkok is being carried out in both general background areas and kerbside areas. There are seventeen fully-automated roadside air quality monitoring stations to monitor the air pollution and provide meteorological data in Bangkok. The Bangkok Metropolitan Administration (BMA) also has one ambient air and noise quality monitoring station at Rajthevi district office along with one mobile unit. Meteorological parameters are also measured at many of the monitoring sites which increases the capability to analyse the pollution situation. Continuous air quality monitoring stations are placed in residential, commercial, industrial and mixed areas of Bangkok. The locations are carefully selected to ensure that monitoring stations are not

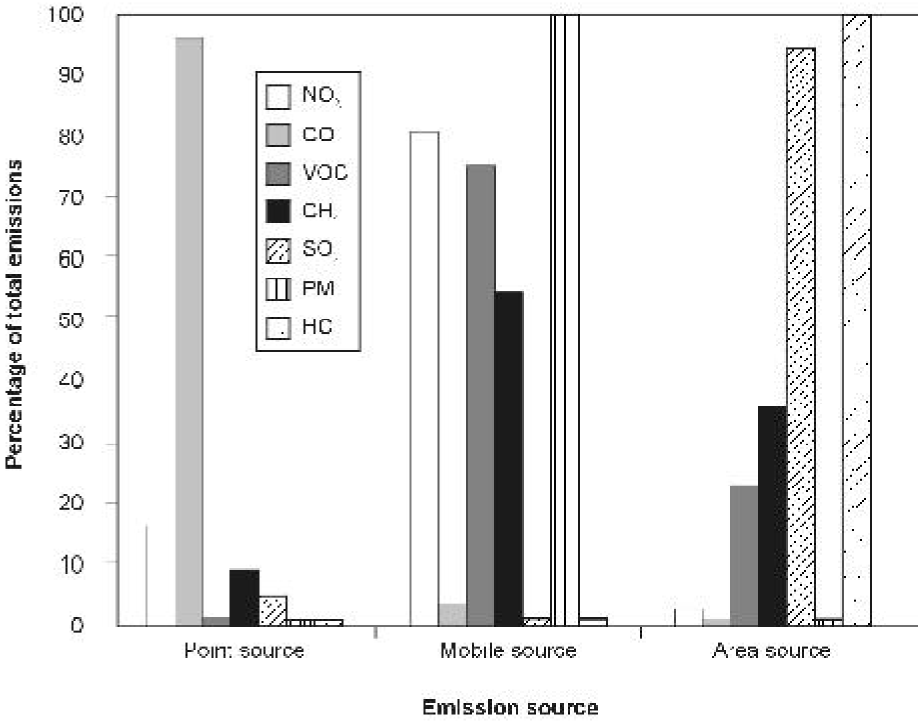

Figure 3.1.1 Percentage of emissions in Bangkok Metropolitan Region by source type in 1997
Source: PCD Thailand, 1997

directly influenced by any particular major sources so that the quality of the general ambient air in Bangkok is monitored and impacts to general population can be evaluated.

Impacts of Air Pollution

Studies have shown that air pollution has harmfully affected the health of Bangkok residents. In comparison with other Thai citizens, Bangkok residents are prone to chronic inflammation respiratory diseases. The cases of throat irritation of varying degrees of severity are as high as 60 per cent in the general Bangkok population.

Most of the health studies conducted in Bangkok and its surrounding areas have focused on three main air pollutants: PM_{10}, Pb and CO. The health effects examined were centred on respiratory-related illnesses. A World Bank-funded project in Bangkok in 1998 showed an association between respiratory symptoms and PM_{10}. This study found increases in daily incidence of upper respiratory symptoms per 30 µg/m^3 increase of PM_{10} oft 9 per cent for children, 26 per cent for adults who worked and lived at the roadside, and 9 per cent for adults who worked and lived in more protected environments. Similar exposure-response relationship were found for lower respiratory symptoms. The study also found that a 30 µg/m^{3}daily increase in PM_{10} resulted in a 5.3% to 17.6% daily increase in hospital admissions. (Radian International, 1998)

According to figures from the Bangkok Air Quality Management Project, a 10 µg/m^3 reduction in the annual average of PM_{10} concentrations in Bangkok would result in an estimated reduction of:

- 700–2,000 premature deaths;
- 3,000–9,300 new cases of chronic respiratory diseases;
- 560–1,570 respiratory and cardiovascular hospital admissions;
- 2,900,000–9,100,000 days with respiratory symptoms severe enough to restrict a person's normal activities; and
- 2,200,000–74,000,000 days with minor respiratory symptoms.

Economic evaluation of air pollution in Bangkok has been well documented compared to other Asian cities. The World Bank-funded study found that Bangkok residents spent an average of 12.5 per cent of their total medical expenses on respiratory illnesses alone. It was also determined that a 20 µg/m^3 reduction in annual average PM_{10} concentrations in Bangkok would result in an estimated savings of 65-175 billion baht. These savings largely outweigh the costs of mitigation measures used to reduce particulate matter (Radian International, 1998).

Enforcement and Control Strategies

Both the central Thai government and the BMA have developed a clear policy to improve air quality. A high priority has been placed on improving air quality and the government's general policy on air pollution is to mitigate air pollution problems in non-attainment areas and to keep air quality in attainment areas within ambient air quality standards. The setting of ambient air quality standards, emissions standards, and fuel quality standards is predominantly the responsibility of the national government.

Emissions standards are set by the central government and enforced mainly through the local government, although the national government controls emissions for stationary sources. All new and existing stationary sources are required to be in compliance with the emission standards of the Ministry of Industry of Thailand under the Factory Act and of the Ministry of Science, Technology and Environment under the Enhancement and Conservation of National Environmental Quality Act.

As proof of its commitment to improving air quality, Thailand adopted some of the Asian regions' strictest standards for vehicle emissions. Thailand has adopted the vehicle emission standards of the European Union as reference standards for light duty gasoline vehicles, light duty diesel vehicles, and heavy duty diesel vehicles. Implementing dates in Thailand are generally 2 years after the same standards have been enforced in Europe. Due to the large number of motorcycles in Bangkok, Thailand has adopted the second and third stage motorcycle emission standards of Taiwan, the world's most stringent. Standards are implemented through new-car standards set by the central government, in addition to the requirement for routine inspection and maintenance of vehicles by the municipal administration.The main role of the local government in air quality management is in enforcement of existing policies through inspection and public awareness-raising. BMA declared 1999 as the Air Pollution Mitigation Year and implemented the following 13 measures:

- Providing free car engine tune-up service stations for the public.
- Publishing car engine maintenance manuals for public distribution
- Setting up black smoke inspection points in 50 districts jointly with the traffic police.
- Setting up six mobile black-smoke inspection units in 6 areas.
- Setting up motorcycle white smoke and noise level inspection units in the inner area of Bangkok.
- Reporting about air pollution in critical areas in cooperation with Pollution Control Department through the display boards and air quality reports to promote pollution-free streets.
- Designating pollution-free streets, which prohibited single occupant-vehicles. Originally, there were 3 streets, later increased to 8 streets.
- Paving road shoulders to reduce dust.
- Enforcing windscreens for buildings which were under construction.
- Enforcing dust controls for trucks by covering loads and cleaning wheels.
- Putting up campaign boards to inform the public on various measures being implemented.
- Designating car-free streets to reduce air pollution.
- Improving fuel quality by joint efforts to reduce air pollution.

Table 3.1.3 Ambient air quality standards of Thailand (1995)

Pollutants	1- hr average		8 - hr average		24 - hr average		1- month average		1 - year average**		**Methods**
	mg/m^3	ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3	ppm	
CO	34.2	30	10.26	9	-	-	-	-	-	-	Non - Dispersive Infrared Detection
NO_2	0.32	0.17	-	-	-	-	-	-	-	-	Chemiluminescence
SO_2/[a]	0.78	0.30	-	-	0.30	0.12	-	-	0.10	0.04	UV - Fluorescence
TSP	-	-	-	-	0.33	-	-	-	0.10	-	Gravimetric - High Volume
PM_{10}	-	-	-	-	0.12	-	-	-	0.05	-	Gravimetric - High Volume
O_3	0.20	0.10	-	-	-	-	-	-	-	-	Chemiluminescence
Pb	-	-	-	-	-	-	1.5	-	-	-	Atomic Absorbtion Spectrometer

Notes:

geometric mean; **/a 1-hr SO_2 Standard 1.3 mg/m^3 for Mae Moh area

Furthermore, the national and municipal governments have worked together on public transport issues to reduce the use of motor vehicles. The Thai Government, through cooperation and planning with the BMA, has also developed mass transit projects for solving transportation problem, particularly rail transport system.

Conclusions

Vehicular emissions have been reduced by controlling fuel quality and establishing emission standards for new vehicles. Phasing out of Pb in gasoline, completed in 1996, resulted in a substantial reduction of Pb in air down to approximately 0.22 mg/m^3, well below the World Health Organisation's guideline value of 0.5 mg/m^3 (annual average). The introduction of unleaded gasoline also enabled the use of catalytic converters in gasoline cars and new emission standards led to the improvement of diesel vehicles. The most obvious source of air pollutants in Bangkok is the two-stroke motorcycles, which emit large amounts of smoke. Standards for low-smoke lube oil and emission standards are being implemented in stages resulting in gradual conversion from two-stroke engines to four-stroke engines. Air quality in Bangkok has improved enormously compared with previous decades largely as a result of there being far fewer buses, trucks and motorcycles emitting smoke.

There has been a vast improvement in Bangkok's air quality management capabilities in recent years. Stringent unleaded fuel policies have greatly reduced ambient lead concentrations and new vehicle emissions standards have helped to control ambient and roadside levels of CO, NO_x and SO_2. Emissions controls have been progressive and are contributing to improving air quality, although the levels of TSP, PM_{10} and O_3 have increased in recent years. It is notable that the Thai government has pursued the stringent emissions standards of Europe. Although Bangkok has still to attain relatively "clean" urban air, the integrated approach and strategies of national and local air quality management promise further improvements in Bangkok's air.

3.2 Beijing

Situational Analysis and Urban Air Quality Trends

Beijing, the capital of the People's Republic of China (PRC) is an independently administered municipal district, covering a vast 16,808 km^2. The capital of the world's most populous country, Beijing is one of the fastest growing urban agglomerations. The Beijing Environmental Protection Bureau (EPB) estimates the population of metropolitan Beijing to be 12.5 million, with a floating population estimated to be about 3.5 million.

With its entry into the World Trade Organization in 2001, China has made great progress towards modernization, with Beijing at its political centre. Beijing's economy has had a growth rate of 10 per cent per year from 1996–2000 and is expected to grow at 9 per cent per year for the next five years. However, with such rapid economic development, Beijing is also facing the problems of growing urbanization. Whereas the major sources of air pollution in the past were from the development of industry in the city, nowadays a major source is emissions from the transport sector, and Beijing, in its long-range planning to modernize, has placed a heavy emphasis on motor vehicles as the basis for transportation planning. The most popular mode of transportation is still the bicycle with Beijing having more than 8 million bicycles. However, due to rapid economic development and higher household incomes, in conjunction with a more consumer-based, social status-conscious society, the residents of Beijing are moving towards vehicular transport. Although car ownership has recently increased dramatically – 300 per cent in the past decade – the number of cyclists has not significantly decreased due to the accessibility of bicycles. However, the per capita usage in terms of kilometres travelled has declined. As part of the 2008 Olympic Games Action Plan to curb urban air pollution, Beijing will adopt administrative measures to encourage greater bicycle use (China Daily, 2002).

Industry experts attribute the rapid rise in the number of motor vehicles to more foreign automobiles being imported following cuts in tariffs, abolition of quota systems, falling prices for domestically-made automobiles and rising incomes for Beijing residents.

Compared to other large Asian cities, a WHO/UNEP study found that, in 1992, Beijing had moderate lead (Pb) problems, serious-to-moderate sulphur dioxide (SO_2) problems and a moderate ozone (O_3) problem (UNEP/WHO, 1992). In 1998, the Beijing EPB cited total suspended particles (TSP), SO_2 and nitrogen oxides (NO_x) as the main problem air pollutants. TSP exceeded the local and national standards by 89 per cent, SO_2 by 100 per cent and NO_x by 204 per cent (Beijing EPB, 1999). A 2001 analysis by the Beijing EPB showed that the increased number of motor vehicles in the city mirrored an increase in ambient levels of NO_x. The dominant sources of SO_2 in Beijing are heavy industries and power plants, which make up 72 per cent of total SO_2 emissions. The sharp increase in SO_2 concentrations in industrial areas from 1990 seems to have been caused by industrialization, urbanization and increased consumption of fuel for heating. The growing number of diesel vehicles contributed only a minor amount to the total SO_2 emissions.

According to the State of Environment Report 2000, published by China's State Environment Protection Agency (SEPA), 36.5 per cent of the 338 Chinese cities, for which monitoring data are available, met the national air quality standards applicable to residential areas in 2000 – an increase of 3.4 per cent compared to 1999. Those with "moderate" or "heavy" pollution fell from 40.6 per cent to 33.1 per cent. Leaded gasoline was prohibited nationwide in mid-2000, potentially eliminating 1,500 tons of annual lead emissions. In Beijing, the average concentration of SO_2 is reported to have fallen by 13 per cent compared to 1999; emissions of NO_x have been reduced by 15 per cent, TSP by 14 per cent and carbon monoxide (CO) by 7 per cent. In 1999, O_3 levels exceeded standards for a total of 199 days, however, these levels have since decreased (SEPA, 2001).

Plans for the 2008 Beijing Olympics have catalysed many environmental efforts by Beijing Municipal Government and the national government to clean up Beijing. One of the major beneficiaries of this effort is