3.9 Mumbai

Situational Analysis and Urban Air Quality Trends

Mumbai is located on India's west coast and consists of a peninsula originally composed of seven islets. Drainage and reclamation have caused the islets to join and form the present – day Mumbai (Mumbai) Island, with the Arabian Sea to the west, and Mumbai harbour and the inlet of Thane creek to the east. Mumbai has a mean elevation of 11 metres above sea level and consists of several islands on the Konkan coast. It has a tropical savannah climate. The annual average temperature is 25.3 °C, with a maximum of 34.5 °C in June and minimum of 14.3 °C in January. Average annual precipitation is 2,078 mm with July having the maximum rainfall. High pollution concentrations usually occur in the winter when adverse meteorological situations with weak winds may prevail. Mumbai harbour is India's busiest, handling more than 40 per cent of India's maritime trade. Besides being India's financial and commercial centre, Mumbai is also one of the most industrialized Indian cities. There are approximately 40,000 small and big industries in the city, of which 32 have been classified as hazardous. Industries in the air-polluting category include textile mills, chemical, pharmaceutical, engineering and foundry units. Process emissions and those from fuel consumption, constitute the main sources of air pollution. Major air pollution sources include a giant fertilizer/chemical complex; two oil refineries and a thermal power plant, all based in CHEMBUR, a suburb on the eastern coast of Mumbai (World Bank, 1997). Mumbai's population was 16.4 million in 2001 (www.censusindia.net/results/million_plus.html)

Heavy industry on the island tends to create most of the pollution, which is often blown by westerly winds over mainland Mumbai. The natural wind movements cause a ventilation effect and help maintain the quality of ambient air over the coastal city. Thus, the annual average concentrations of SO_2 and NO_2 in Mumbai are lower than that of the inland Delhi megacity. However, 24 hour averages of SO_2 and NO_2 do show occasional violations of national air quality standards. (CPCB, 2001)

Mumbai is the only Indian city to have good environmental pollution data covering the last 25 years. There has been a declining trend of SO_2 over the years, and besides a few aberrations, the annual mean levels have been below the WHO guideline value of 50 µg/m^3. This may be because of the low usage of furnace oil and the use of low-sulphur coal for heating purposes in the textiles mills. Moreover, a number of them were closed in the inner city area and relocated elsewhere. This is the main reason for the declining trends of SO_2 in the atmosphere. The chemical industry accounts for nearly all SO_2 emissions in Mumbai, estimated to be around 157,000 tonnes per annum. The levelling off in emissions is due to the introduction of natural gas as a major fuel source from the newly opened gas fields located off the west coast. Monitoring conducted in the Air Pollution Survey of Greater Mumbai indicates that SO_2 levels probably started to decrease as a result of planning measures such as the relocation of industry and increased stack height.

In 1978, the annual level of NO_2 was around 13 µg/m^3, which was less than the WHO guideline value of 40 µg/m^3 but from 1978 onwards up to 1982 there was a steep growth in the levels of NO_2 reaching 50 µg/m^3 in 1991, well over the WHO guideline value. This increase in the levels of NO_2 is probably due to the tremendous growth in the number of petrol and diesel vehicles in the city.

Of greater concern are the levels of suspended particulate matter (SPM) as annual concentrations always exceeded the WHO guideline range (60-90 µg/m^3) reaching a peak of 385 µg/m^3 in 1987. After 1987, the annual average came down to 285 µg/m^3 by 1991 and it more or less maintained the same level until 1999. However, SPM emissions have increased significantly in recent years and are projected to continue rising. Domestic emissions have remained relatively constant in the past and are forecast to remain stable despite the projected increase in population. This is in part through the switch from biofuels (such as wood charcoal and animal dung) and coal, to less dirty fuels such as liquid petroleum gas (LPG) and kerosene. SPM emissions attributable to transport have increased greatly. Recent estimates suggest that transportation, especially motor vehicles, accounts for approximately 35 per cent of particulate emissions in the Greater Mumbai area. This proportion is likely to increase further with increasing motor vehicle traffic. Diesel vehicles and very old vehicles are the main sources of particulate matter from the transport sector.

It is estimated that domestic CO emissions account for 11 per cent of the total emissions. Over the past 20 years, the proportion of domestic CO has decreased as the transport sector has gained in importance. However, domestic emissions have increased overall and are likely to increase further in coming years with increasing population. Recent research on CO emissions suggests that domestic sources and in particular biofuels, such as wood, charcoal and dung, make a larger contribution to urban emissions than originally believed. Personal exposure, especially indoors is a very important factor for consideration when examining health effects.

A comprehensive emissions inventory For Mumbai was developed as part of the URBAIR project (World Bank, 1997). Table 3.9.1 gives the total air pollutant emissions from various sources in Greater Mumbai. Re-suspension of road dust, stone crushers, refuse burning, wood combustion and diesel vehicle exhaust were identified as the major contributors to the total TSP load. Similarly, for SO_2 emissions, the major contributors were industrial fuel oil combustion and power plants. In the case of nitrogen oxides (NO_X), major emission sources were vehicles and power plants.

The number of motor vehicles in India increased from 0.3 to 37.2 million during the period 1951–1997 and in 1997 the total number of registered motor vehicles in Mumbai was 800,000 (MoST, 2000). The increase in motor vehicle population is reflected in CO emissions from this source. Estimated emissions for Mumbai have increased from 69,000 tonnes per annum in 1970 to 255,000 tonnes per annum in 2000. Most of this increase is attributable to motor vehicle transport which is estimated to be responsible for 89 per cent of total CO emissions.

Petrol-driven motor vehicles are the main source of ambient lead (Pb). The number of petrol-driven motor vehicles has risen enormously. Monitoring indicates that annual airborne Pb levels have fallen significantly since the 1970s to between 0.25 and 0.33 $\mu g/m^3$, well below the WHO (2000) guideline of 0.5 $\mu g/m^3$ although it is likely that kerbside levels will be much higher. Pb levels in street dust are also likely to be high such that accumulation and re-suspension of dust will also result in increased exposure.

Air Quality Monitoring

The Municipal Corporation of Greater Mumbai (MCGB) monitors the air quality within the city limits; MCGB has measured ambient air quality regularly at 22 monitoring stations in Mumbai for over 15 years. These monitoring stations measured the air pollutant levels according to the WHO proposed guidelines and methods. The pollutants measured are SO_2, SPM, oxides of nitrogen (NO_x) and ammonia (NH_3). Ambient air quality is also occasionally measured at selected

Table 3.9.1 Total annual emissions in Greater Mumbai, 1992-1993 (tonnes/year)

Emission sources	Total suspended particulate matter (TSP)	PM_{10} (Particulate matter less than 10 microns in diameter)	Sulphur dioxide (SO_2)	Oxides of nitrogen (NO_x)
Vehicle exhaust	3,673	3,673	3,490	19,520
Re-suspension from roads	10,200	2,550	-	-
Power plant	1,500	1,500	26,000	11,200
Industrial (fuel combustion)	1,817	1,496	38,710	4,085
Industrial processes	6,053	-	-	-
Domestic	4,432	2,235	1,688	1,344
Refuse burning/ dumps	4,108	4,108	26	153
Marine	560	469	9,350	1,245
Total	32,343	16,031	79,264	37,547

Source: World Bank (1997)

traffic junctions in Mumbai for SO_2, NO_x, CO and Benzo(a)pyrene from total and respirable particulate matter.

MPCB also has eight mobile ambient air quality monitoring vans. These vans are fully computerized and automated for the monitoring of SO_2, NO, NO_2, CO, NH_3, CH_4, SPM, non-methane hydrocarbons (NMVOC) total hydrocarbons (HC), wind speed and direction, and air temperature and humidity. Occasional monitoring of CO and HC have been undertaken at a number of roadside sites in the past but at present, there is no coordinated monitoring program for these two pollutants or for ozone (O_3). According to an assessment by the URBAIR World Bank project, the MCGB air monitoring laboratory operates under significant financial constraints which affect methodological and manpower capacities, although the analyses that are available are good.

Impacts of Air Pollution

The air is highly polluted with SPM in most Indian cities. This has led to a high incidence of associated health effects on the population manifested in the form of sub-clinical effects, impaired pulmonary function, use of medication, reduced physical performance, frequent medical consultations and hospital admissions with complicated morbidity and even death in the exposed population. Respiratory infections account for 10.9 per cent of the total burden of diseases in India, which may be due to both the presence of communicable diseases and high air pollution levels (World Bank, 1993).

A WHO/UNEP study (1992) compared prevalence of respiratory diseases in different areas of Mumbai, classified according to ambient average concentrations of SO_2. The study revealed a relatively higher prevalence of most respiratory diseases in polluted urban areas compared with rural control area.

The World Bank (1997) Greater Mumbai study estimated the costs that could be attributed to the impacts on health and mortality due to high levels of PM_{10} in Mumbai. The total costs in 1991 due to the effect of PM_{10} alone was approximately Rs. 18.2 billion. The study also showed that about 97 per cent of the Mumbai population was exposed to annual average TSP concentrations exceeding the WHO (1979) air quality guideline. Of this, 8 per cent were exposed to TSP levels that were double the guideline, which includes approximately 300,00 drivers, other roadside workers, roadside residents, and those who live near stone crushers (World Bank, 1997).

The medical impacts of air pollution were documented in a recent (2002) local study by Shankar and Rao (2002) in the Mumbai area. This study showed that health effects were significantly greater in highly-polluted areas compared with low or less-polluted areas of Mumbai.

Enforcement and Control Strategies

The national government has taken a number of measures such as legislation, emission standards for industries, guidelines for siting of industries, environmental audit, EIA, vehicular pollution control measures, pollution prevention technologies, action plans for problem areas, development of environmental standards, and promotion of environmental awareness. However, despite all these measures, air pollution still remains one of the major environmental problems. At the same time, there have been success stories such as the reduction of ambient Pb levels (due to the introduction of unleaded petrol) and lower ambient SO_2 levels (due to progressive reduction of sulphur content in fuel) (Panwar, 2002)

The government has formulated a number of legislative measures, policies and programmes related to air pollution including the Air (Prevention and control of pollution) Act, 1981 and the Environment (Protection) Act, 1986. India has also adopted the Male declaration on Control and Prevention of Air Pollution and its Likely Transboundary Effects for South Asia in April 1998.

Ambient air quality standards (both short-term, i. e., 24 hourly, and long-term, i.e., annual) have been laid down for industrial, residential/rural/other, and sensitive areas with respect to pollutants such as SO_2, NO_X, SPM, (see Table 3.9.2) respirable particulate matter (RPM), NH_3 and Pb. For CO, 1 hour and 8 hour standards have also been prescribed.

The various measures taken by government to mitigate emissions from transport sector are as follows:

Stringent emission norms

Mass emission standards for new vehicles was first introduced in India in 1991. Stringent emission norms along with fuel quality specifications were laid down in 1996 and 2000. Euro I vehicle emission standards are applicable from 1 April 2000 and Euro II standards will be applicable all over India from 1 April 2005. However, in the case of the National Capital Region (NCR), the norms were brought forward to 1 June 1999 and 1 April 2000 for Euro I (Bharat Stage I) and Euro II (Bharat Stage II), respectively (CPCB, 1999; SIAM, 1999).

Table 3.9.2 Indian ambient air quality standards (Source: CPCB, 2000)

	Sulphur dioxide (SO_2)		Oxides of nitrogen (NO_x)		Suspended particulate matter (SPM)	
	*	**	*	**	*	**
Time weighted average	Annual average (ì g/m^3)	24 hour average (ì g/m^3)	Annual average (ì g/m^3)	24 hour average (ì g/m^3)	Annual average (ì g/m^3)	24 hour average (ì g/m^3)
Industrial area	80	120	80	120	360	500
Residential, rural and other area	60	80	60	80	140	200
Sensitive area	15	30	15	30	70	100
Method of measurement	Improved West and Gaeke methods	UV fluorescence	Jacab and Hocheiser modified (Na-Arsenite methods)	Gas phase chemilumione scence)	High volume sampling (Mean flow rate not less than 1.1 m^3/minute)	

*Annual arithmetic mean of minimum 104 measurements in a year taken twice a week 24-hourly at uniform interval.
** 24-hourly values should be met 98% of the time in a year. It may exceeded 2% of the time but not on two consecutive days.

Cleaner fuel quality

To conform to the stringent emission norms, it is imperative that both fuel specification and engine technologies go hand in hand. Fuel quality specifications for the whole country have been laid down by the Bureau of Indian Standards (BIS) for gasoline and diesel for the period 2000–2005 and beyond 2005.

Given the increased usage of diesel in India it has become necessary to reduce the sulphur content of diesel. The directive by the Supreme Court, the Ministry of Petroleum and Natural Gas requires the supply of diesel with 0.05 per cent (500 ppm) sulphur content in the entire NCR from July 2001. In Mumbai, all vehicles have been required to use 0.05 per cent sulphur in diesel from October 2000.

Unleaded gasoline was introduced in April 1995 in the four metro cities of Delhi, Mumbai, Calcutta and Chennai. Lead has been phased out in the entire country since 1 February 2000. Similarly the benzene content is to be reduced and now, unleaded petrol with 1 per cent benzene and 0.05 per cent sulphur content is being supplied in the NCR. It will also be extended further to other parts of the country. The use of LPG as fuel for automobiles has also been permitted.

Inspection and maintenance (I&M)

The most important step towards emission control for the large in-use fleet of vehicles is the formulation of an inspection and maintenance system. It is possible to reduce pollution loads generated by vehicles by 30–40 per cent through proper periodical inspections and maintenance of vehicles (CPCB, 2000). I&M measures for in-use vehicles are an essential complement to emission standards for new vehicles. In India, the existing mechanism of I&M is inadequate. Thus, there is a great need to establish effective periodic I&M programmes.

Conclusions

Mumbai is one of the most polluted city in the world, its air quality problems mainly attributable to increasing traffic and industrialization. However, planning enforcement measures, such as the relocation of industries and increased stack heights, together with the introduction of natural gas have proven to be partially successful in slowing the decline in air quality and should be encouraged further. The use of low-sulphur coal, a relatively small motor vehicle population (per capita) and the scrubbing effect of the monsoons help to reduce, to some extent, ambient air pollution in the city.