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# Urbanization and Changing Air Quality in Delhi—A Comparative Analysis and Strategy for Its Better Management

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**Abstract:** Air pollution, a demon created by mankind, can lead to consequences lasting from hours to decades. It has become a serious and growing problem in rapidly expanding cities of India where unprecedented and unplanned urbanization accompanied by rapid vehicular growth are among the major factors that exacerbate air quality. Delhi, the capital city of India, is facing an uphill task to provide clean air to its citizens. The present study analyzes the data of particulate pollutants (i.e. SPM, RSPM or $PM_{10}$) concentration over the 17 years to assess the changing ambient air quality of the study area. The relationship between outdoor and indoor pollution levels was evaluated based on primary data collected from 1583 households of respective areas. On the bases of both primary and secondary sources of data, it can be summarized that the air quality in the study area has been deteriorating day by day and despite the implementation of different clean fuel policies, the pollutants were well above the standard limit set by Central Pollution Control Board (CPCB). Use of indigenous plants as pollutants absorber was suggested to mitigate and manage this problem in the sustainable urban development perspectives. It is also recommended that more efforts should be made to understand the dynamics of urban environmental problems.

**Key words:** Delhi, pollution, urbanization, CPCB, particulate pollutants.

## Introduction

Urbanization, a vital global phenomenon, refers to the process of city establishment and growth; the term commonly connotes population increase in the city from internal growth and immigration as well as their spatial expansion (Detwyler and Melvin, 1972; Maurya, 1989). Rapid urbanization process has been underway for more than 250 years and has become a global salient feature of 21st century specially with its prime locus in the poorer parts of Asia and Africa. The urban population is growing two and half times faster than its rural counterpart and the level of urbanization officially crossed the 50 per cent mark by 2008. United Nations projection further shows that by 2025, more than three fifths (5.2 billion) of the world population will live in urban areas. Consequently, cities in both developing and developed countries are emerging as the major form of human settlement giving rise to a number of undesirable environmental consequences, poor air quality being one amongst them (Reddy, 1989; Bach, 1972).

Air pollution, despite being around for a century, has become one of the most dangerous and most widespread kind of environmental pollution in urban areas around the world, specially in developing countries where pollution level often surpasses several times the maximum level recommended by World Health Organization (WHO, 1999; Lvovskg, 1998), only in the last few decades. Rapid population growth, change in land use pattern, high level of energy consumption, burgeoning vehicular population, heavy concentration of industries, incineration of solid waste, and lack of environmental regulations etc. are the major anthropogenic factors which, either individually or collectively, have worsened the air quality in most of the mega cities of the world (Reddy, 1989; Bach, 1972; Doygun, 2005). An estimated number of 3000 different air pollutants are supposed to originate from these sources (Mohanraj and Azeez, 2005).

Air pollutants are found either in gaseous form or in the form of particulates such as dust, fumes, smoke and mist etc. Particulate Matter (PM) is currently the focus of attention worldwide due to its deleterious health effects in the form of increased mortality, morbidity, and deficits in pulmonary function and cardiovascular and neurobehavioural effects (Dockery et al., 1993; Mage et al., 1996; Devi, 2003). The gravity of the situation can be imagined by the fact that when the people exposed to PM levels of as low as 47 $\mu g/m^3$ suffered a mortality rate as much as 48 percent higher than those exposed to lower levels (Dockery, 1993). A study conducted by WHO to assess the damage from exposure to the high levels of particulates in 126 cities worldwide, where the annual mean levels exceed 50 $\mu g/m^3$, reveals that these damage may amount to about 130,000 premature deaths; over 500,000 new cases of chronic bronchitis and many more health effects each year. In aggregate terms, this is equivalent to 2.8 million Disability Adjusted Life Years (DALYs) lost for this sample of nearly 300 million people or nine DALYs lost per 1000 exposed residents (Dec notes Research Findings, 1996). Moreover, atmospheric problems such as mist formation, visibility reduction, and soiling of building and cultural monuments etc. are among the other repercussions of the particulate pollutants (Joseph and Nagendran, 2004; Agarwal, 2005; Saxena, 2004).

PM consists of a complex mixture of organic and inorganic substances, contributed by both natural and anthropogenic sources. Among the particulate matters, Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter (RSPM or $PM_{10}$) are two major ubiquitous contaminants which are the matter of great concern in the contemporary world because of their adverse impact on air quality and human health including physical, social and mental well being. SPM includes the particulates having particle diameter less than 100 μm that are generated from fossil fuel burning, industrial processes and vehicular exhaust whereas RSPM or $PM_{10}$ have diameter less than 10 μm and generally arise from road dust, vehicular exhaust, wind blown dust, agriculture, construction, fire places, refuse burning etc. $PM_{10}$ may also arise from incomplete combustion of any fuel and from other pollutants viz. $NO_X$, $SO_X$, organics etc.

In the wake of rapid process of urbanization, human condition in urban habitat has been degrading throughout the world and urban environment has become less livable and less attractive to the present urban residents. It is, therefore, desirable to evolve a philosophy of urban planning and formulate a set of plans and policies, aiming at a rational direction of urban growth and create an urban environment congenial for human living. A geographical study of spatial interaction between man and his environment at micro level will help in creating new insights to understand the gravity of the problem and will provide interesting material to social scientists, planners and decision makers concerned with the problems of urban areas. It is with this intention that Delhi, having the highest percentage of urban population in India and also being a centre that has been witnessing rapid growth in urban population as well as urban area from the past six decades, is selected for intensive study.

Delhi, the capital city of India, faces the problem of air pollution like other mega cities of the world with increased urbanization and augmented demand for mobility (Air Quality in Delhi- NAAQMS/17/2000-01; Gupta, 2003; Kumar and Hussain, 2003; Kumar and Singh, 2003). It is estimated that about 3000 metric tonnes of air pollutants are emitted everyday in the city (Kumar and Singh, 2003). Specifically, the city is suffering from extremely high levels of particulate air pollutants, with levels of total suspended particulates sometimes reaching five times the maximum level suggested by WHO. This effort is devoted to study the impact of urban development on ambient air quality of Delhi and consider it as an indicator of the large framework of the Indian urban system. The findings can be utilized to formulate comprehensive policies and planning with a geographical approach for proper urban set up that will be applicable at all levels. The best course open is to explore the various aspects of urban environmental problem and prepare the ground for further research in this area on descriptive lines. Some studies (Janssen, 2000; Ramchandran, 2000) have indicated a strong correlation between outdoor and indoor PM concentrations, suggesting that outdoor concentrations may be considered as a proxy for indoor concentrations. Keeping in view the above point, it is tried to analyze the spatio-temporal variation in the concentration of outdoor particulate pollutants in the ambient air of Delhi during the period 1990-2007 and make calculation about air quality in future. It is also attempted to assess whether outdoor pollution has impact on indoor air quality in the respective areas. Finally, some suggestions are made for the mitigation of the problem and sustainable development of Delhi.

## Study Area

Delhi with 13.89 million population (2001) is the third largest urban centre of India and is one of the prime mega cities of the world. It is situated between the latitude of 28°24′17″ and 28°52″ north, and of 76°50′26″ and 77°20′37″ east longitude at an altitude between 700 and 1000 feet in national capital territory of Delhi and covers an area of 1483 sq. km. Situated on the both sides of the River Yamuna, Delhi is flanked by Uttar Pradesh in the east and Haryana on the north, south and west (Figure 1). It has tropical steppe climate, with an extremely hot summer, average rainfall and moderately cold winter. Dust storms occur frequently during summer month leading to build up of particulate matter in the atmosphere followed by heavy rains of the monsoon which act as a scrubber to the pollutants.

## Data Collection

The study is based on both primary and secondary sources of data. Secondary data were collected from Central Pollution Control Board (CPCB) which has been conducting air quality monitoring at seven locations in the study area. The locations have been categorized based on land use i.e. residential, industrial and traffic intersection (Figure 2). For the collection of primary data, out of four residential areas where CPCB is monitoring pollution level, two areas namely Pitampura and Nizamuddin were selected and among two industrial areas, one area i.e. Shahdara South was selected for measuring indoor pollution. Primary data were obtained through field survey conducted from May 2005 to March 2006 with the help of a questionnaire containing questions regarding presence of pollution, type of pollutants,

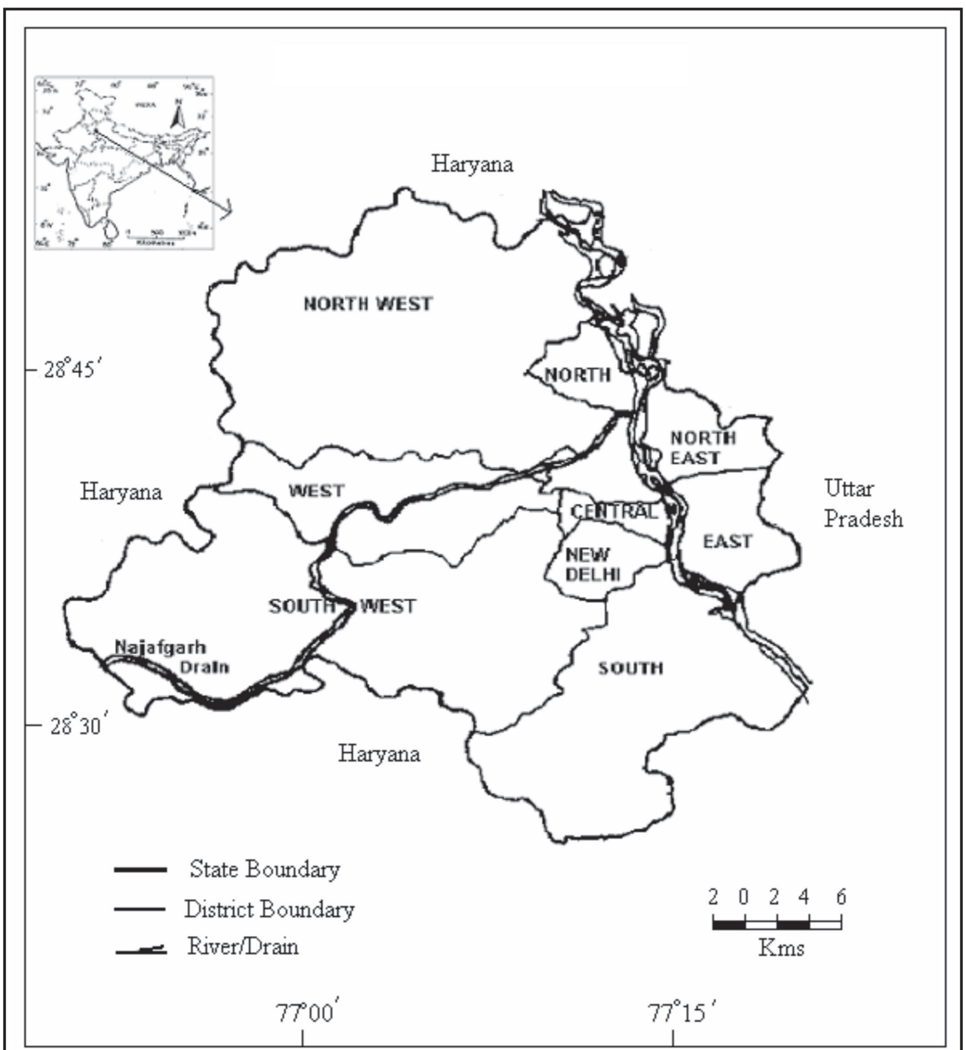


**Figure 1: Locational map of Delhi.**

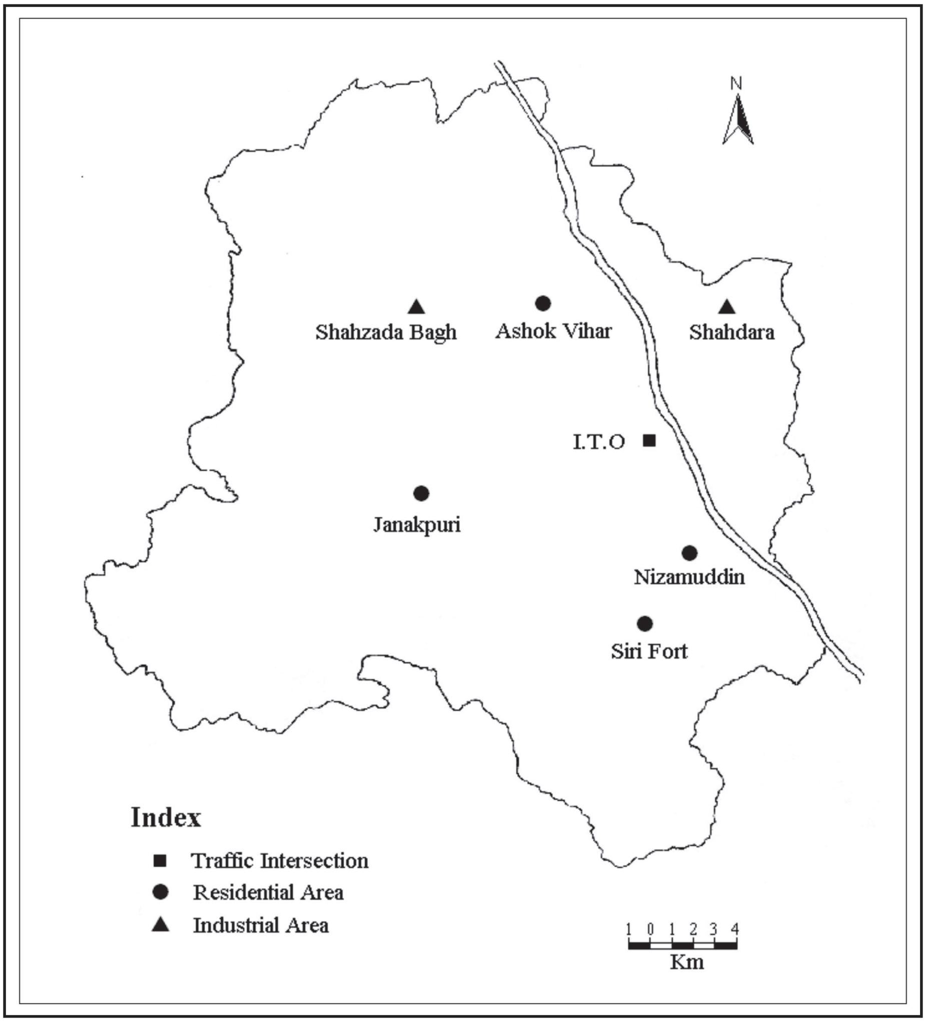


**Figure 2: Air quality monitoring stations in Delhi.**
***Source*: CPCB 2005**

sources of pollution and intensity of pollution. The study has been limited to the heads of the households as it is assumed that the head of the family would be an ideal subject for measuring the different aspects of the household environmental problems. In all 1583 heads of the household have been interviewed from three wards, forming three percent sample of the total household of the region. The strategy adopted to draw a representative household sample has been random. It is good enough for heterogeneous population scattered over large area. The sampled houses have been selected randomly without considering the appearance and location of the house or socio-economic consideration of its occupants.

## Methodology

The collected data were organized, classified and analyzed with the statistical technique viz. time series analysis method (trend line by least square method) as well as visual presentation in the form of graphs, maps and diagrams. It is one of the best ways of obtaining trend value for the entire time period. With this method, a straight line trend is obtained. The equation of straight line is $Y = a + bX$ where 'a' and 'b' are constants. This equation of straight line establishes a functional relationship in X and Y series and as such can be used to forecast future value. Spatial variation in air quality has been made by calculating Exceedence Factor (EF) which is derived by following method.

EF = Observed annual mean concentration of air pollutants/Annual air quality standard for respective pollutants and land use area class

The present analysis is divided into two sections; first section examines the spatio-temporal variation in the concentration of outdoor pollutants and the second section ascertains the level of indoor pollution at household level in selected wards. This is one of the first studies to assess the relationship between outdoor and indoor pollution. This study will provide an important background for additional research on the process of urbanization and its effect on urban environment. The study is based on subjective approach. No instrument was used but most of the relevant indicators were selected and the results are very convincing.

## Result

Figure 3 presents the status of the annual mean concentration of SPM between the years 1991-2006. The concentration of annual average SPM is found to fluctuate in residential areas as well as industrial areas while an overall increase is recorded at traffic intersection throughout the observation period. Annual mean concentration of SPM in 2006 was recorded 373.22 μg/m$^3$ in residential areas, 362.97 μg/m$^3$ in industrial areas and 517.5 μg/m$^3$ at traffic intersection against the standard limit of 140 μg/m$^3$, 360 μg/m$^3$ and 500 μg/m$^3$ respectively. The observed concentration of SPM is increased by 13.09 percent, 7.07 percent, and 3.5 percent in residential, industrial and traffic intersection respectively in the year 2006. On the basis of exceedence factor (Table 1) air quality in residential area and traffic intersection come under the category of critical pollution as their exceedence factor is 2.66 and 3.69 respectively. Whereas the quality of air in industrial area is categorized in high pollution (EF = 1.0). From the data it can be seen that the industrial area and traffic intersection more or less follow the standard limit set by the CPCB but in residential areas it is nearly three times more than the standard limit. The trend of annual mean concentration of SPM is presented in Figure 4. The annual mean concentration of SPM was found to show a fluctuating rising trend with its average value equal to 32.618 μg/m$^3$ per year. While the average concentration over the observation period is calculated 784.17 μg/m$^3$. The quality of air seems to be deteriorated further because the values calculated for the years 2010 (1469.14 μg/m$^3$), and 2015 (1632.23 μg/m$^3$) are found far beyond the limit.

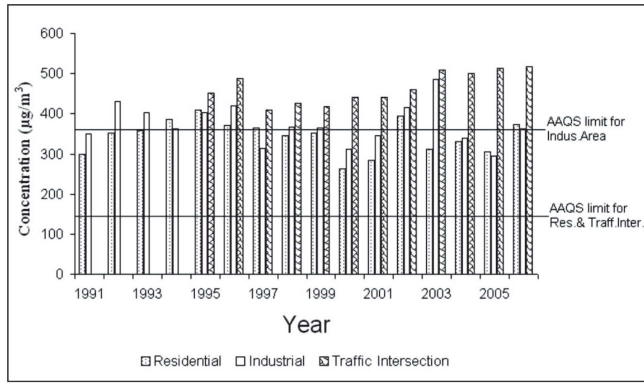


**Figure 3: Status of Annual Mean Concentration of Suspended Particulate matter in the ambient air of Delhi.**

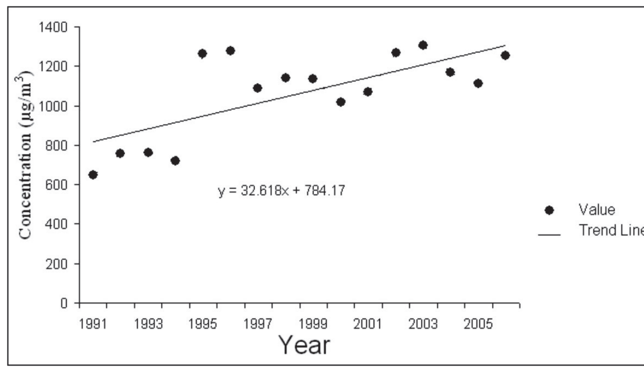


**Figure 4: Trend of Suspended Particulate Matter in the ambient air of Delhi.**

The status of respirable suspended particulate matter (RSPM or $PM_{10}$) from 1998 to 2006 is presented in Figure 5. An upward movement in residential and industrial areas and downward movement at traffic intersection are observed. The annual mean concentration of RSPM recorded 141.04 μg/m$^3$ in residential areas, 161.85 μg/m$^3$ in industrial areas and 291.25 μg/m$^3$ at traffic intersection against NAAQS limit of 60 μg/m$^3$, 120 μg/m$^3$ and 60 μg/m$^3$ respectively. It shows that the concentration of RSPM increased by 22.08 percent in residential area,

**Table 1: Exceedence factor of SPM and RSPM in the ambient air of Delhi**

| *Categories* | *Standard limit* | *EF of SPM* | *EF of RSPM* |
|---|---|---|---|
| Critical pollution | EF > 1.5 | Residential (2.66)<br>Traffic intersection (3.69) | Residential (2.35)<br>Traffic intersection (3.65) |
| High pollution | EF between 1.0-1.5 | Industrial (1.0) | Industrial (1.34) |
| Moderate pollution | EF between 0.5-1.0 | | |
| Low pollution | EF < 0.5 | | |

*Source:* Calculation based on the data from CPCB 2006.

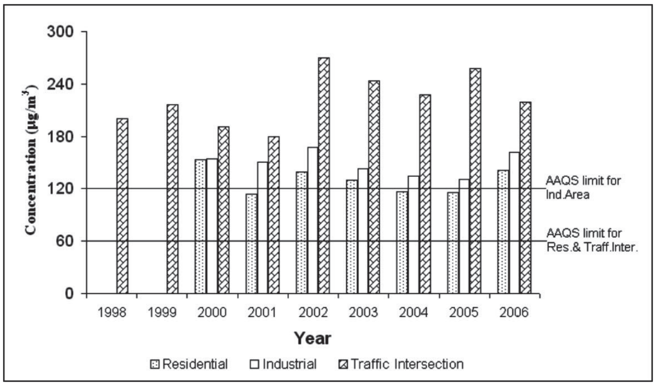


**Figure 5: Status of Annual Mean Concentration of Respirable Suspended Particulate Matter in the ambient air of Delhi.**

by 23.52 percent in industrial area and decreased by 14.92 percent at traffic intersection for the year 2006. On the basis of exceedence factor the residential and industrial areas come under the category of critical and high pollution while air quality at traffic intersection despite showing a negative growth come under the category of critical pollution (Table 1).

The trend of annual mean concentration of RSPM from 1998 to 2006 is presented in Figure 6. The annual mean concentration is found to show a fluctuating rising trend. It has been observed that after an initial decrease for the year 2001, the annual mean concentration enhanced for the year 2002, remain more or less constant upto the year 2005 and again was found to rise for the year 2006. The concentration increased at an average rate of 0.8364 µg/m$^3$ per year and the mean concentration of concerned pollutant over the observation period was recorded as 493.75 µg/m$^3$. The projected value for the years 2010 (511.13 µg/m$^3$), and 2015 (515.49 µg/m$^3$) are also quite high that depicts the criticality of the problem.

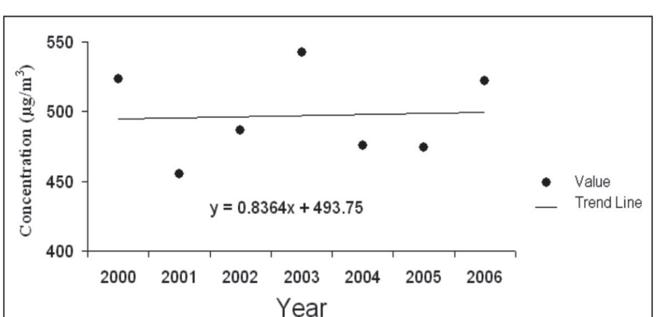


**Figure 6: Trend of Respirable Suspended Particulate Matter in the ambient air of Delhi.**

## Discussion

Historically, Delhi came into existence as a result of powerful urban forces (Aziz, 1983). It has remained India's capital for nearly ten centuries. Starting from Indraprastha, Delhi of today has developed around Tuglakabad, Lalkot, Jahanpanah, Siri Fort, Puranaqila, Shahjanbad, Firozabad to New Delhi. The last phase in the historical evolution of Delhi is represented by post-independence growth. The partition of India in 1947 triggered major changes that were to alter the demographic and morphological structure of the city. It is estimated that about one lakh people left for Pakistan and thrice the number came to the city which led to the mushrooming of over two hundred new residential colonies by 1951 (Singh, 2003). During 1941-51, highest population growth rate i.e. 106.6 per cent is recorded (Table 2).

The time for significant change that began with the independence of the country is continuing till date. Being a national capital, Delhi is the hub of economic, administrative and social activities and nodality in terms of means of transportation and communication is attracting more and more people not only from neighbouring states but the whole country. No other city has grown so phenomenally as Delhi in the recent past. From a population of barely two lakhs in 1901, it increased to 13.89 million in 2001 recording decadal growth rate of 51.93 percent as compared to 46.94 percent in 1981-1991 (Table 2). The growth of industries closely followed the rise in its population as it increased from 8000 in 1951 to 1,29,000 in 2002 (Census of Industrial Units, 2002). Similarly, the spatial dimension of the city has been found to be very dynamic since its beginning.

**Table 2: Growth of population and area in Delhi (1901-2001)**

| *Decadal years* | *Population* | *Decadal increase (%)* | *Area (sq.km)* | *Growth in %* |
|---|---|---|---|---|
| 1901 | 2,14,115 | - | 43.3 | - |
| 1911 | 2,37,944 | 11.13 | 43.3 | 0 |
| 1921 | 3,04,420 | 27.94 | 168.1 | 288.22 |
| 1931 | 4,47,442 | 46.98 | 169.6 | 0.89 |
| 1941 | 6,95,686 | 55.48 | 170.1 | 0.29 |
| 1951 | 14,37,134 | 106.58 | 195.8 | 15.11 |
| 1961 | 23,59,408 | 64.17 | 326.3 | 66.65 |
| 1971 | 36,47,023 | 54.57 | 451.4 | 38.34 |
| 1981 | 57,68,200 | 57.09 | 591.9 | 31.11 |
| 1991 | 84,71,625 | 46.95 | 685.3 | 15.78 |
| 2001 | 1,28,19,761 | 51.35 | 800 (appr.) | 16.73 |

*Source:* Director of Census Operation (2001).

The city's urban area was found to show approximately a twenty-fold increase during 1911-2001 i.e. it increased from 43.25 sq. km in 1911 (Maitra, 2005) to 924.68 sq. km in 2001 (Primary Census Abstract, 2001).

In the wake of urbanization and rapid spatial structure over the last fifty years, intra-city travelling frequency has increased. Consequently, the number of automobiles has been continuously rising. During 1974-2005, the number of registered motor vehicles has increased more than nineteen times from 2.35 lakhs to 44.9 lakhs (Table 3). The vehicle fleet projected at current growth rate will result in more than seven million vehicles in the city by 2020 (Transport Department, 2005). As a result, vehicular emissions have become the dominant source of air pollution, responsible for more than two-third of the total air pollution followed by industrial (20 per cent) and domestic (eight per cent) sources (A Report by Dept. of Env., 2005; Air quality status and trend in India, 2000). Vehicular emission is a matter of prime concern in the study area due to its large share in particulate pollution load and also being a ground level source it has maximum impact on air quality (NAQMS/14/1999-2000; Air Monitoring Department, 2006).

The recent research shows increase in the proportion of petrol fuelled three wheelers to CNG has led to an increase in $PM_{10}$ concentration. One possible reason for this may be poor CNG three wheeler technologies, at least for the first generations of CNG three wheelers introduced in Delhi. These three wheelers are characterized by poor quality of the piston rings, as well as the improper maintenance of air filters, which are causing abnormally high wear and tear of the piston rings, allowing lubricating oil to leak from the oil pump to the combustion chamber and generate white visible smoke. This smoke may well be what is causing the increase in $PM_{10}$ levels from CNG three wheelers (EPCA Report, 2004; Bull et al., 2004). Additionally, recent increase in the proportion of diesel cars also appears to be increasing $PM_{10}$ levels in Delhi. Finally, for similar reasons, an increase in the proportion of diesel light trucks also appears to increase $PM_{10}$ concentration (Balanchandaran, 2000). Besides, particulate pollutants in Delhi's environment are also contributed by non-exhaust particles which originate from wear and corrosion of road pavements and vehicle components, e.g. tyres and brakes and particles originating in the road surroundings, industrial processes, increasing construction activities in the form of residential and commercial complexes, ring roads and metro railway etc., loss of vegetation and thermal power plants which produce nearly 6000 metric tons of fly ash per day (A Report by Dept. of Env., 2005; NAQMS/14/1999-2000). Delhi has three major power plants namely Badarpur thermal power plant (705 MW), Indraprastha thermal power station (247 MW) and Rajghat thermal power station (135 MW) with the total generation capacity of 1087 MW (Mega Watts). They are responsible for as much as 10 per cent of the total air pollution load.

**Table 3: Growth of vehicles in Delhi (1991-2025)**

| *Year* | *Total vehicles (lakh)* | *Growth rate (%)* | *Private car (lakh)* | *Growth rate (%)* | *% of private car to total vehicles* |
|---|---|---|---|---|---|
| 1991 | 19.24 | 10.71 | 4.28 | 15.45 | 22.25 |
| 1992 | 20.65 | 8.28 | 4.69 | 10.46 | 22.71 |
| 1993 | 21.99 | 6.83 | 5.10 | 8.55 | 23.19 |
| 1994 | 23.73 | 6.76 | 5.58 | 9.30 | 23.51 |
| 1995 | 25.76 | 8.36 | 6.18 | 10.24 | 23.99 |
| 1996 | 27.94 | 8.11 | 6.86 | 10.08 | 24.55 |
| 1997 | 30.33 | 8.29 | 7.65 | 11.38 | 25.22 |
| 1998 | 31.67 | 6.51 | 8.05 | 8.44 | 25.42 |
| 1999 | 33.02 | 5.85 | 8.44 | 6.98 | 25.56 |
| 2000 | 35.10 | 6.30 | 9.10 | 7.82 | 25.93 |
| 2005 | 44.19 | 5.18 | 11.86 | 6.06 | 26.84 |
| 2010 | 53.28 | 4.12 | 14.62 | 4.65 | 27.44 |
| 2015 | 62.37 | 3.41 | 17.38 | 3.78 | 27.86 |
| 2020 | 71.46 | 2.91 | 20.13 | 3.16 | 28.16 |
| 2025 | 80.55 | 2.55 | 22.89 | 2.74 | 28.14 |

*Source:* Transportation Dept., Govt. of NCT, Delhi, 2005.

Moreover, Delhi has tropical semi-arid climate with hot summer, cold winter and monsoon rainfall. Local disturbances in environment, frequent dust storm and hazy conditions during the months of May and June and winds blowing from Thar Desert bring dust that builds up high particulate matter levels in ambient air of Delhi.

Indoor air pollution in the house of the selected wards has been analyzed in terms of sources of pollution, type of pollution and intensity of pollution. Table 4 depicts that 62.57 per cent of the respondents observed air pollution in their houses whereas 37.43 per cent reported for no pollution. As far as the sources of pollution is concerned, cooking fuels claimed the largest share of 43.33 per cent while the neighbours and household industries got 35.05 per cent and 21.62 per cent respectively. Concerning the type of pollution found in the respondents' house, it has been observed that 59.24 percent of the respondents claimed for particulate pollutants, specially fine dust whereas 40.76 reported for smoke. As far as the intensity of pollution is concerned, low intensity recorded is reported by 30.05 per cent of the respondents followed by negligible intensity (26.26

**Table 4: Indoor air quality in the respondents' house**

| *S. No.* | *Name of areas* | *Air pollution in the house* | | *Source of pollution* | | | *Type of pollutants* | | *Intensity of pollution* | | | | *Total* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Yes* | *No* | *Cooking fuels* | *Neighbours* | *Household industries* | *Particulate* | *Gaseous* | *High* | *Medium* | *Low* | *Negligible* | |
| 1 | Pitampura | 42.87 | 57.13 | 47.14 | 34.18 | 6.52 | 63.22 | 36.78 | 23.54 | 17.41 | 28.70 | 30.32 | 100 |
| 2 | Nizamuddin | 59.32 | 40.68 | 61.32 | 19.63 | 11.68 | 40.54 | 59.46 | 41.50 | 15.83 | 25.00 | 17.66 | 100 |
| 3 | Shahdara | 62.15 | 37.85 | 48.34 | 31.83 | 15.82 | 64.71 | 35.29 | 37.75 | 20.68 | 32.90 | 8.67 | 100 |
| | Total | 62.57 | 37.43 | 43.33 | 35.05 | 21.62 | 59.24 | 40.76 | 25.28 | 18.39 | 30.05 | 26.26 | 100 |

*Source:* Calculated by author (2005-06).

per cent), high intensity (25.28 per cent) and medium intensity (18.39 per cent). The present result of the indoor pollution is very much consistent with the CPCB findings.

Regarding the status of indoor pollution, the different sampled areas show contrasting features. In Pitampura 42.87 per cent of the respondents claimed for indoor air pollution followed by Nizamuddin (59.32 per cent), and Shahdara (62.15 per cent). Among the different sources of pollution i.e. cooking fuels, neighbouring hotels, automobiles and household industries, cooking fuels appear to dominate in Nizamuddin (61.32 per cent) followed by Shahdara (48.34 per cent), and Pitampura (47.14 per cent). Pollutants from neighbourhood appear to dominate Pitampura (34.18 per cent) while in Shahdara and Nizamuddin it is recorded at 31.83 per cent, and 19.63 per cent respectively. In the case of household industries, Shahdara claims the remarkable share of 15.82 per cent. It is followed by 11.68 per cent, and 6.52 per cent in Nizamuddin and Pitampura respectively (Table 4). As far as the type of pollutants is concerned, particulate pollutant claims the remarkable share of 64.71 per cent in Shahdara followed by Pitampura (63.22 per cent), and Nizamuddin (40.54 per cent). Concerning the intensity of pollution, high intensity of pollution is reported by 41.50 per cent of the respondents in Nizamuddin, 37.75 percent in Shahdara, and 23.54 percent in Pitampura. The low intensity of pollution dominates Shahdara i.e. 32.90 per cent while in Pitampura and Nizamuddin it is reported by 28.70 per cent and 25.00 per cent respectively.

## Conclusion and Suggestion

The above analysis makes it clear that the air quality in the study area has been degrading day by day. To address this problem, Indian government has taken several stringent measures such as emission standards for both manufacturing stage and in-use vehicles, switching to cleaner fuels (i.e. unleaded petrol, reduction of sulphur in diesel, reduction of benzene content in petrol, compressed natural gas), phasing out of old vehicles and closing or relocating polluting industries etc. (NAAQM Series 18/2001-2002). Despite such efforts pollution level in the study area is alarming. Some environmental friendly technology accompanied with social approach can be taken to fight the menace as under.

In order to control emissions, an integrated approach with many essential components are required: improvement of public transport system (e.g. mass rapid transport system, integrated rail-cum-bus transit system); optimization of traffic flow and improvement in traffic management (e.g. traffic control system, upgraded fast motorways and reserved lanes for different vehicles to enable transit traffic to pass unhindered, removal of encroachment on roads, regulation of construction activities and repairing of roads); better use of the existing ring railway and metro railway (as phase 1 of the Delhi Metro that was 84 percent under-utilized in 2006); installation of particulate filters and new high efficiency electrostatic precipitators to reduce particulates from diesel and petrol driven vehicles and from industry and power generation plants respectively; providing green vegetation blanket on dry non-vegetated areas and plantation of pollutant tolerant tree species [*Mangifera indica (Mango), Ficus religiosa (Peepal), Psidium guava (Guava), Azadiracta indica (Neem), Acacia Arabic (Babool)* etc.] in polluted hot spots because vegetation normally act as an absorbent of various air pollutants filtering out dust, soot, smoke and many other fine particulate matter present in air by process of absorptation, detoxification, accumulation and/or metabolization. Development of ring towns with regional rapid transit system to decentralize population as well as certain industrial and commercial activities etc.; top priorities to increase pedestrian access to create safe routes for cycling; mass awareness campaign regarding air pollution (community level organizations); and prohibition of the open incineration/combustion of solid wastes etc. are some of the measures that can realize the dream of the citizen-friendly city.

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