IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

SPATIO-TEMPORAL VARIATION OF AIR POLLUTION IN DELHI – A FOCUS ON RESPIRATORY DISEASES

Dr. Nitasha Malhotra and Dr. Shyamoli Sen

ABSTRACT

The city of Delhi has developed a negative reputation of being one of the most polluted cities in the world. The reason being its unique geographic location and the phenominal growth it has witnessed in the last few decades. Long term exposure to harmful air pollutants increases the risk of respiratory illnesses such as asthma, allergies, chronic bronchitis and lung cancers. This paper throws light on the aspect of air pollution and its spatial and temporal variations in Delhi within a specific time period. This attempt to study the spatio-temporal variation has been specifically done in order to examine the changing pollution scenario, whether good or bad within the specific time gap as this acts as a pre-cursor in understanding the various respiratory diseases resulting from the adverse pollution scenario in the city

Delhi, the capital city of India, is a large city having great strategic and historic importance. Over the last few decades it has seen phenomenal growth in population due to the immense potential it has had in attracting migrants from all parts of the country for higher education, job opportunities, small and large businesses and so on. This has led to rapid changes in landuse, infrastructural developments, construction activities, transportation systems, vehicular traffic. All this has contributed immensely to making the city as one of the most polluted in the world. The unique geographic location of this city contributes more to this problem especially in the winter season when the region experiences temperature inversion. There has been increased concern over the adverse effects of air pollution on respiratory health of individuals which has made it one of the leading issues in the public health scenario.

Largest exposures to health damaging air pollution probably occur in the developing world, especially in urban areas. The global burden of disease (GBD) of the World Health Organisation (WHO) released in December, 2013 says air pollution is the sixth most dangerous killer in south Asia. Around 65 percent of the air pollution deaths occur in Asia and close to quarter of this happen in India. Much of these health impacts are on respiratory health which seem to occur among the poorest and most vulnerable population as indicated by numerous researchers.

Long term exposure to harmful air pollutants increases the risk of respiratory illnesses such as asthma, allergies, chronic bronchitis and lung cancers. Children and the elderly are particularly vulnerable to these airborne toxicants due to their weak immunity status and it is generally found that these problems manifest themselves in a hyper-urbanized scenario like Delhi more clearly than other areas as is seen in the recent times (Yaari, et al.,2008)

This paper throws light on the aspect of air pollution and its spatial and temporal variations in Delhi within a specific time period. This attempt to study the spatio-temporal variation has been specifically done in order to examine the changing pollution scenario, whether good or bad within the specific time gap as this acts as a pre-cursor in understanding the various respiratory diseases resulting from the adverse pollution scenario in the city.

1.1. NEED FOR THE STUDY OF AIR POLLUTION

Air Pollution is essentially an urban phenomenon as the processes of urbanization such as industrialization and vehicularisation are intimately related. Speedy and unplanned development of a city like Delhi gave an impetus to the process of urbanization and primacy. The high density of population in the city led to associated vehicular, industrial and domestic emissions affecting health of inhabiting citizens (CPCB, 2001-02). This adverse impact of air pollution impacted health in general and respiratory health in particular of Delhiites, which led to the need for the development of the concept of emission inventory, which provides a blueprint of the pollution burden on the health of human beings. Health impacts due to air pollution are estimated in terms of mortality and morbidity, which are derived from air quality data using dose-effect relationships. In principle, such relations are found through statistical comparison of death rates and morbidity in areas with different air quality problems. Globally, it is estimated that there are about 8 million deaths due to air pollution every year. Unfortunately, in India due to the constraint of lack of monitoring mechanism of spatial pollution data on day to day basis as well as limitations of time, there is no such data available at present (TOI, 2014). Nonetheless, it is a fact that without proper availability of pollutant exposure data, it is not possible to understand the impact of toxic exposure on respiratory health of individuals.

Furthermore, it is also pertinent to understand that why such a study is relevant in the context of a city like Delhi. After Independence, the city became a major centre of commerce, industry and education which resulted in the city sprawling in leaps and bounds over the years and thus it became a construction hub leading to indiscriminate emission of particulate matter coupled with a burgeoning rise in vehicular pollution causing maximum damage to respiratory health (CPCB, 2020). This pollution is thus a palpable manifestation of the intense pressure of urbanization (Landsberg, 1981).

The major polluting gases in the city are sulphur dioxide (SO_2), nitrogen oxide (NO_2), carbon dioxide (CO_2) and methane (CH_4). For the present study only the first two have been considered as one finds continuous monitoring of these gases by concerned authorities like Central Pollution Control Board (CPCB) and National Environmental Engineering Research Institute (NEERI). Apart from these two, the present research has also studied particulate matter as it is a crucial aspect from the respiratory health point of view. All these three pollutants taken together act as a direct potent force of altering respiratory health of individuals that plays the most crucial factor in the context of this study. Delhi is known as a 'Particulate City', as a result of which study of particulate matter is of utmost importance in the context of the present research.

Air pollutants are classified as primary or secondary, based on their characteristics at the time of emissions and physical/chemical changes, they undergo while in the atmosphere. Primary pollutants are defined as those that are emitted into the atmosphere directly from the identifiable sources and remain scattered in the atmosphere in the same chemical form like particulates. Secondary pollutants are recognized as those which are formed in the atmosphere by the reaction among two or more primary pollutants like nitrogen dioxide. Sources of air pollutants can be point sources, line sources and non-point sources. The point sources include emissions from domestic sources and industrial sources, whereas, line sources include vehicular emissions and non-point sources include fugitive emissions, emissions from construction activities and from refuse burning. As mentioned earlier, this chapter deals with only those pollutants that have been continuously monitored over the years by authorities like CPCB and NEERI. The major sources are:

Table 1.1: Anthropogenic Sources of Major Greenhouse Gases

Pollutant	**Main Emission Source Categories**
Particulate Matter	Dispersion originated matter forms from breakdown of liquid or solid bulk material, i.e. by grinding, atomization, natural dispersion, wind erosion, etc. The condensation originated matter develops from a build up from molecular dimension after heating and cooling.
NO_2	Use of synthetic fertilisers, fossil fuel combustion, biomass
	combustion, soil and other agricultural emissions, nitric acid
	production.
SO_2	Fossil fuel combustion, biomass combustion, sulphuric acid production,
	zinc, lead and copper smelting and cement manufacturing.

Source: Garg and Shukla (2002)

1.2. SPATIO-TEMPORAL VARIATION OF AIR POLLUTION FROM 2000 TO 2008

The present research has studied the spatio-temporal variation of SO_2, NO_2 and SPM and RSPM over Delhi for the years 2000 and 2008 with the help of maps generated from CPCB monitored air pollution data (unit used is micrograms/cubic metre) from various monitoring stations of Delhi which has been shown in Table 1.2 and 1.3. These two years have been randomly selected but the time gap of 8 years has been deliberately kept as this would provide a meaningful analysis of the temporal variation in Delhi. The monitoring stations also differ slightly over the two years as CPCB keeps changing its monitoring locations from time to time. Two maps have been generated each for 2000 and 2008 based on the CPCB monitored pollution data. The first map is for SPM and RSPM (in 2008, CPCB monitored only RSPM and SPM data was not monitored) and the second map is for SO_2 and NO_2 for both the years respectively.

In addition to the map-wise analysis of pollution scenarios of 2000 and 2008, it was felt that mere analysis of values per se do not reveal the actual picture as norms according to the National Ambient Air Quality Status (NAAQS) have changed during this time gap. It is therefore, this paper has also analyzed the air quality with respect to the NAAQS based on a factor called the Exceedence Factor (EF). Exceedence factor is the ratio of annual mean concentration of a pollutant with that of a respective standard. In other words, the EF provides a clear idea about the degree of violation of stipulated norms set by NAAQS. The EF is calculated as follows:

EF = Observed Annual Mean Concentration of Criteria Pollutant / Annual Standard for the Respective Pollutant and Area Class

The four quality of air pollution categories that can be assessed based on this EF criteria are:

Critical pollution (C) : when EF is > 1.5, **High pollution (H)** : when EF is between 1.0 – 1.5, **Moderate pollution (M)** : when EF is between 0.5 – 1.0; and **Low pollution (L):** when the EF is < 0.5

It is obvious from the above categorization, that the locations in either of the first two categories are actually violating the standards, although with varying magnitude. Those, falling in the third category are meeting the standards as of now but likely to violate the standards in future if pollution continues to increase and is not controlled. However, the locations in Low pollution category have a rather pristine air quality and such areas are to be maintained at Low pollution level by way of adopting preventive and control measures of air pollution.

It is important to mention here that EF as a criteria to analyse the violation of pollution standards was used by CPCB for the 2000 data, however, the present research has employed the same method to analyse the 2008 data as well because of the fact that the use of a similar criteria to analyse the data for both the years would facilitate an ideal comparison.

1.2.1. Pollution Scenario in 2000

As discussed above, analysis of the pollution scenario has been made on the basis of maps generated from the CPCB data from different monitoring stations as given in Table 1.2 and EF values given in the said table.

SPM (2000) – The SPM values in Figure 1.1 have been indicated by proportional circles each of which corresponds to the location-specific data given in the above table. Out of the total of 9 monitoring locations, Shahzada Bagh, Shahdara and Najafgarh are industrial areas and the remaining 6 i.e. Nizamuddin, Ashok Vihar, Janak Puri, Siri Fort, Netaji Nagar and Town Hall are all residential areas. The map shows highest values at Najafgarh (671) followed by Town Hall (590) and Netaji Nagar (491). Najafgarh, on one hand has large tracts of land dedicated to agricultural activities including barren land as well while on the other a lot of this barren land is being converted to non –agricultural land uses which is leading to a spur in construction activities in this area. All these factors in conjunction with each other can be attributed to such high SPM levels. Contrarily, the lowest value is seen in Siri Fort which is about 225 micrograms/cubic metre.

As far as the EF is concerned, the three industrial locations of Shahzada Bagh, Shahdara and Najafgarh have little higher air quality standard than their residential counterparts as seen in the above table. If one looks at the EF and the resultant air quality, it is seen that barring Shahzada Bagh (0.95) and Shahdara (0.78), all other seven locations have critical pollution levels. It is noteworthy that since the last two to

Figure 1.1

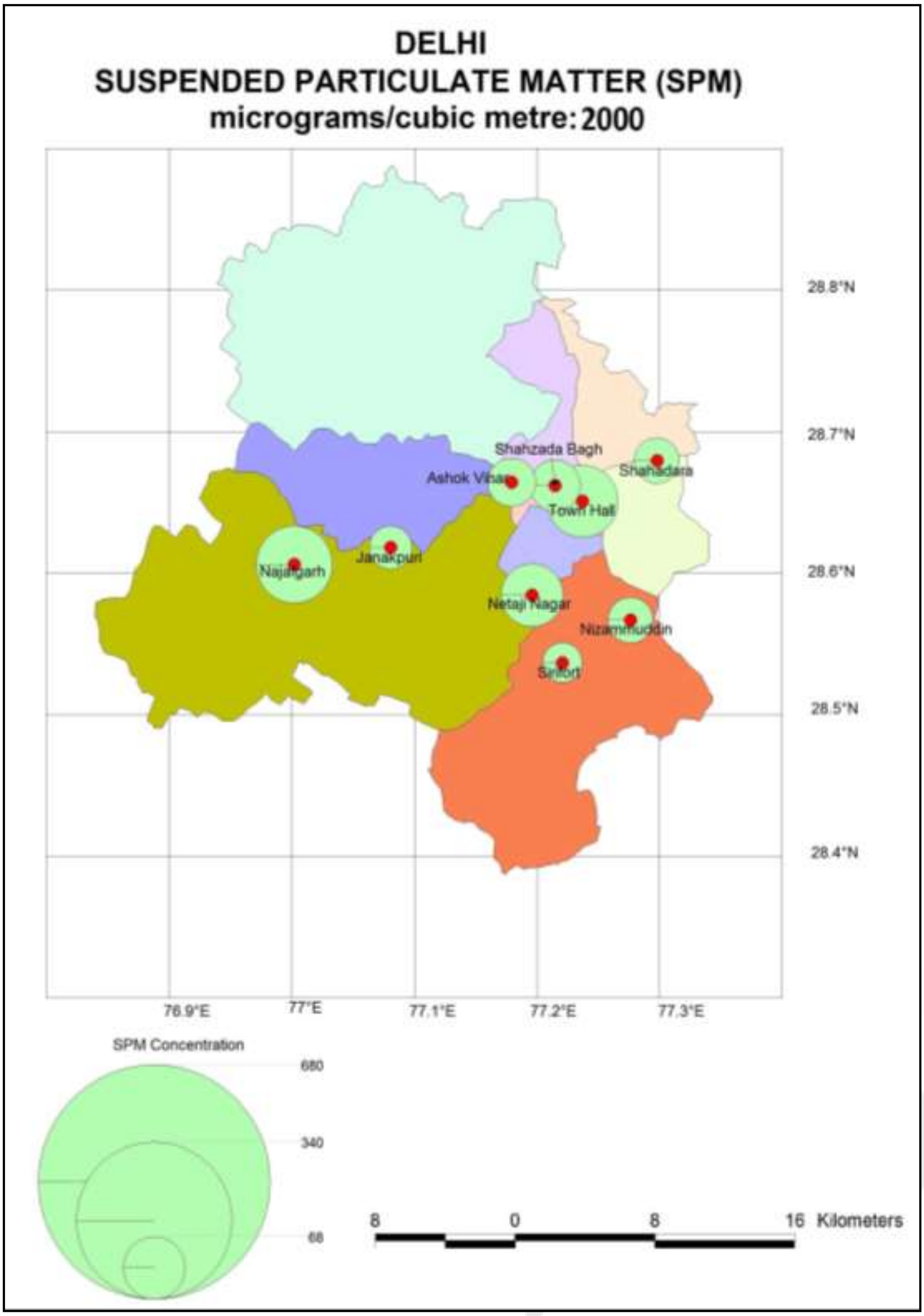

DELHI
SUSPENDED PARTICULATE MATTER (SPM)
micrograms/cubic metre: 2000
28.8°N
28.7°N
28.6°N
28.5°N
28.4°N
76.9°E
77°E
77.1°E
77.2°E
77.3°E
Shahzada Bagh
Ashok Vihar
Shahdara
Town Hall
Janakpuri
Najafgarh
Netaji Nagar
Nizammuddin
Siriort
SPM Concentration
680
340
68
8
0
8
16
Kilometers

Figure 1.2

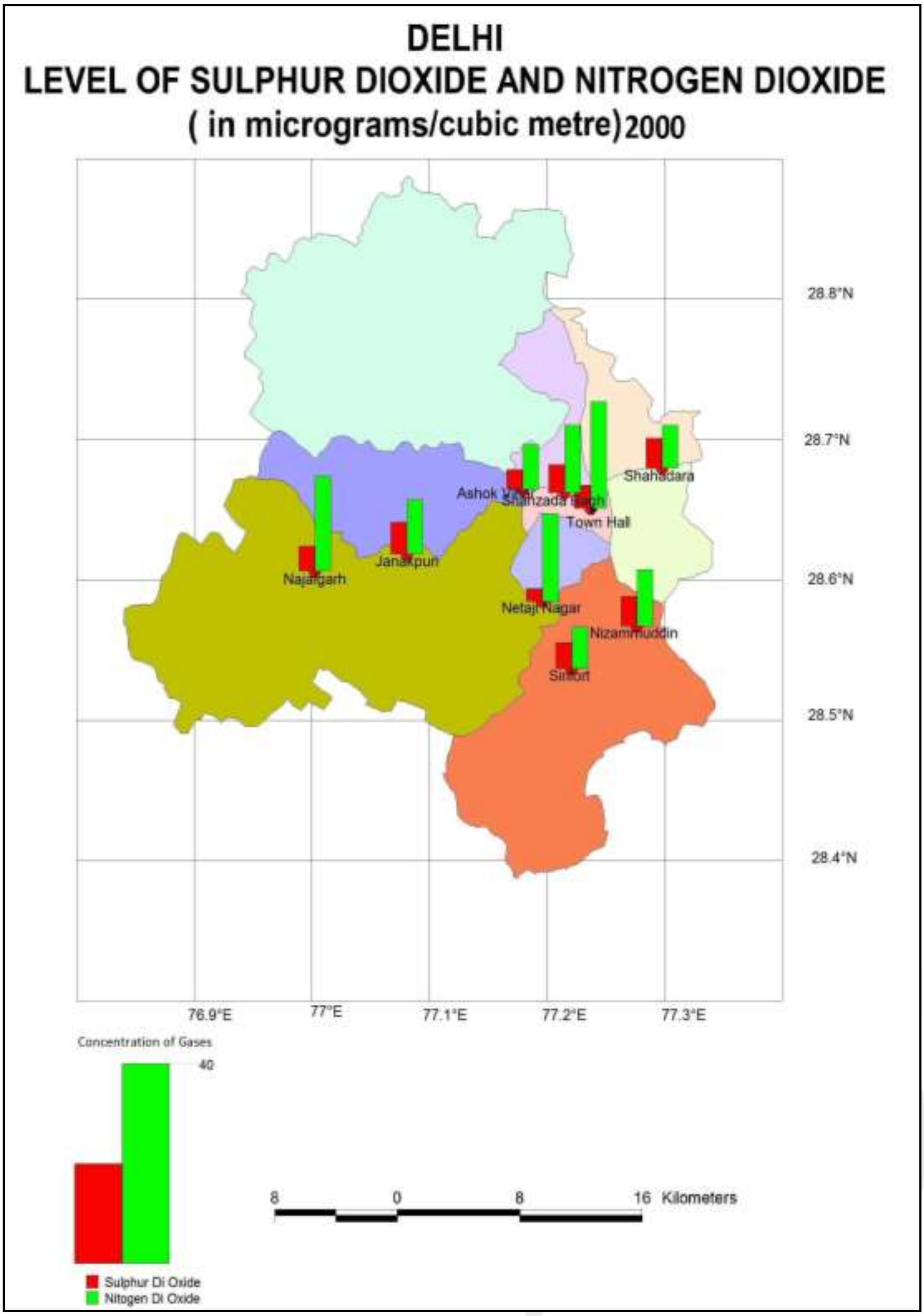

DELHI
LEVEL OF SULPHUR DIOXIDE AND NITROGEN DIOXIDE
(in micrograms/cubic metre) 2000
28.8°N
28.7°N
28.6°N
28.5°N
28.4°N
76.9°E
77°E
77.1°E
77.2°E
77.3°E
Shahdara
Ashok Vihar
Shahzada Bagh
Town Hall
Janakpuri
Najafgarh
Netaji Nagar
Nizammuddin
Sirifort
Concentration of Gases
40
8
0
8
16
Kilometers
Sulphur Di Oxide
Nitogen Di Oxide

Table 1.2: Level of Air Pollution, National Ambient Air Quality Standards (NAAQS) and Exceedence Factor (EF) during 2000

Area	SPM	NAAQS	EF	Air Pollution	SO_2	NAAQS	EF	Air Pollution	NO_2	NAAQS	EF	Air Pollution
Nizamuddin	279	140	1.99	C	18.2	60	0.3	L	33.6	60	0.5	M
Ashok Vihar	306	140	2.18	C	11.6	60	0.1	L	27	60	0.4	L
Shahzada Bagh	342	360	0.95	M	17	80	0.2	L	41.4	80	0.5	M
Shahdara	282	360	0.78	M	17.7	80	0.2	L	26	80	0.3	L
Janakpuri	242	140	1.72	C	18.6	60	0.3	L	32.5	60	0.5	M
Siri Fort	225	140	1.58	C	15.9	60	0.2	L	24.6	60	0.4	L
Netaji Nagar	491	140	3.5	C	8.3	60	0.1	L	52.6	60	0.8	M
Najafgarh	671	360	1.8	C	14.8	80	0.1	L	57	80	0.7	M
Town Hall	590	140	4.2	C	14.3	60	0.2	L	64	60	1.06	H

Note: C-Critical, M-Moderate, H-High, L-Low
Source: National Ambient Air Quality Status 2000, NAAQMS/2001-02, CPCB

three decades, Delhi has been witnessing excessive construction activities which have resulted in such high levels of particulate matter in the ambient air.Furthermore these construction activities are mostly concentrated in the residential areas of Delhi. Also, since Najafgarh although an industrial area, also houses large colonies and also has large tracts of agricultural land thus witnessed such critical levels of SPM pollution.

SO_2 and NO_2 – This has been represented by horizontal bars (Figure 4.2). In 2000, SO_2 values are much lower than the NO_2 values. This is primarily because NO_2 is largely released by vehicles and pollution norms were not as stricter in 2000 as they are at present. For SO_2, highest and lowest values are seen at Janak Puri (18.6) and Netaji Nagar (8.3) respectively. NO_2 values are highest at Town Hall (64) and lowest at Siri Fort (24.6).

Delhi has always experienced low levels of SO_2 over the years. The same can be seen from the above data which reveals a low level of SO_2 pollution at all the 9 locations. This low level of pollution can be attributed to the absence of certain specific industries such as chemicals, fertilizers, leather etc. which usually emit SO_2 in large quantities into the air.

With respect to EF, NO_2 pollution was moderately high in Delhi during 2000. Nizamuddin (0.5), Shahzada Bagh (0.5), Janak Puri (0.5), Netaji Nagar (0.8) and Najafgarh (0.7) have moderate pollution; Ashok Vihar (0.4), Shahdra (0.3) and Siri Fort (0.4) have low pollution. High pollution is only seen in Town Hall at a level of 1.06. It is relevant to mention here that NO_2 is largely emitted by vehicles and Town Hall has a very high concentration of traffic and hence it has a significantly high level of NO_2 pollution.

1.2.2. Pollution Scenario in 2008

RSPM (2008) – These values have also been represented by proportional circles (Figure 1.3). The residential areas are Nizamuddin, Pitampura, Siri Fort, Sarojini Nagar, Janak Puri and Town Hall. Mayapuri, Shahzada Bagh and Shahdara are the three industrial areas where CPCB monitoring stations are located. RSPM values are lower than the SPM values if seen comparatively. However, RSPM is more harmful to the respiratory system than SPM as discussed earlier. Since Najafgarh ceased to be a monitoring location in 2008, Town Hall has the highest value of RSPM i.e. 278 micrograms/cubic metre followed by Mayapuri (263) and Janak Puri (219). The lowest value has been recorded at Pitampura (159).

As far as EF of RSPM is concerned, situation is extremely grim. This is because one finds critical pollution levels at all locations and especially the worrisome locations are

Town Hall (6.9) and Mayapuri (6.5). The lowest EF is at Pitampura which is 3.9 but is again much higher than the prescribed standard of 1.5 as discussed earlier.

SO_2 and NO_2 - In the 2008 map (Figure 1.4), it is seen that SO_2 levels have further gone down as compared to the 2000 level. This can be attributed to the fact that since SO_2 is primarily an industrial pollutant and relocation of industrial units to peripheral areas automatically reduced SO_2 emissions within the city. However, this declining trend is not seen in the case of NO_2. The highest and lowest NO_2 level is seen at Town Hall at 77 micrograms/cubic metre and Pitampura at 38 micrograms/cubic metre respectively. Such an appalling rise in NO_2 levels can be attributed to the ever-growing traffic congestion in the city in general and Town Hall in particular. It is interesting to note that Delhi adds more than 1000 vehicles every day to its roads (CPCB, 2008).

SO_2 values are highest at Mayapuri (13) followed by Pitampura (10). All other locations have less than 10 micrograms/cubic metre of SO_2. For EF values shown in Table 1.3, SO_2 levels are again very controlled even in 2008 as all locations exhibit low level of pollution.

All these locations have an EF levels of SO_2 lower than 0.5. NO_2 levels are much higher than SO_2 levels. The highest is seen at Town Hall followed by Mayapuri at 1.9 and 1.8 respectively both having critical pollution. The lowest is seen at Pitampura at 0.9 which means it has moderate pollution. It is seen that all other locations have either moderate or high pollution. Higher levels of NO_2 can be solely attributed to vehicular emissions as NO_2 is primarily a vehicular toxicant. In a recently published article, it was seen that NO_2 concentration in 2012 in North Delhi, South Delhi and Central Delhi was 123.29, 199 and 140.5 micrograms/m^3 as against the ambient norm of 80 micrograms/m^3.

Figure 1.3

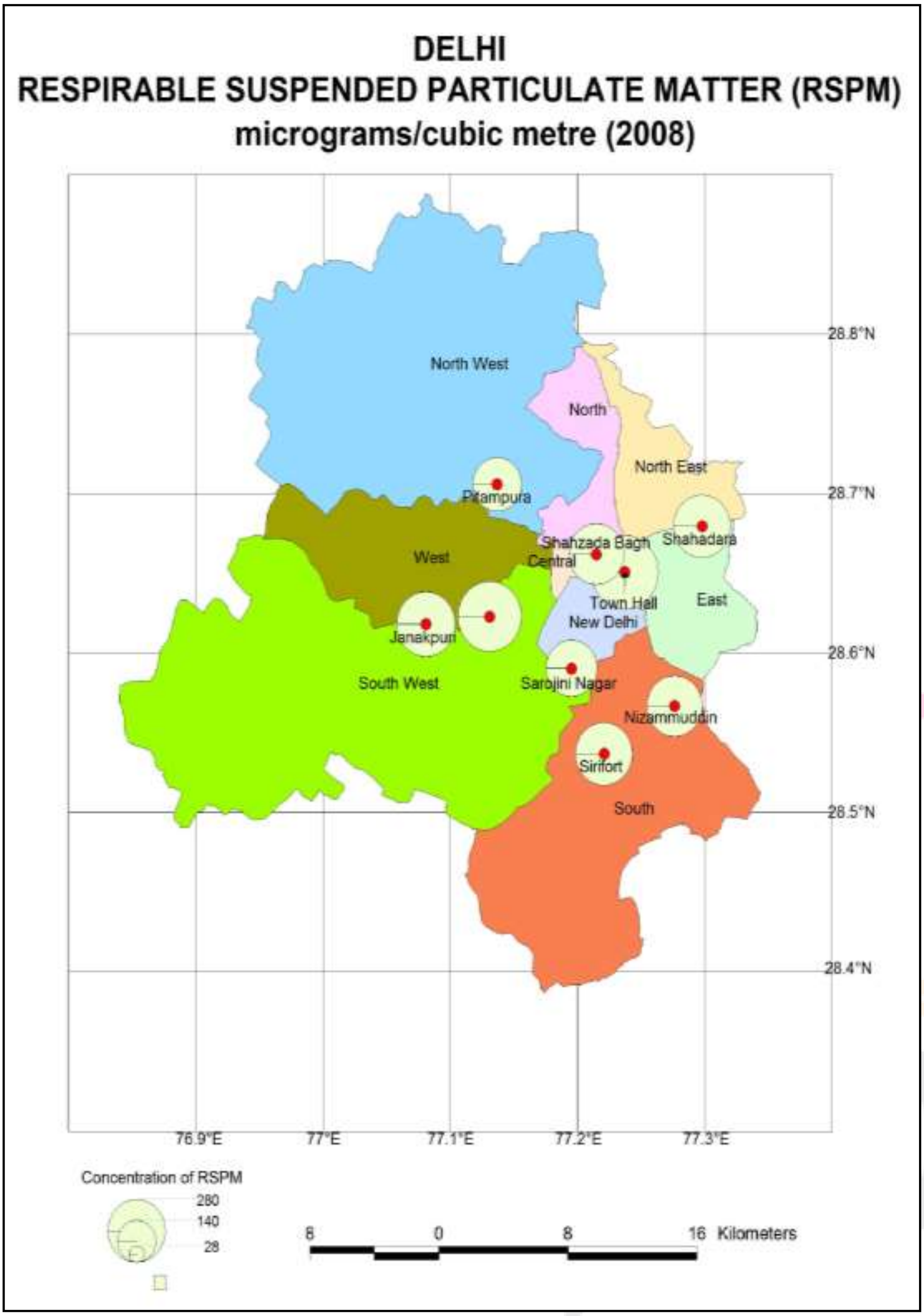

DELHI
RESPIRABLE SUSPENDED PARTICULATE MATTER (RSPM)
micrograms/cubic metre (2008)
North West
North
North East
Pitampura
West
Shahzada Bagh
Central
Shahadara
Town Hall
East
New Delhi
Janakpuri
South West
Sarojini Nagar
Nizammuddin
Sirifort
South
28.8°N
28.7°N
28.6°N
28.5°N
28.4°N
76.9°E
77°E
77.1°E
77.2°E
77.3°E
Concentration of RSPM
280
140
28
8
0
8
16 Kilometers

Figure 1.4

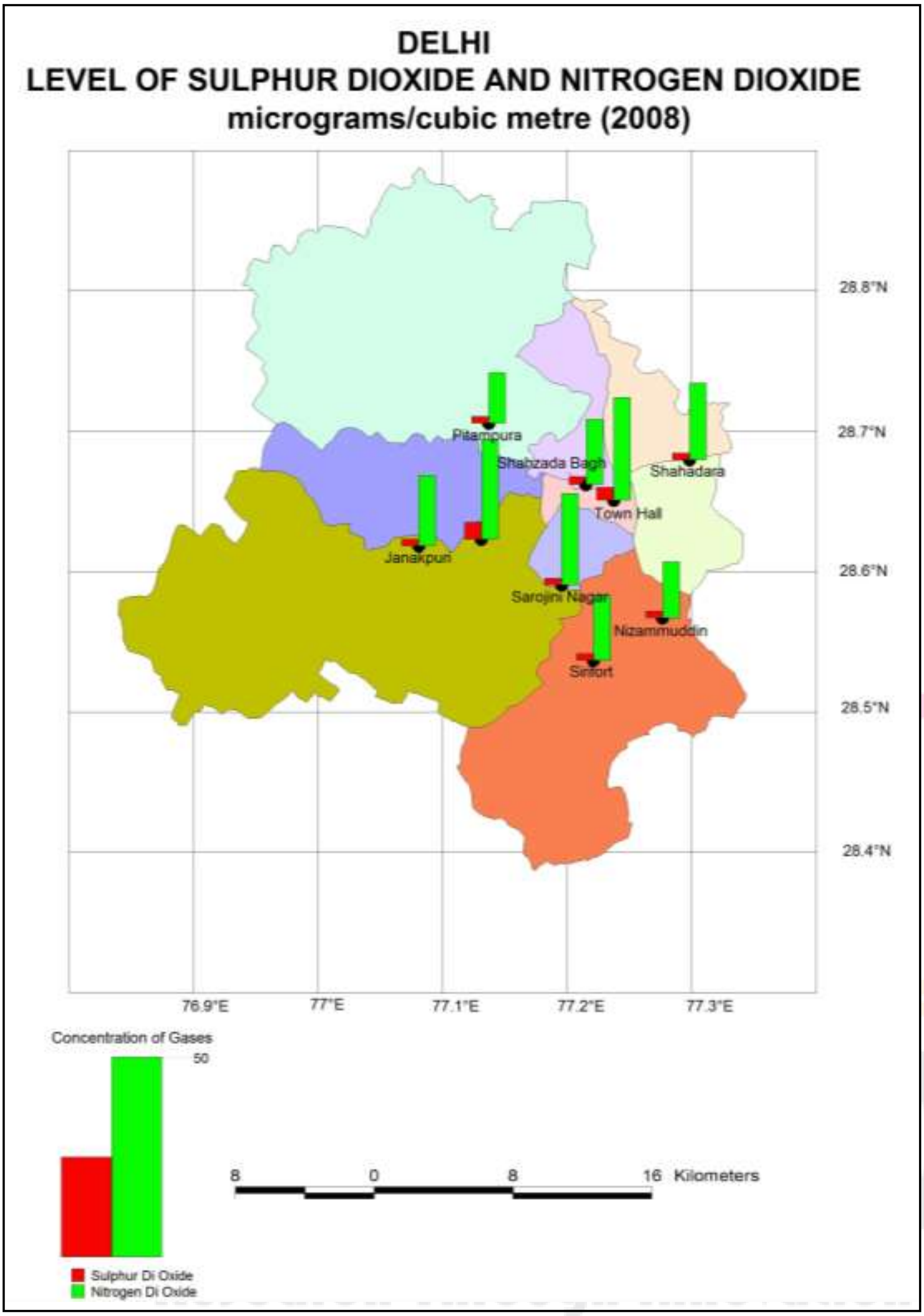

DELHI
LEVEL OF SULPHUR DIOXIDE AND NITROGEN DIOXIDE
micrograms/cubic metre (2008)
Pitampura
Shahzada Bagh
Shahadara
Town Hall
Janakpuri
Sarojini Nagar
Nizammuddin
Sirifort
28.8°N
28.7°N
28.6°N
28.5°N
28.4°N
76.9°E
77°E
77.1°E
77.2°E
77.3°E
Concentration of Gases
50
8 0 8 16 Kilometers
Sulphur Di Oxide
Nitrogen Di Oxide

Table 1.3: Level of Air Pollution, National Ambient Air Quality Standards (NAAQS) and Exceedence Factor during 2008

Area	RSPM	NAAQS	EF	Air Pollution	SO_2	NAAQS	EF	Air Pollution	NO_2	NAAQS	EF	Air Pollution
Nizamuddin	200	40	5	C	5	50	0.1	L	42	40	1	M
Mayapuri	263	40	6.5	C	13	50	0.2	L	75	40	1.8	C
ShahzadaBagh	203	40	5	C	6	50	0.1	L	49	40	1.2	H
Shahdara	210	40	5.2	C	5	50	0.1	L	58	40	1.4	H
Pitampura	159	40	3.9	C	5	50	0.1	L	38	40	0.9	M
Siri Fort	215	40	5.3	C	5	50	0.1	L	49	40	1.2	H
Sarojini Nagar	180	40	4.5	C	5	50	0.1	L	69	40	1.7	C
Janak Puri	219	40	5.4	C	5	50	0.1	L	53	40	1.3	H
Town Hall	278	40	6.9	C	10	50	0.2	L	77	40	1.9	C

Note: C-Critical, M-Moderate, H-High, L-Low
Source: National Ambient Air Quality Status 2008, NAAQMS/2009-10, CPCB

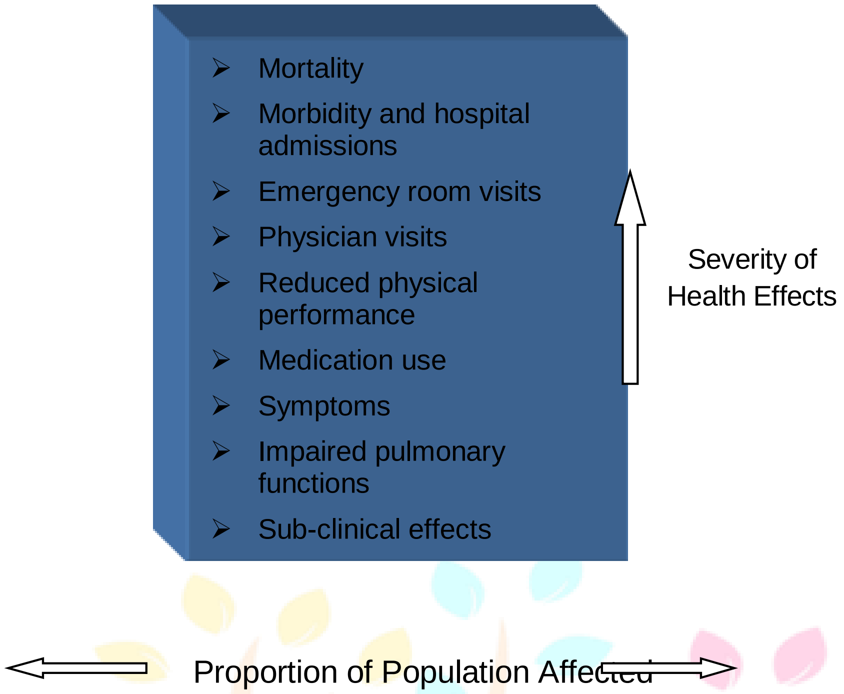
The PM10 concentration was 999.8, 621 and 436 micrograms/m^3 for these three locations respectively as against the ambient standard of 200 micrograms/m^3. Here, both the NO2 and PM10 levels are way above the ambient standards. PM10 scenario is very worrisome since it has direct links with total pulmonary performance of an individual. Thus it is evident that spatially as well as temporally, Delhi's pollution levels violate the stipulated norms as seen in the above figures (Mail Today, 2012).

1.3. RESPIRATORY DISEASES ASSOCIATED WITH AIR POLLUTANTS

According to the WHO Global Burden of Diseases Report 2010, nearly 6,20,000 premature deaths took place in India as a result of air pollution. Of all cities, experts feel that Delhi is the most vulnerable as it has the highest pollution level and has been held as one of the world's most polluted cities by global bodies including WHO (TOI, 2014). The city seems to be paying an increasingly heavy price for its deteriorating air quality due to air pollutants generated by rising industrial activities, burgeoning vehicular population, increasing power generation and domestic emissions resulting in exposure of a large population segment. An average of 23 people die every day due to respiratory diseases in the capital, a number that has doubled in the past four years, data released by the Delhi government reveals.
Doctors warn that worsening air quality, a major trigger for respiratory conditions such as chronic bronchitis, lung cancer and infections, may cause more fatalities in the coming years if appropriate measures are not taken.
The latest statistical handbook, released by Delhi government shows respiratory diseases to be the fastest growing killer in a city where fatalities from most other ailments were declining (TOI, 2012).

In a study of school children by Paramesh (2002), it was examined how urbanisation, air pollution and environmental tobacco smoke causes and even triggers allergic respiratory disorders, especially asthma in school going children. Results were based on a two-pronged approach, one on hospital based study and second on school based study of children.

Figure 1.5: Effects of Air Pollution on Human Health



Source: CPCB, 2000.

It is certainly a challenge for medical experts and planners to control the respiratory ailments that are being experienced in all round the year indicating that Delhi's pollution scenario is grim and worrisome. The health effects caused in exposed population may not be directly due to affect of ambient concentration of pollutants, but rather based on the doses of pollutants received by respective receptor population. Air pollution damages the human respiratory system in various ways leading to further complications as is indicated in the Figure 1.5.

In India, Lvovsky et.al, (2000) reviewed the impact of particulate matter and discussed the issues relating to economic valuation of sickness and premature deaths due to outdoor air pollution. The pooled estimate of 0.84 percent change in all-cause mortality relative to a 10 microgram/m^3 change in PM10 concentration was derived from a number of acute exposure studies. Similar to estimates of mortality, concentration-response functions were also derived for morbidity impacts such as respiratory hospital admissions, chronic bronchitis, cough, asthma etc. (Lvovsky, et.al, 2000).

In another study, based on annual average concentration levels of PM10 and total city population in 2001, the number of cases of excess mortality and morbidity for Indian mega-cities, viz., Delhi, Mumbai, Kolkata and Chennai were estimated (Nema and Goyal, 2006). It was observed from the figures that highest number of cases of excess mortality occurred in Delhi as compared to other metro cities. In fact, experts fear that in coming years, the heavy density of particulate matter in the city could cause havoc to the respiratory health of Delhiites (TOI, 2014).

Although all pollutants discussed above damage the respiratory health of individuals, however, different air pollutants pose different threats to the human respiratory system some of which are discussed in this section. Particulate air pollution result in changes in respiratory health status and depict several respiratory symptoms. Upper respiratory symptoms are stuffy or runny nose, sinusitis, sore throat, wet cough, etc. The lower respiratory symptoms include wheezing, dry cough, phlegm, dyspnea or shortness of breath, chest tightness and pain. The impaired lung function are the sensitive indicators of acute exposure of particulate air pollution. Asthma, allergies and bronchitis are other manifestations of health damaging effects of particulate pollution. Therefore, particulate matter in ambient air is associated with decrements in lung function as particulates enter the lung directly without being impeded by the nasal cavity owing to their small range of size. Thus comparatively, RSPM is smaller in size than SPM and is not impeded by nasal cavity as a result is more damaging in general. An association between SPM air pollution and pulmonary function reduction has been reported in several epidemiological studies. RSPM (PM2.5) has been associated with increased respiratory symptoms, including cough, wheeze and shortness of breath. Interestingly, the relationship between SPM air pollution and asthma is stronger than for RSPM. Contrarily, RSPM is associated with COPD than SPM. Therefore, study of SPM and RSPM is extremely crucial in the context of the present research.

NO_2 exposure can cause decrement in lung function, increased airway responsiveness to broncho-constrictions at concentration exceeding 1.0 ppm. Exposures for about 3 to 4 years leads to incidences of bronchitis, emphysema, edema and have adverse effects on lung performance. The most common acute exposure to SO_2 at concentration >=0.4 ppm is induction of broncho-constriction in asthmatics after exposure lasting only 5 minutes. High level exposures leads to chronic bronchitis incidences and even morbidity effect. The children, elderly, smokers and those with chronic respiratory difficulties are most vulnerable group of population (World Bank, 2003). In other words, long term exposures to health damaging pollutants can also reduce life expectancy of individuals by complete alteration of the lung function caused by diseases like COPD, which when diagnosed at a later stage proves fatal in most cases.

Since the last two decades, researchers are examining the effects of urbanisation on global climate change and climatic parameters of the city of Delhi. In fact, large cities like Delhi can modify some of the climatic parameters in their immediate vicinity, resulting in a relatively small-scale but important variation in climate, which is called a ‘microclimate’. Delhi is a classic example of such formation of a microclimate wherein due to excessive energy use and due to vehicularisation and other urban processes, there has been uncontrolled emission of Greenhouse Gases (GHGs) like CO_2, SO_2, NO_2, etc. as a result of which the surface air temperature is 15^{o}C, which is 3^{o}C above normal. This is an indication of the problem of climate change in the city (Kumar, 2003). Therefore, uncontrolled emission rates of GHGs automatically leads to uncontrolled pollution in the atmosphere coupled with particulate pollution. In addition, another important facet of pollution which forms part of temporal variation and which solicits great attention from researchers is seasonal aspect of Delhi's pollution, although the present research is not analysing data from a seasonal point of view. However, it is worth mentioning that from Delhi's point of view, pollution touches an extreme level in the months of November to January i.e. the winter months leading to a spurt in asthma and bronchitis cases, which is relevant to the present topic in general. This rise in pollutant levels is particularly appalling in case of SPM and RSPM. Many studies have been conducted throwing light on this issue. Most have attributed it to the typical winter phenomenon of inversion of temperature and absence of winds and rainfall which fails to disperse the pollutants from the air and as a result forms a thick envelope of haze near the ground reducing visibility to 400 metres on an average. For instance, in a 4 year study conducted by School of Environmental Studies, Jawaharlal Nehru University has concluded that the blinding haze that chokes the city in winters is primarily composed of SPM and 80 percent of this particulate matter is from natural sources and is even worsened by vehicular emissions. Another important source could be the smoke resulting from the burning of agricultural waste in Punjab and Haryana which quickly moves towards Delhi and forms a thick envelope of smog around the city (TOI, 2014). Moreover, this smog contains SPM which is not able to escape or settle down and remains suspended and causes severe respiratory problems during the winter months. In general, the winter months experience high levels of SPM and RSPM than SO_2 and NO_2 than other months (CPCB, 2008). It is thus Delhi hospitals experience a spurt in respiratory cases by 25 to 30 percent due to the cold weather coupled with high particulate suspension in the air. It is noteworthy that although summers also have high levels of pollution but it is not threatening to health since winds and occasional rainfall prevents the dust to remain suspended in the atmosphere.

To estimate health damages associated with air pollution in developing countries, policy makers are often forced to extrapolate results from studies conducted in industrialised countries. However, such extrapolation may not always hold true since particulate pollution levels in developing countries are higher than their developed counterparts. In addition, in developing countries, people die at younger ages and from different causes than industrialised countries implying that such extrapolation of impacts of air pollution may be misleading. In such a similar study, a comparative analysis of pollution deaths was undertaken between Delhi and few US cities. These results revealed that 70 percent of all deaths in US occur after the age of 65. In case of Delhi, over 70 percent of all deaths occur before the age of 65, with over 20 percent occurring before the age of 5. In another study in 1991 wherein data was obtained from the New Delhi Municipal Corporation of Delhi (NDMC) region of Delhi which houses a large concentration of Delhi's premier hospitals and accounts for one-fourth of the total 60,000 deaths in the city on an average, it was seen that about 20-25 percent of medically certified deaths are attributable to causes associated with air pollution. Therefore, such studies are indicative of the fact that estimation of health impacts relating to air pollution are not feasible, unless researchers focus their attention on emission inventory and exposure statistics.

In *conclusion*, it can be said that barring SO_2, all the other pollutants analyzed in the above discussion exceeded the ambient air quality standards set by CPCB in both the analyzed years. It is seen that value wise, figures may have marginally declined from 2000 to 2008 barring NO_2, but in reality, pollution scenario has become more critical in 2008 than 2000 since the NAAQS have also become stricter in 2008 as compared to 2000. Another noticeable fact is that spatially, Town Hall is the most vulnerable location on the pollution front since it has been maintaining its criticality from 2000 to 2008. This is followed by Mayapuri in 2008 and Najafgarh in 2000 both serving as hub of urban processes such as industrialization, construction activities and vehicularization.

Moreover, SPM and RSPM levels are comparatively much higher than SO_2 and NO_2 in Delhi's atmosphere. This has a direct relationship with respiratory health scenario of individuals residing in Delhi as particulate matter is most significant determining the morbidity and mortality profile of humans in most of the respiratory diseases. These diseases include chronic respiratory diseases like asthma and allergy, respiratory emergency room visits and hospital admissions due to aggravated asthma and bronchitis, acute respiratory symptoms due to decreased lung functions etc. (Lvovsky, 2000).

Finally, pollution scenario during the winter months leading to the increased incidences of the aforementioned respiratory health problems is certainly a matter of grave concern for all, which is a matter of ongoing research. Since measuring individual exposures is not a practicable exercise, it is assumed that the subjects or inhabiting citizens have certain exposures to the worsening air pollution scenario as discussed above as they happen to be residents of Delhi for a considerable period of time. But, the threats of air pollution does not end here. The most frightening impact of this preventable disaster could come from lung cancer as several pollutants contain chemical carcinogens such as benzene, form-aldehyde and polycyclic hydrocarbons. These may act as slow poisons and may certainly add to the burden of cancer in the society. Therefore, it is felt that Delhi needs to initiate urgent steps to control the burgeoning pollution in the form of stringent emission norms and lifestyle modifications.

References

CPCB (2008), *National Ambient Air Quality Status 2008*, NAAQMS/2009-10, CPCB

CPCB (2000)**,** *National Ambient Air Quality Status 2000*, NAAQMS/2001-02, CPCB

CPCB (1999), *Air Quality at Major Traffic Intersections of Delhi*, NAAQMS/11/1998-99, CPCB

Garg, Amit and P. R. Shukla, (2002), *Emissions Inventory of India*, Tata McGraw Hills, New Delhi.

Goyal, S.K., et.al (2007), *Urban Air Pollution in India, Status and Future Challenges*,

National Science Academy, New Delhi, 2007

Kumar Bhuwan and R.B. Singh (2003), *Urban Development and Anthropogenic Climate Change,Experience in Indian Metropolitan Cities*, Manak publications, New Delhi

Lvovsky, K, et.al., (2000), 'Environmental Costs of fossil fuels: a rapid assessment methods with application to six cities' in *The World Bank Environment Department Papers,* No. 78, October 2000, Washington D.C., USA

Mail Today (2012), 'Delhi witnesses 30 percent rise in respiratory diseases due to high pollution and chill' in *Mail Today*, January 6, 2012.

Nema and Goyal, et.al., (2006), 'Understanding urban vehicular pollution problem vis-à-vis Ambient air Quality – Case Study of a Mega City (Delhi, India)' in *Environmental Monitoring and Assessment* (2006); 119, Springer

Paramesh, k, et.al., (2002), 'Environmental factors and respiratory diseases' *accessed* at www.worldjournal.org

Times of India (2012), '23 Delhiites die everyday due to respiratory ailments' in *Times of India,* November 21, 2012.

Times of India (2012), 'Indian Female Smokers Outpuff Males' in *Times of India*, August 17, 2012

Times of India (2014), 'Air Pollution affecting even foetal growth' in *Times of India,* December 5, 2014.

World Bank (2003), *For a Breath of Fresh Air, Ten Years of Progress and Challenges in Urban Air quality management in India 1993-2002*, Environmental and Social Development Unit, SE Asia, World Bank 2003

Yaari, E., et.al (2009), ' Genetic Environmental interactions in asthma and allergy, a study in a closed population exposed to various environments' in *Annals of Allergy, Asthma and Immunology,* Vol 102(3), 2009