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Status of Tropospheric Ozone and Other Primary Air Pollutants After The Implementation of CNG in Delhi

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This paper estimates the status of air pollutants (primary pollutants and one of the secondary pollutant-tropospheric ozone) in Delhi after mandating the use of compressed natural gas (CNG). The objective of our study has two issues- whether CNG conversion has impinged on the primary pollutants and tropospheric ozone pollution profile or whether the physiography, climate and major emission sources are responsible factors for spatial pattern of pollution in Delhi. To carry out the analysis, daily ambient air quality secondary data of NO_x, SO_x, CO, SPM and RSPM (Jan 2002-Dec 2006, ITO crossing; Source-Central Pollution Control Board, Delhi) was used. Besides this secondary pollutant (ozone) and meteorological data's (Jan 2002-Dec 2006, Lodhi Road; Source-India Meteorological Department, Delhi) were also collected and analyzed. The results however, do not indicate an all round improvement in ambient air quality of Delhi. Except SO_2 all primary air pollutants (NO_2, SPM, RSPM and CO) are increasing from the last five years (2002-2006) at Site- I (ITO) and ozone concentration was reported to be increasing from 2002-2006 at Site-II (Lodhi Road) as well as at Site-I (ITO). Moreover, the concentration of ozone was higher at Site-I than at Site-II in all the reported years.

Key Words: Compressed natural gas (CNG), Tropospheric ozone, Primary pollutants, Delhi.

INTRODUCTION

Today there is an overwhelming evidence that various pollutants do and will continue to affect life on this planet. Globally, the quality of air and water is deteriorating because of population explosion, rapid industrialization and urbanization. In Delhi, total 3,000 metric tones of pollutants belched out everyday, close to two-third (66 %) are from vehicles. Similarly, the contribution of vehicles to urban air pollution is 52 % in Mumbai and close to one-third in Kolkata[1]. In Delhi, the contribution of vehicular pollution has increased only in past 2-3 decades, earlier it was partly 23 % in 1971 rose to 43 % in 1981 and became 63 % in 1991[2]. In fact, 1996 is considered to be the peak year in terms of air pollution load. The trend of contribution and pollution from vehicular sector has been alarmingly increased from 23 % (1970-71) to as much as 72 % by the year 2001[3]. The concentrations of conventional air pollutants including sulfur dioxide, particulates (PM_{10} and $PM_{2.5}$), ozone, nitrogen dioxide, carbon monoxide and air toxics, are rising and in many cases they are above the World Health Organization's guidelines for ambient air-quality standards. Moreover, even with mounting evidence of the negative health effects of air pollution[4], Delhi largely have been unable to stem the rising tide.

In 1984, the Central Pollution Control Board (CPCB) of the Indian Ministry of Environment and Forests instituted the National Ambient Air Quality Monitoring network, later renamed the National Air Monitoring Program, to monitor ambient air quality in a number of Indian cities. Under this network, the CPCB maintains seven air-quality monitoring stations in different parts of Delhi. In the year 2001, WHO listed Delhi as the fourth-most polluted mega city in the world but compared to other cities in India, Delhi was not at top. The surprisingly topper was Gajroula- an unknown small town in Uttar Pradesh[5]. But the recent release of report from CPCB[6], presents deadly facts about air pollution levels in Indian cities. According to the report, Ahmedabad's air is the most noxious. Kanpur, Solapur and Lucknow follow closely and Delhi improved its rank from 4th to 5th[7]. The present scenario of Delhi was far more better than from the period of 1987-2000. From 2001 onwards, the condition of Delhi's pollution had changed drastically because of implementation of CNG and EURO-III norms but CNG reports good results. According to Salve[8] as per the availability and the sources of implementation, CNG qualifies to be one of the most prominent alternative fuels. It stands substantially better than conventional fuels both in life cycle emissions and vehicle exhaust emissions. Delhi CNG experiment has been hailed as among the few success stories in recent times, where it is being proclaimed that a substantial reduction in vehicular pollution has been achieved in a very short time. From one of the most polluted cities of the world in 1999, Delhi bagged the ‘clean city international award’ in May 2003 for successfully converting its public transport of 9000 buses to CNG[9]. Infact, mandating the use of CNG for public transport is only one of the instruments used in Delhi. Earlier studies shows that the impact of other fuels other than CNG had not lead to significant fall in air pollution[10]. The compressed natural gas (CNG) is a clean-burning alternative or safe fuel for vehicles with a significant potential for reducing harmful emissions especially fine particles. Being lighter than air, it disperses easily into the atmosphere and does not form a sufficiently rich mixture for combustion to take place. Compressed natural gas is 130 octane, which is considerably higher than 93 octane for petrol and consequently CNG vehicle is more energy efficient. Higher octane rating allows higher compression ratio, improved thermal efficiency and reduced carbon dioxide emissions. Compared to petrol or diesel, CNG vehicles emit 40 % less of nitrous oxide (a toxic gas that creates smog), 90 % less of hydrocarbons (which carry carcinogens), 80 % less of carbon monoxide (a poisonous pollutant) and 25 % less of carbon dioxide (a major greenhouse gas). Further, noise level of CNG engine is much lower than that of diesel[11]. Diesel combustion emits 84 g/km of such components as compared to only 11 g/km in CNG. The levels of greenhouse gases emitted from natural gas exhaust are 12 % lower than diesel engine exhaust when the entire life cycle of the fuel is considered[12]. It has also been found that one CNG bus achieves emission reduction equivalent to removing 85-94 cars from the road[13]. However, high vehicle cost, shorter driving range, heavy fuel tank, expensive distribution and storage network and potential performance and operational problems compared to liquid fuels are some of the drawbacks of CNG[14]. Even after the implementation of CNG, the pollution levels in Delhi are still increasing so the focus of the present study is on Delhi for two particular reasons: (i) for the past several years, Delhi is among the ten most polluted cities of the world and (ii) After implementation of the CNG clean fuel still Delhi share a significant higher level of air pollution.

EXPERIMENTAL

Secondary source data of primary pollutants and one of the secondary pollutant *i.e.* tropospheric ozone has been collected from Site-I (ITO) from Central Pollution Control Board website[15] and moreover, the meteorological and tropospheric ozone data was purchased from Indian Meteorological Department, Delhi & Pune of Site-II (Lodhi Road).

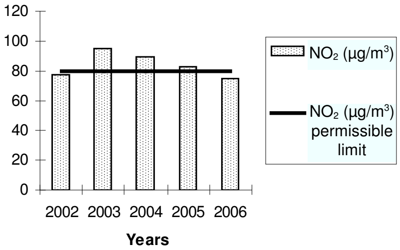
RESULTS AND DISCUSSION

The results of secondary data collection from Site-I (ITO) (Source: CPCB) depicted the profile of primary pollutants (NO_2, SO_2, SPM, RSPM and CO) and one of the secondary pollutant *i.e.* O_3 (Fig. 1). The highest concentration of NO_2 (95.25 μg/m^3) was reported in the year 2003 and in other reported years, either it crosses permissible limit (80 μg/m^3) or hovered around it as shown in Fig 1a. So, it is quite interesting to note that even after the implementation of CNG programme in Delhi, NO_x level is still showing increasing trend. It may be due to diesel vehicles whose sale in Delhi has registered an increase of 106 % since 1999. These vehicles emits 3 times more NO_x than petrol vehicles. Surprisingly, emissions from a poorly maintained CNG fleet can also increase NO_x because advanced testing facilities are not available for accurate NO_x measurements[16].

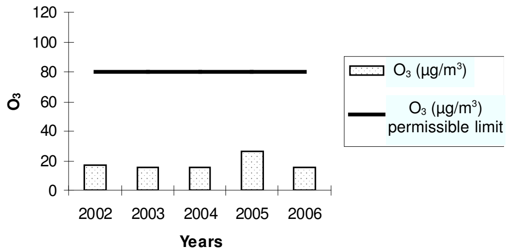
In Fig. 1b, the concentration of ozone at 25.88 μg/m$_3$ was the highest in the year 2005. However, it did not cross the threshold level (80 μg/m$_3$) for plant species as prescribed by NCLAN (National Crop Loss Area Network). Increase in ozone level may be due to the increase in precursor gases (NO_x, CO, VOCs)[17].

The profile of SO_2 (Fig. 1c) shows highest concentration (12.15 μg/m^3) in the year 2006. Interestingly, SO_2 is the only pollutant which shows significant decrease in the level after the implementation of CNG programme. Another mitigation policy measure that appears to have had a positive impact on air quality is the reduction in the sulphur content of diesel and petrol which converts SO_2 to sulphates (a fine particle)[15].

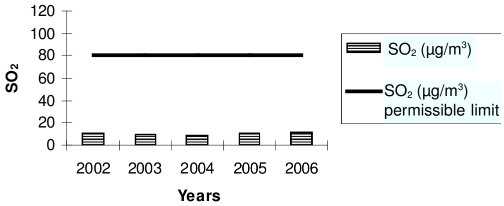
It is noticed in Fig. 1d that highest concentration of CO (3028.22 μg/m^3) was observed in the year 2002 and in following years (2002-2006) either it crosses or have approached the threshold value (2000 µg/m_3). In Fig. 1e, highest concentration of SPM (557.64 µg/m^3) was recorded in the year 2003 whereas in case of RSPM (Fig. 1f), highest concentration (272.82 µg/m^3) was recorded in the year 2002. In other years also, their concentrations crossed their respective permissible limits (200 µg/m^3 for SPM and 100 µg/m_3 for RSPM). After the implementation of CNG programme, these pollutants are not showing decreasing trend, rather their concentration is increasing due to poor three - wheeler technology which includes poor quality of piston rings as well as the improper maintenance of air filters[18].



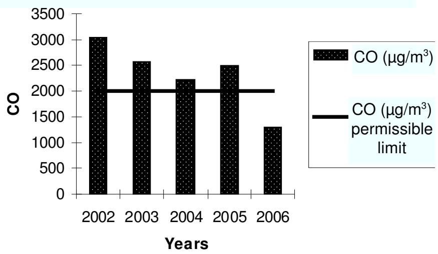
(a) Trend of NO_2



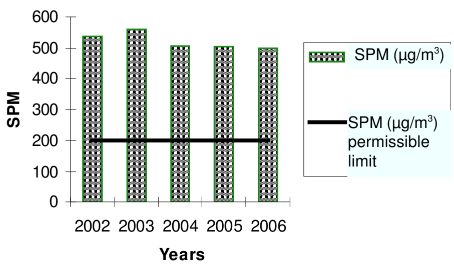
(b) Trend of O_3



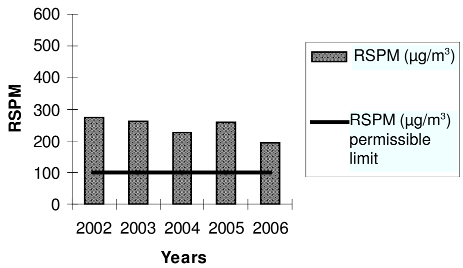
(c) Trend of SO_2



(d) Trend of CO



(e) Trend of SPM



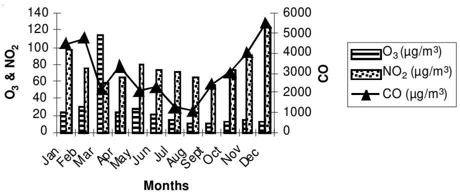
(f) Trend of RSPM

Fig. 1. Trend of primary pollutants (NO_2, SO_2, CO, SPM and RSPM) and secondary pollutant (O_3) from 2002-2006 at Site-I (ITO), Delhi (Source: CPCB)

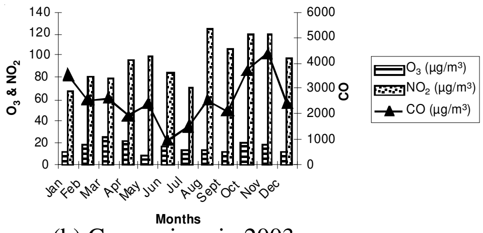
The comparison of O_3 with NO_2 and CO can be seen in Fig. 2. At the ITO site, NO_2 and CO levels have remained consistently two to four times higher than the permissible limits throughout the reported years. It clearly shows that when concentration of NO_x and CO increases, then O_3 decreases (Fig. 2a-e). This is due to scavenging reactions of NO_x or disruption of photolytic cycle by CO and other hydrocarbons due to which concentrations of NO_2 and O_3 do not increase in the atmosphere on account of the formation of peroxy radicals[19]. These peroxy radicals prevent the reaction of O_3 with NO, thus terminating the cycle and causing O_3 to accumulate. A comparative study of O_3 with NO_2 and CO suggests that during winter seasons of all reported years (Nov-Dec), a strong anti correlation exists among them[20]. Production of ozone resulting from the chemical loss of CO *via* $OH^{\bullet}$ radicals during these months may be the explanation of anti correlation of these pollutants. Moreover, low ambient temperature, lower mixing depth, temperature inversion and higher consumption of fuels aggravate the pollution problem, especially the NO_x during winter months[21]. Interestingly, in 2002 (Fig. 2a), during the month of March, the ozone concentration was highest as compared to other months (in all the reported years) it might be due to less concentrations of NO_x and CO and other meteorological conditions.

Presently, concentration of ozone is showing an increasing trend, not only primary pollutants but meteorological parameters are also responsible for this increment. The meteorological data collected in (2002-2006) from Mausam Bhawan, New Delhi of Site-II (Lodhi Road) are mainly daily ambient temperature, wind speed, relative humidity and surface ozone value. The highest ozone concentration was found to be 45.92 $\mu g/m^3$ in Oct, 2005 at Lodhi Road as compared to concentrations observed in other reported years. The highest concentration of ozone was observed to be 25.84 $\mu g/m^3$ in March' 2002, 26.39 $\mu g/m^3$ in May' 2003 and 16.70 $\mu g/m_3$ in June' 2004 and 27.68 $\mu g/m_3$ in April 2006 (Fig. 3). This might be due to favourable meteorological conditions and biogenic VOCs since Lodhi Road is a dense vegetative area. According to Pleijel[22] and Salve *et al.*[8] dense vegetation gives rise to the production of VOCs which are responsible for the production of ozone.

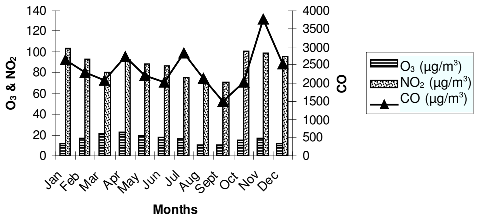
The relation of meteorological parameters with ozone is shown in Fig. 4. In all the reported years (2002-2006), almost similar trend of variation of concentration of ozone with variation in metrological parameters was observed. For example, when temperature increases, ozone concentration also increases. This is due to initiation of photochemical ozone formation by the precursors of ozone[8]. Relative humidity is another contributing factor which influences ozone formation as shown in Fig. 4a-d. It can be interpretated with the photolysis of ozone which can produce activated oxygen atom the $O(^1D)$. This activated atom can react with water vapour (relative humidity) to produce hydroxyl radical[14]. The hydroxyl radical undergoes further reactions, some of which eventually lead to production of ozone. The amount of ozone in a location subsequently depends on the NO_x/VOC mixture. These reactions can collectively constitute a sink for ozone. In relation to wind speed, the trend



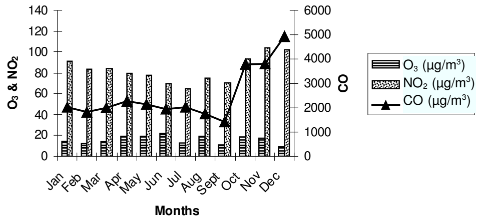
(a) Comparison in 2002



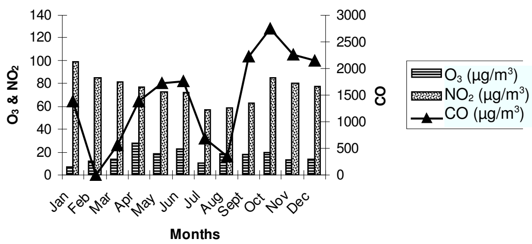
(b) Comparison in 2003



(c) Comparison in 2004



(d) Comparison in 2005



(e) Comparison in 2006

Fig. 2. Comparison of O_3 with NO_2 and CO in 2002-2006 at Site-I (ITO), Delhi (Source: CPCB)

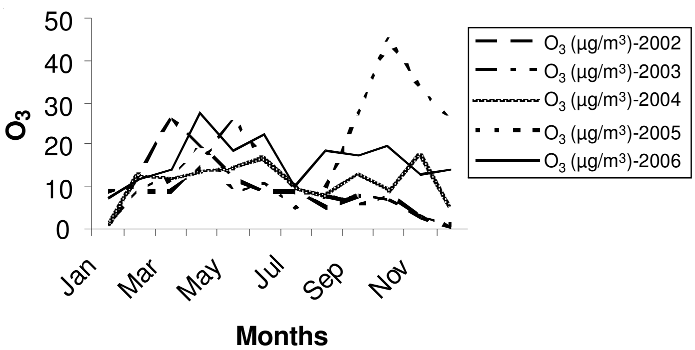
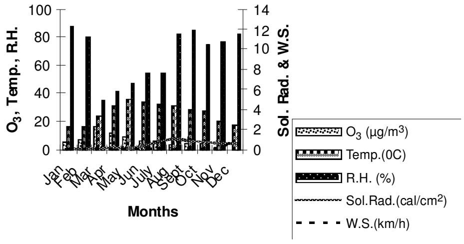
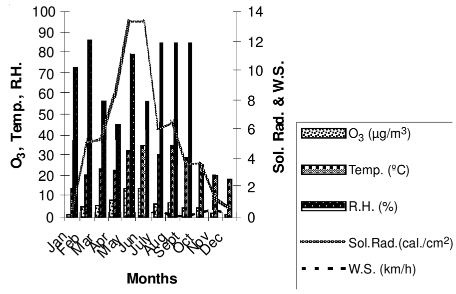


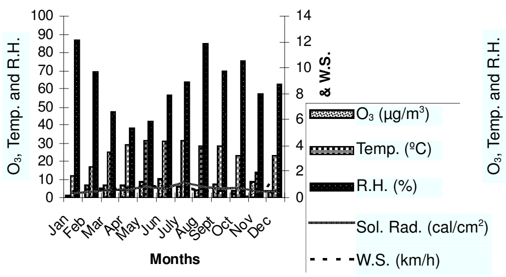
Fig. 3. Trend of ozone concentration at Site-II (Lodhi Road), Delhi (Source: IMD, Pune)



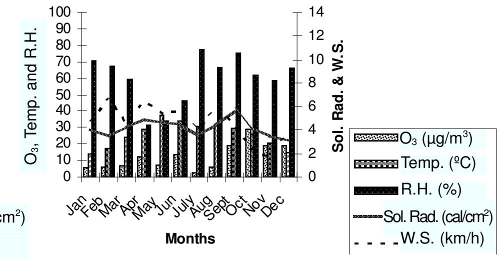
(a) Ozone with meteorological Parameters in 2002



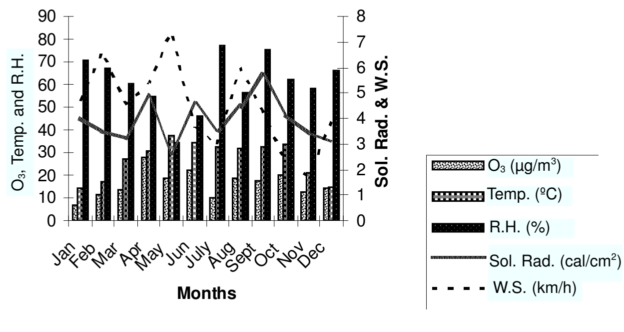
(b) Ozone with meteorological Parameters in 2003



(c) Ozone with meteorological Parameters in 2004



(d) Ozone with meteorological Parameters in 2005



(e) Ozone with meteorological, Parameters in 2006

Fig. 4. Relation of ozone with meteorological parameters in 2002-05 at Lodhi Road, Delhi (Source: IMD, Delhi)

always shows that when there is low wind speed, the ozone concentration increases. Low wind speed (< 3 m/s) favours high ozone production as ozone accumulates near its precursor emission source areas and higher wind speed (> 6 m/s) causes increased dilution of local concentrations of ozone and its increased transportation from one source region to another[23]. Interestingly, in the year 2005, the highest ozone concentration of (30.2 ppb) was reported during the month of October (Fig. 4d), as compared with other months of reported years. This might be due to cumulative effect of low wind speed, high temperature and low relative humidity.

The comparison has been made between the two sites *i.e.* Site-I and Site-II on the basis of ground level ozone concentration. The ozone was found to be higher at Site-I (ITO) than at Site-II (Lodhi Road) in all the reported years (Fig. 5). This might be due to the fact that ITO is a heavy traffic intersection area and therefore it has high emission rate of pollutants whereas Lodhi Road is a residential area where the rate of emission of pollutants is low.

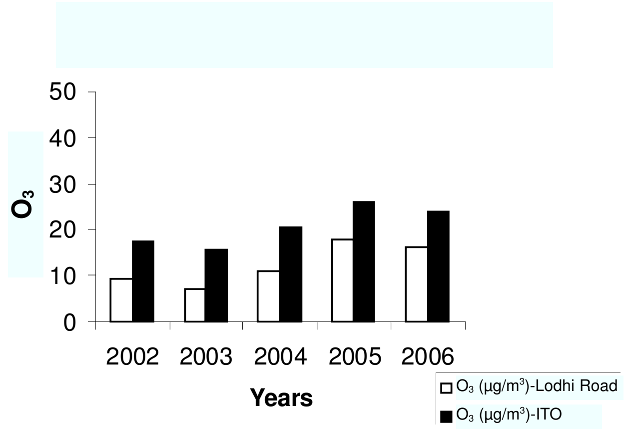


Fig. 5. Comparison of ozone concentration at Site-I (ITO) and Site-II (Lodhi Road), Delhi from 2002-2006. (Source: CPCB, Delhi & IMD, Delhi & Pune)

Conclusion

From secondary data it is concluded that except SO_2, all other primary pollutants (NO_2, SPM, RSPM, CO) are increasing from the past 5 years (2002-2006) at ITO, Delhi site. Moreover, ozone concentration also reported to be increasing from 2002-2006 at Lodhi Road as well as at ITO site. Therefore, after mandating CNG in Capital Delhi, ambient air quality data (in respect to ozone and its precursor gases) do not indicate an all around improvement in Delhi.

The monitoring of toxic air pollutants is a costly affair. Although CPCB has already initiated good steps to monitor these toxic pollutants (primary and secondary) regularly but the problem is still remain. Once more we have to initiate our thought process on how we can get rid off the harmful secondary pollutants everyday and also to force the government to make standards for these secondary pollutants immediately.

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