Air Pollution Scenario over Delhi City

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Siddhartha Singh and S.K. Peshin

Abstract

The rise in population and growth in economic activity have led to an increase in pollution in Delhi. About 55 % of Delhi's population live within 500 m of the roads with a high level of pollution which leads to higher exposure of population to air pollutants, thus resulting in health problems. In order to analyse the air pollution scenario in Delhi, a study has been conducted of the different criteria pollutants, e.g. NO_2, SO_2, CO, $PM_{2.5}$ and PM_{10}, along with a study of surface ozone (O_3) for the period 2008–2011. The data of 10 stations of the air quality monitoring network of the India Meteorological Department along with the data collected by the Central Pollution Control Board have been analysed. The data of respirable suspended particulate matter (RSPM) shows that its concentration in Delhi's air is double that of the national limit. Significant changes have been noticed from year to year in concentrations of all pollutants in Delhi, which may be due to meteorological factors and changes in emissions from different sources of air pollutants. The level of surface ozone has been found rising due to high vehicular emissions in the city. The inverse relationship between surface ozone concentration and relative humidity indicates that the major photochemical paths for the removal of ozone become effective when humidity increases in Delhi. The study of CO/NOx ratios in comparison to ratios of SO_2/NOx reveals that CO/NOx ratios are higher which indicates that vehicular emissions are the major sources of air pollution in Delhi.

Keywords

Air pollution • Particulate matter • Surface ozone • Respirable particulate matter

Introduction

Delhi is the largest metropolitan city by area covering 1,484 km^2 and the second largest by population in India. Delhi features an atypical

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version of the humid subtropical climate (Koppen Cwa, *Köppen* climate classification Cfa or *Cwa*). The high influx of population in Delhi, increase in consumption patterns and unplanned urban and industrial development have led to the problem of air pollution. About 55 % of Delhi's population live within 500 m of the roads with a high level of pollution which leads to higher exposure of population to air pollutants, thus resulting in health problems. The pollution levels in Delhi have been rising due to continuous increase in the number of motor vehicles (MoEF 1997) as well as increase in emissions from other sources, e.g. domestic sources, small-scale industries and non-road sources such as construction activities. The data generated over the years by the Central Pollution Control Board (CPCB) reveal that suspended particulate matter (SPM) and respirable suspended particulate matter (RSPM/PM_{10}) exceed permissible levels at many locations in Delhi. The air pollution problem becomes complex due to the multiplicity and complexity of air-polluting source mix (e.g. industries, automobiles, generator sets, domestic fuel burning, road side dusts, construction activities). Vehicular emissions are of particular concern since these are ground-level sources and thus have the maximum impact on the general population. Meteorological conditions play a significant role in spreading pollutants from roadways into residential areas (Srivastava and Jain 2005), causing widespread air pollution. To reduce vehicular pollution in Delhi, the government of Delhi has taken many measures, e.g. the use of heavy-duty compressed natural gas engines (CNG) and the development of metro railway. Goyal and Sidhartha (2003) have evaluated the impact of CNG implementation on air pollution and discovered a decrease in air pollutants due to a switch from diesel to CNG in Delhi's transport system. However, an increase in NOx concentrations was observed after the switch, and no discernible impact on ambient PM10 and CO concentrations was noted, stemming from CNG implementation (Mukherjee and Kathuria 2006).

In order to analyse the air pollution scenario in Delhi, a study has been made of the different criteria pollutants, e.g. NO_2, SO_2, CO, $PM_{2.5}$ and PM_{10}, along with a study of surface ozone (O_3) for the period 2008–2011.

Data Used

The data of the air quality monitoring network of the India Meteorological Department (IMD) along with the data collected by the Central Pollution Control Board have been analysed for the criteria pollutants, e.g. NO, NO_2, NOx, SO_2, CO, $PM_{2.5}$ and PM_{10}, along with a study of surface ozone (O_3) over the period 2006–2011. However, the data available vary from site to site and from pollutant to pollutant. The ambient air quality has been monitored by the CPCB at the Income Tax Office (ITO), one of the busiest traffic intersections, located on Bahadur Shah Zafar Marg in downtown, Delhi. The IMD's monitoring sites have been chosen near busy traffic intersections, residential areas, large-scale industrial areas, etc. which are representative of Delhi's scenario. The QA/QC procedures are explained in more detail in CPCB website. The location map of Delhi is shown in Fig. 6.1.

Results and Data Analysis

Variations of monthly averaged concentrations of NO_2, NO, NOx and SO_2 have been shown in Figs. 6.2, 6.3, 6.4 and 6.5, respectively. The levels of oxides of nitrogen exceed the National Ambient Air Quality Standards of 80 $\mu g/m^3$ at ITO. A decrease in NO_2, NO and NOx concentrations at ITO after 2007 may be noticed. During the monsoon period (July–September), the concentrations of NO_2 and NO are lower in comparison to other seasons of the year. The concentrations of nitrogen oxides at ITO vary year to year and are affected by traffic flow patterns (Gokhale and Khare 2007).

The concentrations of SO_2 have been found below the CPCB standards as shown in Fig. 6.5. The main source of SO_2 emission is thermal power plants in Delhi. After the implementation

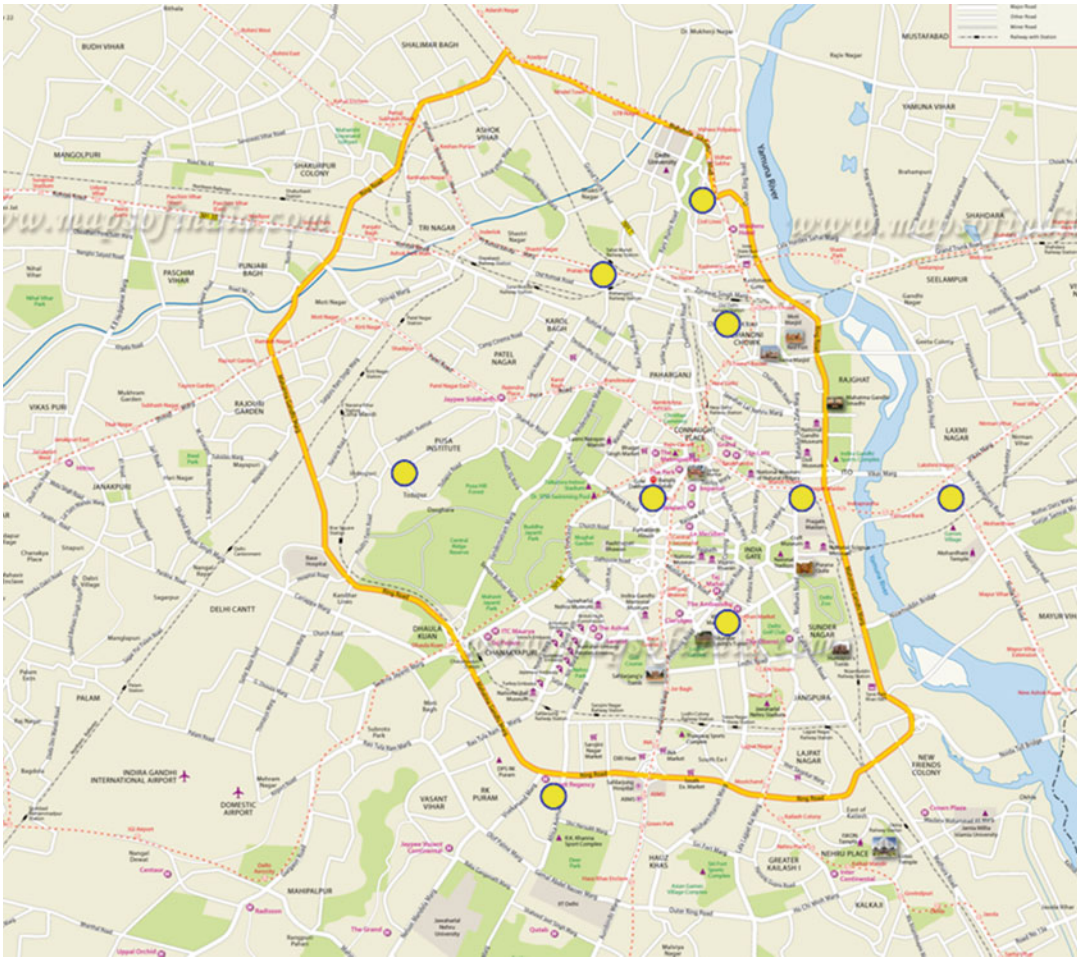


Fig. 6.1 Location of the air quality monitoring stations in Delhi

of rules and regulations for low-sulphur diesel for vehicles in Delhi, the contribution of vehicles to the concentration of SO_2 was very low.

An analysis of hourly concentrations of PM_{10} and $PM_{2.5}$ at Meteorological Complex, Lodi Road, New Delhi, during the period of October 2011–December 2011 as shown in Figs. 6.6 and 6.7 indicates that PM_{10} and $PM_{2.5}$ concentrations are far above CPCB standards. The two distinct peaks in PM_{10} and $PM_{2.5}$ represent the data of Diwali night, 2011. The PM values indicate that the stringent measures imposed on vehicular emissions are inadequate in controlling PM because vehicle exhaust, construction activity and roadside dust are significant sources for particulate matter.

Figure 6.8 shows that there is a decrease in CO concentrations at ITO after 2009, though concentrations crossed the CPCB standard of 2,000 $\mu g/m^3$ during post-monsoon season. The decreasing trend may be due to the lowering of CO concentrations from vehicular sources because of newer, improved engines, advanced emission reduction technology and cheaper fuel like diesel and CNG replacing gasoline (Biswas et al. 2011).

Ozone is produced by the photooxidation of pollutants like CO and hydrocarbons in the presence of adequate amount of nitrogen oxides at low altitudes (Crutzen 1974). Chemical reactions involving O_3 production and removal occur within a time scale of few hours (Raj et al.

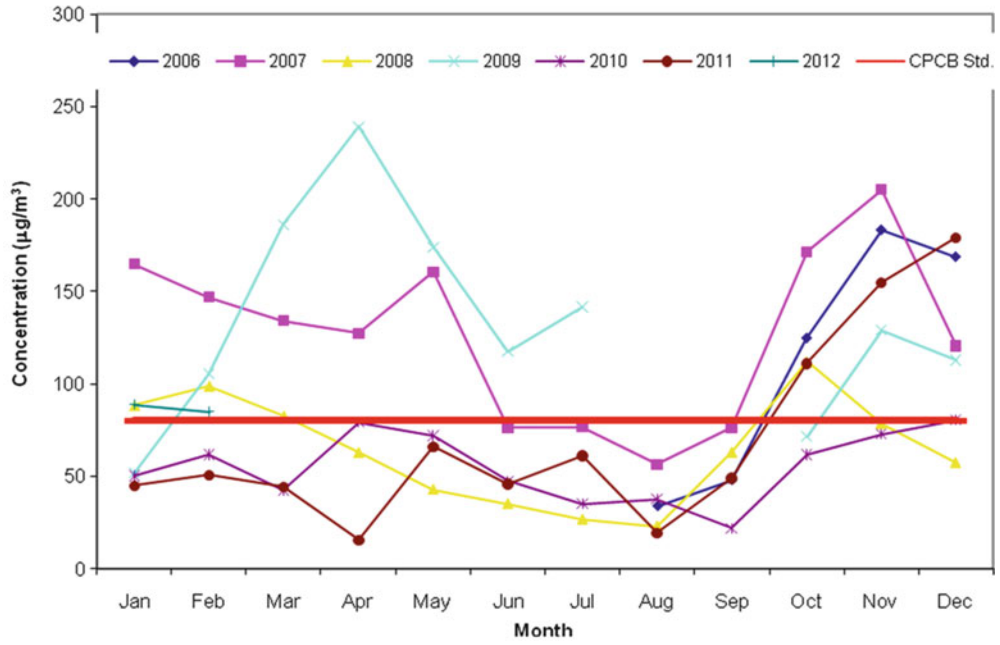


Fig. 6.2 Monthly averaged concentration of nitrogen dioxide (NO_2) at ITO cross section, Delhi

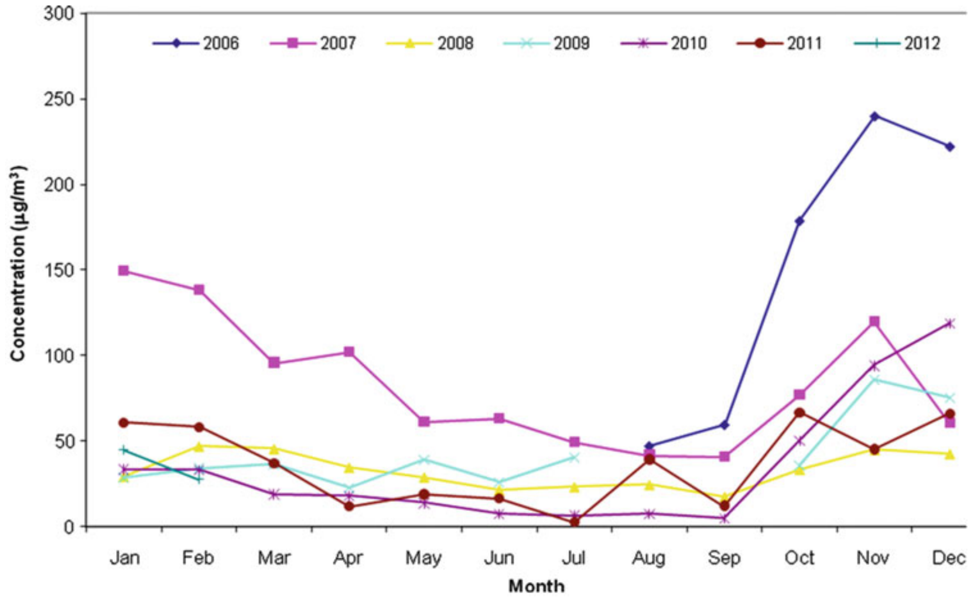


Fig. 6.3 Monthly averaged concentration of nitrogen monoxide (NO) at ITO cross section, Delhi

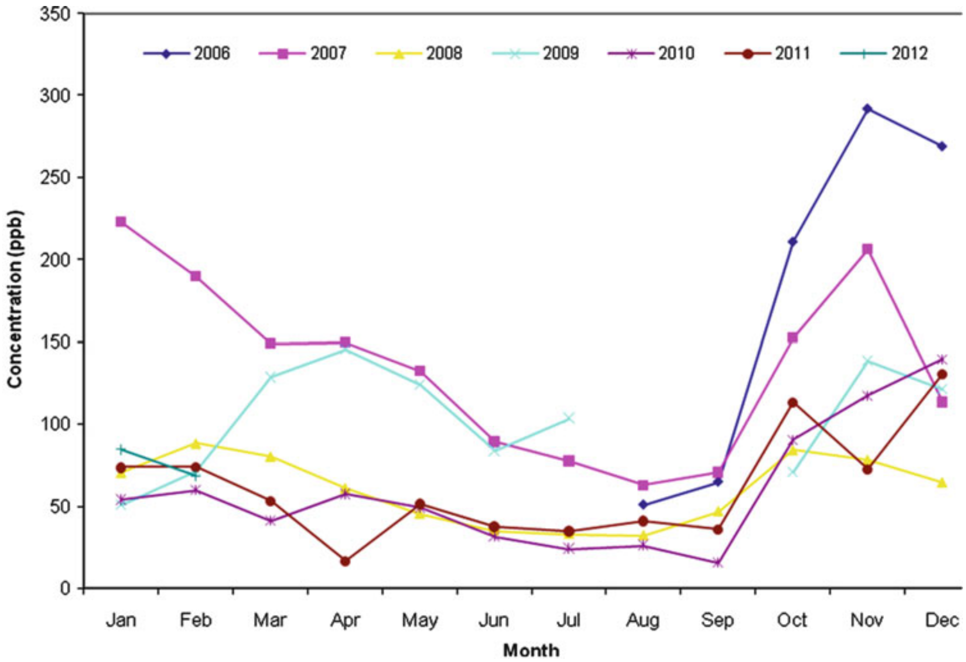


Fig. 6.4 Monthly averaged concentration of nitrogen oxide (NOx) at ITO cross section, Delhi

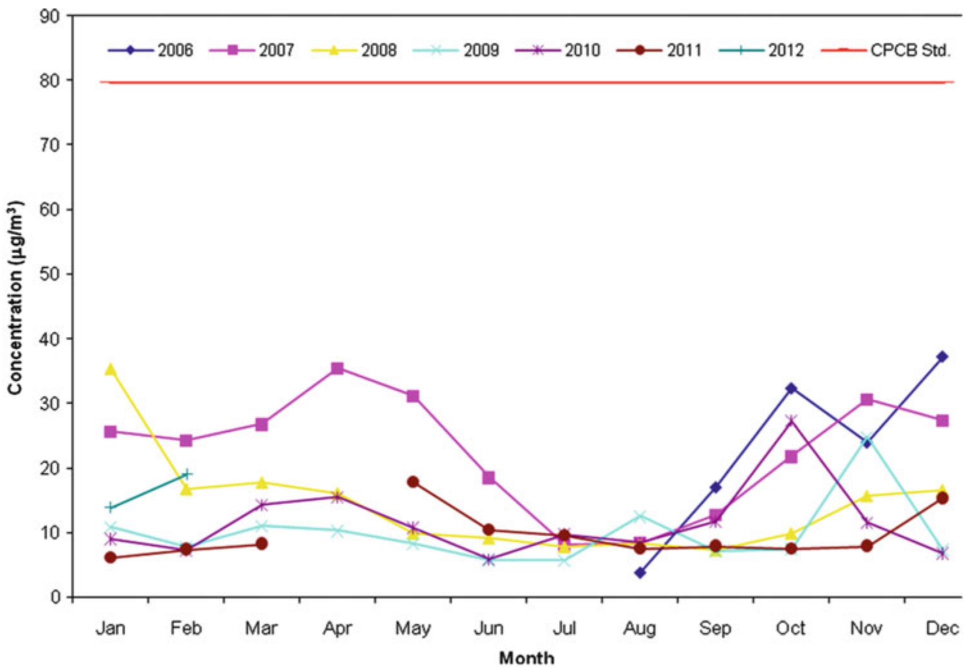


Fig. 6.5 Monthly averaged concentration of sulphur dioxide (SO_2) at ITO cross section, Delhi

Fig. 6.6 Variation of PM_{10} concentration at Meteorological Complex, Lodi Road, New Delhi, during the period of October 2011–December 2011

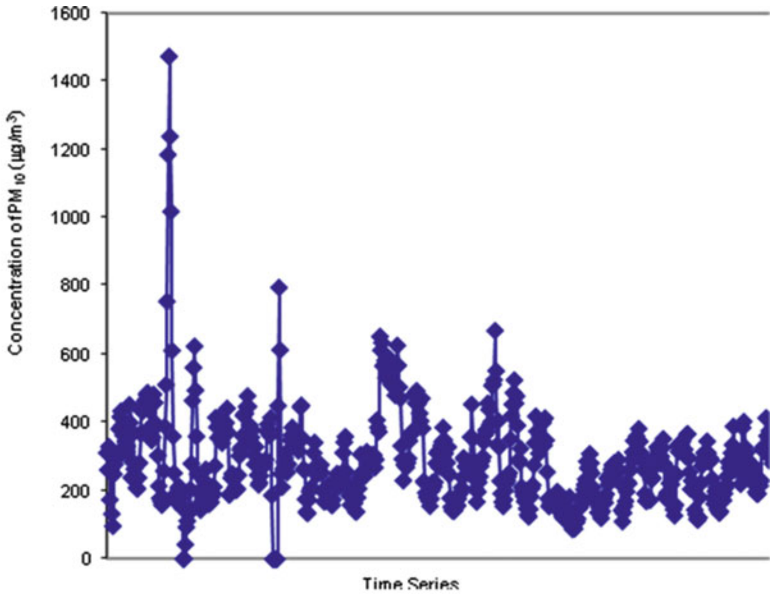
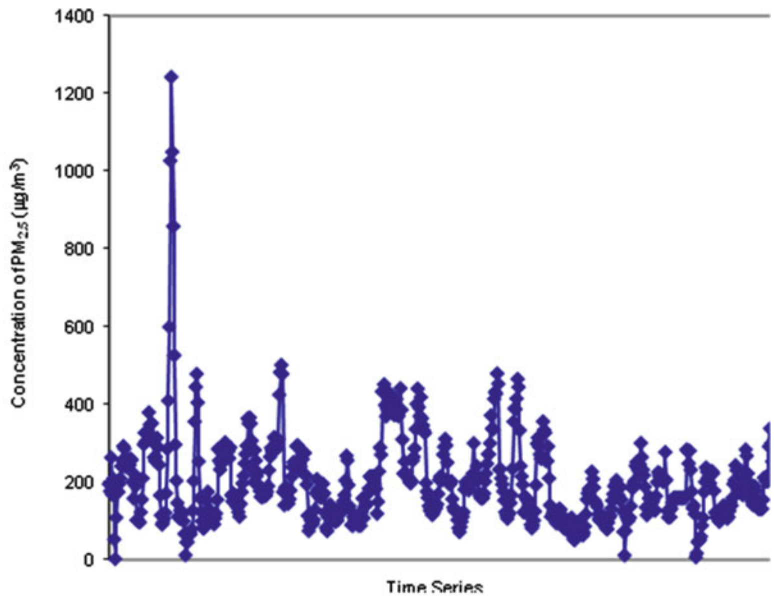


Fig. 6.7 Variation of $PM_{2.5}$ concentration at Meteorological Complex, Lodi Road, New Delhi, during the period of October 2011–December 2011



2003). ITO recorded high ozone concentrations (Fig. 6.9 (a)). The time series of ozone, CO and NOx (Fig. 6.9 (b)) shows that the levels of CO and NOx remained very high, resulting in higher levels of ozone at ITO. Fig. 6.10 indicates that the yearly averaged values of NOx are increasing continuously after the year 2009 which may be due to steady increase in the number of vehicles registered in Delhi, which increases the production of surface ozone. To decrease NOx levels in Delhi, better planning of transport system is required. A considerable decrease in surface ozone concentrations is visible during winter season due to a decrease in solar radiation. A statistical study of 95 large urban communities in the United States found significant association

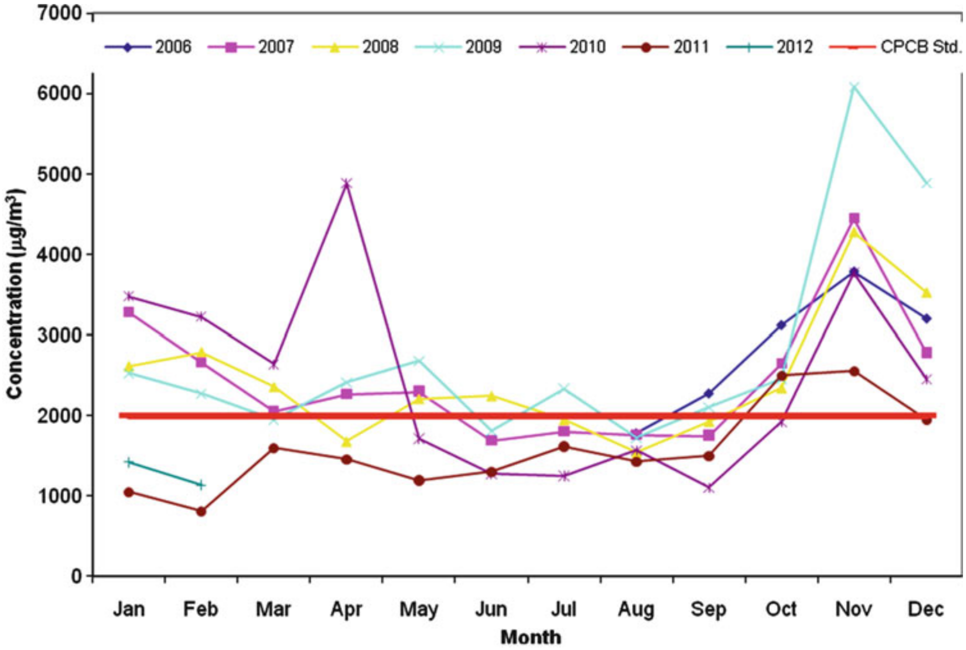


Fig. 6.8 Monthly averaged concentration of carbon monoxide (CO) at ITO cross section, Delhi

between ozone levels and premature death. The study estimated that a one-third reduction in urban ozone concentrations would save roughly 4,000 lives per year (Bell et al. 2004).

Figure 6.11 shows the comparison of CO/NO_2 ratios with SO_2/NO_2 ratios at ITO cross section with considerably higher ratios of CO/NO_2 than SO_2/NO_2 because impacts of mobile source emissions are associated with high CO/NO_2 ratios and low SO_2/NO_2 ratios, whereas impacts of point source are seen with lower CO/NO_2 ratios and higher SO_2/NO_2 ratios.

Conclusions

This study was conducted to examine the status of ambient air quality in Delhi. The observations for the years 2006–2012 have shown that Delhi has started losing the gains of its CNG programme as air is increasingly becoming more polluted, bringing back the pre-CNG days when diesel-driven buses and autos had made it one of the most polluted cities in India. Currently, the maximum level of carbon monoxide (CO) is almost 6,000 $\mu g/m^3$, which is way above the CPCB limit of 2,000 $\mu g/m^3$, though the annual levels have registered a drop. The concentration of particulate matter ($PM_{10}/PM_{2.5}$) is three times higher than CPCB limits. If $PM_{2.5}$ is not regulated, it will result in major health hazards. The number of asthma patients will rise, and in the future there may be a huge rise of lung cancer cases as well. Levels of nitrogen oxide (NOx) have also been increasing after 2009. The high CO/NOx ratios indicate that gasoline-powered vehicles are significant contributors of air pollution in Delhi, while low values of SO_2/NOx indicate that point sources contribute mainly to SO_2 concentrations (Aneja et al. 2001). In the past 5 years, the Delhi Government has taken many initiatives to reduce air pollution, e.g. advanced emission norms of vehicles, restriction on the number of autorickshaws, conversion of buses from diesel to CNG and restricting commercial vehicles from entering the city, but pollution levels are on the rise due to the rise in the number of vehicles. At present, the city adds over 1,000

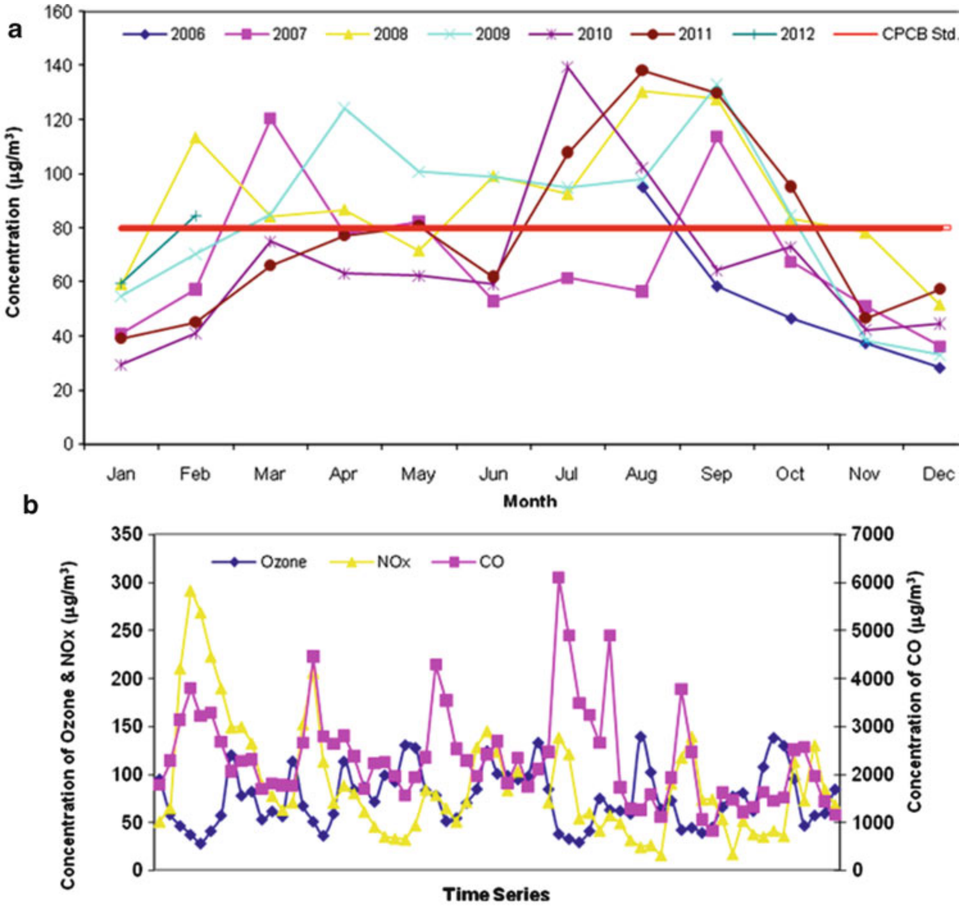


Fig. 6.9 (**a**) Monthly averaged concentration of ozone (O_3) at ITO cross section, Delhi. (**b**) Monthly averaged concentrations of ozone, NOx and CO at ITO cross section, Delhi, during the period of August 2006–February 2012

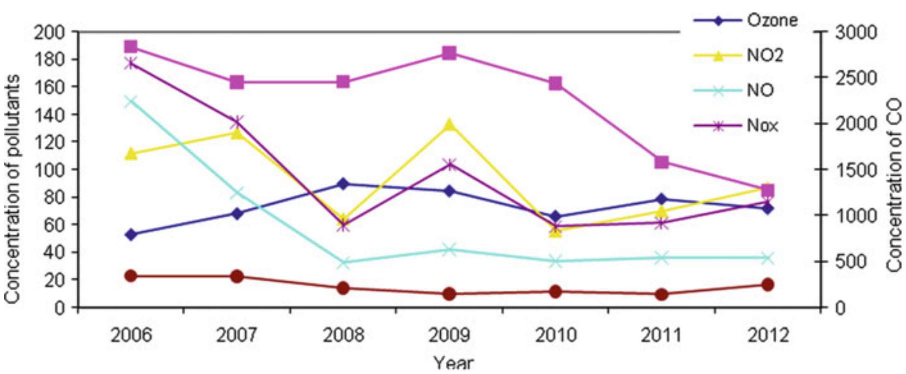


Fig. 6.10 Annual averaged concentration of air pollutants at ITO cross section, Delhi

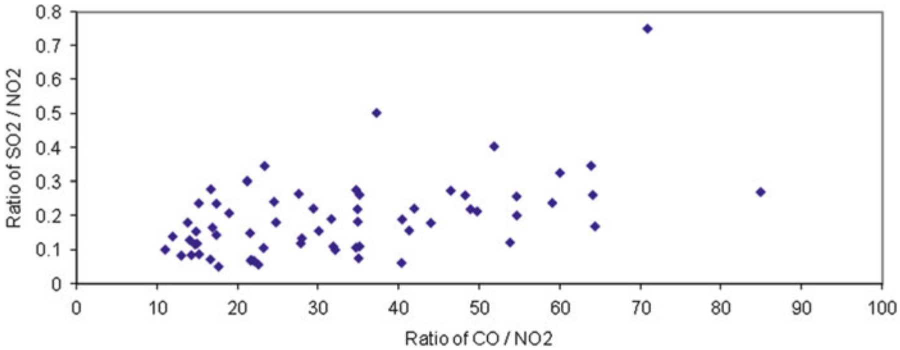


Fig. 6.11 Comparison of CO/NO_2 ratios with SO_2/NO_2 ratios at ITO cross section, Delhi, during the period of August 2006–February 2012

new personal vehicles (mostly diesel vehicles) each day, which is almost double of what was added in the city during pre-CNG days. Diesel vehicles emit more smoke, particles and NOx than petrol vehicles. Along with a rising number of vehicles, Delhi is also dealing with massive dust due to construction activities and a failed effort to control burning of garbage and leaves. To keep Delhi's air environment healthy, more a comprehensive air pollution control policy is required.

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