Analysis of Air Pollution in Tropical Urban Region during summer and Winter Seasons

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Abstract - More pollutants in the air influence on human health. The air pollutants emission problem has received a lot of public attentions and academic researchers in the past decades. The objective of this study is to investigate variations of SO2, NO2, SPM and RSPM since 5 years during summer and winter seasons in Agra. For this reason, data of daily air pollutants from four pollution monitoring stations i.e., Taj Mahal, Itam-ud-daulah, Rambagh and Nunhai areas in Agra were analyzed. The concentrations of these parameters were monitored by continuous monitoring equipment for a period of five years (from 2010 to 2014). There were significant monthly variations in concentrations of air quality parameters. Analysis shows that SO2 and NO2 levels are less compared to RSPM and SPM pollutants which are in acceptable limits of NAAQS standards, whereas RSPM and SPM levels exceeded the standards of NAAQS at all monitoring stations. It is observed the pollutant concentrations are high in all years of winter season compared to summer season due to stable atmospheric conditions. Also high concentrations of NO2, RSPM and SPM pollutants are observed in Rambagh and Nunhai stations as compared to Taj Mahal and Itam-ud-daulah stations.

Keywords: Air pollution, Stations, Seasons, Temporature, Sulphur and Oxides

I. INTRODUCTION

Increase in technology, industrial and agricultural advancement, coupled with increases in population growth, has triggered the deterioration of environmental quality throughout the world. Rapidly growing cities, moretraffic on roads, growing energy consumption and waste production, and lack of strict implementation of environmental regulation are increasing the discharge of pollutants into air, water, and soil.Urban air pollutants arise from a wide variety of sources although they are mainly due to combustion processes. Today the largest source of pollution in most urban areas is due to motor vehicles, anthropogenic and industrialization.The main pollutants affecting the urban areas are CO, NOX, SOX etc. emitted from vehicular traffics, thermal power plants, burning of fossil fuels etc. Hence it is necessary to study the pollution effect in and around urban areas. In this study, human exposure to air pollution has been assessed in a highly industrialized area and vehicular pollution in the urban area during two seasons in a tropical region. The target group for pollution affected was people of low socio-economic level, who are residing and work in the study area as they are subjected to the worst exposure due to air pollution. The major objectives were to investigate the relation between ambient air quality and personal exposure measurements as well as to identify the factors, which effect exposure concentrations. This can provide important inputs for estimation of health risk of the population.

II. BRIEF REVIEW OF THE STUDY

Dispersion of pollutants from traffic and other sources from within urban areas is poorly understood and difficult to predict due to difficulties in modeling airflow and turbulence within and immediately above the urban fabric. The research community has taken steps towards understanding of dispersion within the urban environment by focusing on idealized urban elements.Due to high temperatures over tropics, the more water vapor can be in the air without condensing. Due to high receiving of solar radiation on the tropics the overlying atmosphere becomes very humid. Temperature and pressure both drop quickly with altitude, in the tropics as elsewhere on Earth.Epidemiological

studies have shown that concentrations of ambient air particles are associated with a wide range of effects on human health, especially on the cardio-respiratory system (Bates, 1992; Dockery and Pope, 1994). A growing body of evidence indicates that pollution increases daily deaths and hospital admissions throughout the world (Pope et al., 1995; Zanobetti et al., 2001). Adverse effect of air pollution include an increase in cardiovascular and respiratory problematic persons admitting in the hospitals and leading to deaths in the past 10 years (Harabi et. Al., 2006, Farchini&Mannucci 2007, Chen et.al 2007, Qian et al 2007 and Skarek et al 2007). Gaseous co-pollutants, seasonal patterns or weather did not confound the association between particulate pollution and cardiopulmonary mortality (Schwartz, 1994; Samet et al., 1998, 2000). Air pollution has become a local as well as a regional issue of big cities, industrial centers and surroundings of transport routes, especially roads and highway (Hrdlickova et al., 2008). The increasing development of human activities has given rise to a significant increase in atmospheric pollutants which may have an impact on human health (Atash, 2007). Many developing countries have experienced a progressive degradation in air quality as a consequence of rapid development over the last three decades (Agrawal et al., 2003). In the cities of developing countries, the environmental problems are much greater, because of the overwhelming scale and speed of urbanization (Atash, 2007). In particular, the levels of air pollutants are increasing rapidly in urban areas in many mega cities of the developing world (Agrawal et al., 2003). It is well known that air pollution can harm human health (Zhang et. al., 2007). The increased risks were observed mainly for the population exposed to urban air which is affected predominantly by traffic emissions, emissions from household heating and industries (Skarek et al., 2007). Saini et al 2014 study examined the temporal relationship between meteorological parameters and urban air pollutants in Agra helping to fill avoid in research into the relationships between the atmospheric transport, local meteorology and concentrations of tropospheric air pollutants. Air pollution is one of the most serious environmental problems in Agra, In Agra, air pollution is the result of emissions from a multiplicity of sources, mainly stationary, industrial and domestic fossil fuel combustion, motor vehicles emissions and different Indian seasons. This paper mainly focuses to analyze seasonal trends and assessment of various pollutants namely SO2, NO2, SPM and RSM for 11 years.

III. STUDY AREA

Tropics are the zone within which the Sun is directly overhead at some time during the year, i.e., the zone between the tropics of Cancer and Capricon (23.45^{o}N and 23.45 ^{o} S, respectively). Riehl (1979, Ch.2) study defines tropics as the area in which the diurnal temperature range exceeds the range of annual mean temperature.Agra, located in the state of Uttar Pradesh of northern India, is well known for TajMahal, one of the wonders of the world. The Agra city spreads over an area of approximately 140 sq. km. As per recent census, The total population of Agra is 4 380 793 according to the Directorate of Census Operation in Uttar Pradesh showing a 21% increase in 2011 compared to the 2001 Census. The initial interim data suggest a population density of 1 084 in 2011 compared to 896 of 2001. Total area of Agra district is about 4 041 square kilometers. Agra has 580 396 motor vehicles registered, out of which 27 462 were transport vehicles (Census,2011).The city of Agra is favorably situated commanding administrative, economic, and cultural influence over a very large area. Besides its recent development as an international tourist centreand manufacturing centre, since centuries Agra had flourished with trade, commerce and household industries. The urban area of Agra is divided into *Nagar Mahapalika*(renamed as Municipal Corporation in 1994), Agra Cantonment area and the Dayalbagh and *SwamibaghaPanchayat.* The municipal area is further divided into three parts viz. the main city, the Trans Yamuna and the Tajganj. The municipal areais divided into 90 wards. The jurisdiction of the Agra Urban Area is under the Agra Development Authority (ADA). The sources of pollutants in the city are domestic, industrial, vehicular, DG Sets and natural sources. The air pollution from the industries is mainly due to fuel used in the manufacturing process. The majority of industries in Agra comprise of foundries. Besides a number of *petha*industries are operating in the city, which mainly use coal as fuel. In foundries, the principal source of emission is cupola. The volume of gas exhausted and its concentration depends on the cupola, operations, melting rates, characteristic of charging material and the coke. Gases release while drawing the hot metal and during casting. In the pit type of cupola, emissions are fugitive type. The main pollutants are SPM, sulphur dioxide and carbon monoxide. Agra is famous for '*Petha*' (a type of sweet). There are large numbers of petha manufacturing units. Besides these, there are *halwaiis*, *kumhars*and *bharbhujas*who use coal, cow dung and wood. *Kumhars*have to use cow dung because of the type of firing adopted bythem.The vehicular emissions are one of the major sources of air pollution affecting the urban population in Agra. Unlike industrial emissions, vehicular pollutants are released at ground level and hence the impact on recipient population will be more. The vehicular growth in the city is high and with high growth, the impact of the airpollution from vehicular growth would be tremendous. Due to power breaks daily, a number of DG sets are used in the city. The fuel consumed by the DG Sets by different sectors and the average consumption of diesel varies as per the capacity of the generators.

3.1 Weather & Climate of Agra

Agra features a semiarid climate that borders on a humid subtropical climate. The climate of Agra is divisible into three distinct seasons; summer, monsoon and winter (IMD, 2009). The weather at the experimental site during the summer season (April to June) is hot and dry with temperature ranging from 32 °C to 48 °C and winds are mostly gusty which is predominantly from west and northwest. The relative humidity during summer ranges between 30% and 48%. Large amount of wind blown dust envelops the city during the summer months.

3.2 Database

The data is collected from Central Pollution Control Board (CPCB), New Delhi, website for Agra city the period from 2010-2014 in industrial and residential areas like Tajmahal, Itam-uddaulah, Ram bagh, and Nunhai stations. "CPCB reports 2000a, 2000b and 2001 shows that the CPCB data is a validated data for analyzing the pollution concentration".

IV. METHODOLOGY

Air pollutants consist of gaseous pollutants, odors, and SPM, (suspended particulate matter) such as dust, fumes, mist, and smoke. The concentration of these in and near the urban areas causes severe pollution to the surroundings. The largest sources of human-created air pollution are energy generation, transportation, and industries that use a great deal of energy sources. Depending on their source and interactions with other components of the air, they can have different chemical compositions and health impacts. Since these pollutants are generally concentrated in and around urban areas, the outdoor urban pollution levels are far higher than in the rural areas. Some of the gases mentioned below can seriously and adversely affect the health of the population and should be given due attention by the concerned authorities.

The gases mentioned below are mainly outdoor air pollutants that can and do occur indoor depending on the source and the circumstances. Sources of various pollutants is shown in Fig 1.

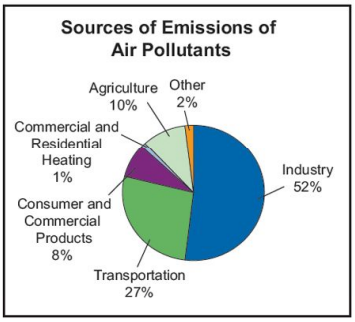

Fig 1.Sources of Air Pollutants

Oxides of nitrogen

This gas can make children susceptible to respiratory diseases in the winters.

Sulphur dioxide

SO_2 (Sulphur dioxide) in the air is caused due to the rise in combustion of fossil fuels. It can oxidize and form Sulphuric acid mist. SO_2 in the air leads to diseases of the lung and other lung disorders such as wheezing and shortness of breath. Long-term effects are more difficult to ascertain as SO2 exposure is often combined with that of SPM.

Suspended particulate matter (SPM) and Respirable SPM

Suspended matter consists of dust, fumes, mist and smoke. The main chemical component of SPM that is of major concern is lead, others being nickel, arsenic, and those present in diesel exhaust. These particles when breathed in, lodge in our lung tissues and cause lung damage and respiratory problems. The importance of SPM as a major pollutant needs special emphasis as a) it affects more people globally than any other pollutant on a continuing basis; b) there is more monitoring data available on this than any other pollutant; and c) more epidemiological evidence has been collected on the exposure to this than to any other pollutant.

V. RESULTS AND DISCUSSIONS

Gaseous pollutants have major negative impacts on health. They also play significant role in environmental changes and changes in atmospheric chemistry. It is expected that the increasing load of atmospheric sulfur dioxide (SO2), nitrogen dioxide (NO2), SPM and RSPM will add to global climate change; therefore, it is necessary to quantify the emissions in the very near future. The concentration of SO_2, NO_2, SPM and RSPM in four locations of Agra city i.e., Tajmahal, Itam-ud-daulah, Ram bagh and Nunhai are analyzed from 2010 to 2014. The pollution levels in these four places of Agra city have been exceeded the WHO air quality guidelines (Faiz and Strum, 2000). The data is collected for industrial and a residential area at different locations in the city. Agra has a tropical climate. Summers (April-June) are extremely hot and maximum temperature can be as high as 45°C while winters (November to February) are foggy. Heavy rains and humidity mark the monsoon season (July-September). January, the coldest month, the mean daily temperature is 10° C and the mean daily minimum temperature is 6°C. The relative humidity during the winter months ranges between 60 to 70%. The downward wind is SSE 29% and NE 6% in summers and it is W-NW 9.4% and NNW 11.8% in winters. Behavior of SO_2, NO_2, RSPM and SPM in Agra city is discussed below.

TajMahal (001)

Trend in monthly average concentration of SO2,NO2, RSPM and SPM s depicted in Fig. 2.

SO2 levels were lower than the NAAQS (annual average) with 4 to 18 µg/m^{3}during summer and winter seasons in the study period. But in comparison with winter season (4-6 µg/m^3), more concentrations are recorded between 10 – 18µg/m^3 in the year 2012, 2013 and 2014. Lower concentration levels are due to greenery and agricultural fields with no industries in the study area as it is tourist spot in the city whereasNO2values exceeded little and are in acceptable limits. Slightly higher values of NO_2 (~30µg/m^3) are observed in winter at TajMahal station compared to winter because due to low temperatures and stable atmosphere the pollutants will reside in the surface layer. Nitrogen dioxide (NO2), a highly reactive gas is formed in the ambient air through the oxidation of nitric oxide (NO). Nitrogen oxides occur in atmosphere naturally and as a result of human activities. Same phenomenon is observed for RSPM and SPM pollutants. Higher concentrations are observed in winter compared to summer from 2010 to 2014 years.

Itam-Ud-Daulah (416)

Fig 3 shows the monthly average concentrations of SO2, NO2, RSPM and SPM pollutants at itam-ud-daulah monitoring station during summer and winter monsoon from year 2010 to 2014. Itam-ud-daulah station is defined as undeveloped area with bad topography. From the figure it is observed that low levels of SO2concentrations are observed during both the seasons in all years of study period. NO2 concentrations are slightly higher when compared to TajMahal site. Also in winter above 50µg/m^3 of NO2 is observed when compared to summer 30 µg/m^3 which again exceeds NAAQS standard. The site is tourist spot so RSPM and SPM concentrations are high as these are observed due to human activities or natural depending on weather and climate. In both the seasons the concentrations are high and exceeding NAAQS standards in Summer RSPM values ranges between 100 to 250µg/m^3 and in winter 200 to 350 µg/m^{3}of RSPM concentrations, whereas SPM concentrations are in the range of 300 to 450 µg/m^3 in summer and 400 to 550 µg/m^3 in winter. It is observed that from the 2010 to 2012 the concentrations of pollutants are increased gradually and in 2013 and 2014 the concentrations of pollutants are reduced.

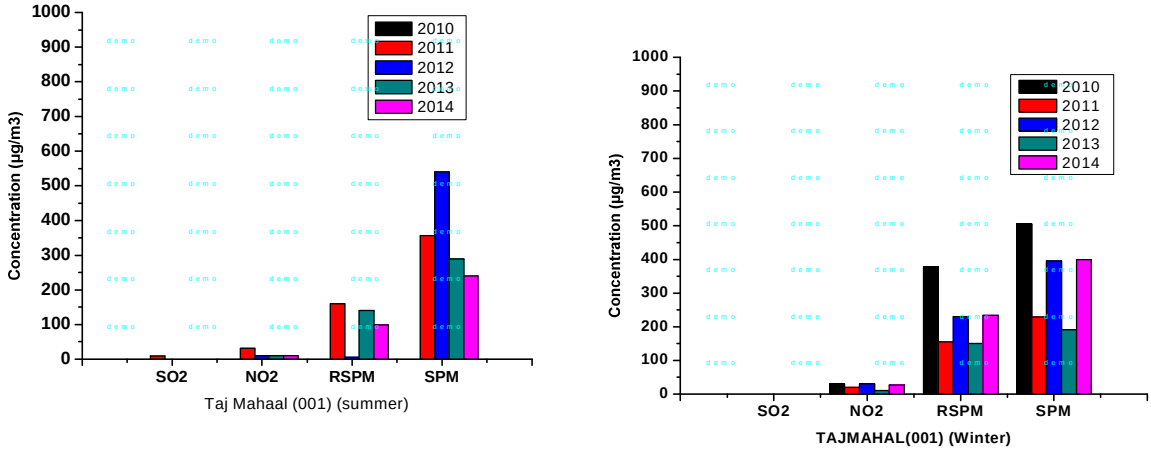

Fig 2: Trends in Monthly Average Concentration of SO2 , NO2 , RSPM and SPMat TajMahal (station code 001), Agra.

Rambagh (417)

Concentrations of SO2, NO2, RSPM and SPM pollutants at Rambagh area are shown in Fig 4 for both summer and winter seasons from 2010 to 2014 years. The study area is an industrial area where emissions from diesel generators that operates during the failure of power and sites being closely situated near toNH-2. As observed in previous stations SO2, NO2 are less (below 35 µg/m^3) in summer season where as in winter NO2 is near to NAAQS standards in all the years. In summer season 180 – 230 µg/m^3 and in winter 320 – 420 µg/m^3 of RSPM concentrations are seen and SPM concentrations are observed high in summer, 570 – 598 µg/m^3 than in winter 496-546 µg/m^3 from 2012 to 2014. The high value in summer is contributed mainly due to soil erosion by wind and unstable atmospheric conditions.

Nunhai (415)

Nunhai is an industrial area where many small scale industries are available. The gaseous pollutant concentrations of SO2, NO2, RSPM & SPM are shown in Fig 5. The concentration levels in both summer and winter seasons from 2010 to 2011 shows that SO2 levels are in acceptable limits of NAAQS standards and other pollutants exceeded the NAAQS standard. NO2 is recorded high concentrations above 50 µg/m^{3}in both the seasons from 2011 to 2014. Whereas RSPM and SPM recorded higher values above 700 µg/m^3 in summer in 2012 and 2013 years which is because of unstable conditions of boundary layer and local atmospheric conditions and in rest of the years winter season recorded higher values. Hence RSPM and SPM values exceeded NAAQS standards.

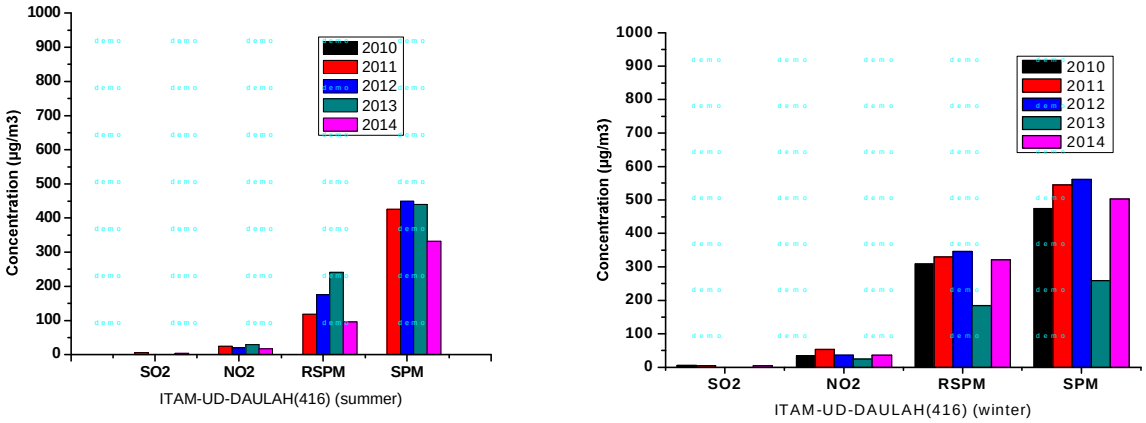

Fig 3: Trends in Monthly Average Concentration of SO2 , NO2 , RSPM and SPM at Itam-Ud-Daulah (station code 416), Agra.

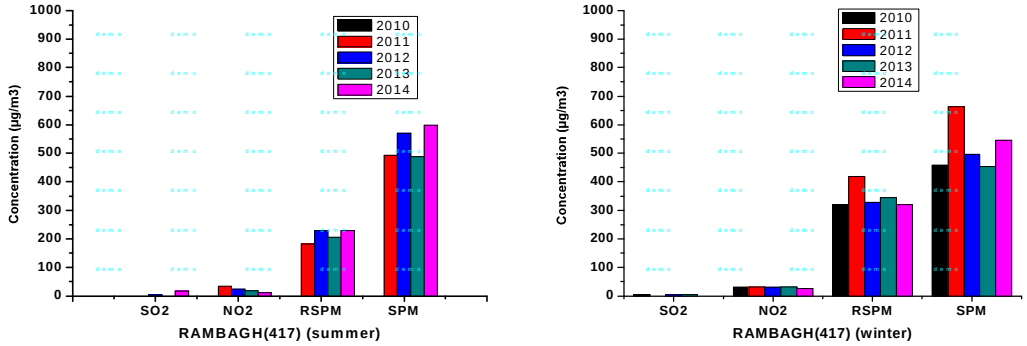

Fig 4: Trends in Monthly Average Concentration of SO2 , NO2 , RSPM and SPM at Rambagh (station code 417), Agra.

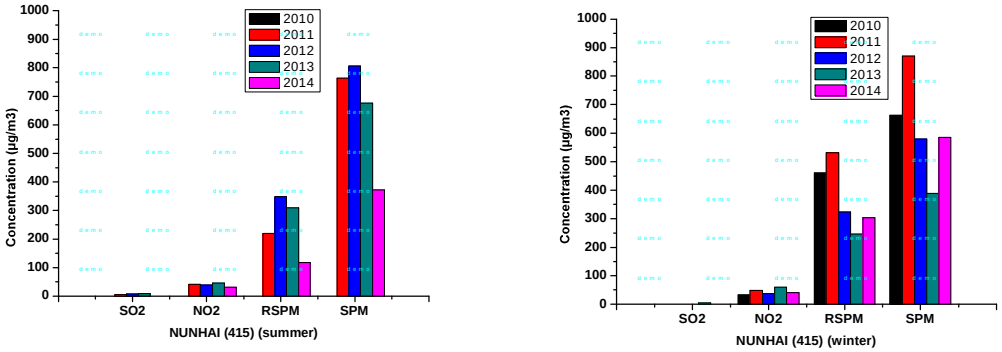

Fig 5: Trends in Monthly Average Concentration of SO2 , NO2 , RSPM and SPM at Nunhai (station code 415), Agra.

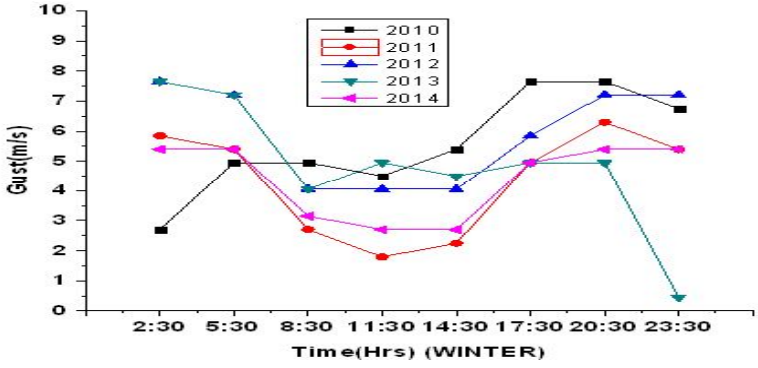

Fig 6: Diurnal variation of temperature in both summer and winter seasons

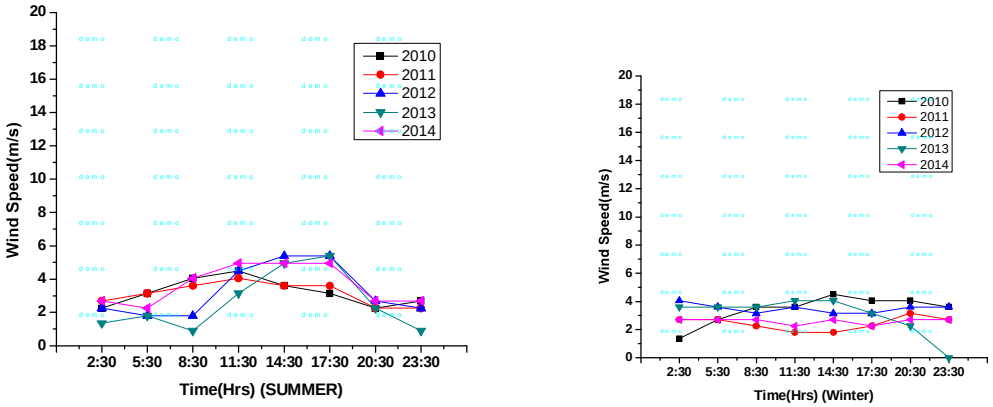

Fig 7 Diurnal Variation of Wind speed in Agra City in Summer and Winter Season from year 2010 to 2011

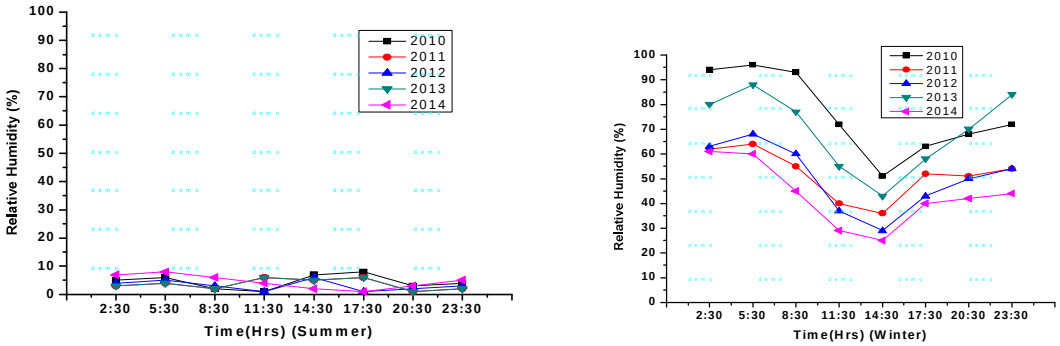

Fig 8 Diurnal Variation of Relative Humidity in Agra City in Summer and Winter Season from year 2010 to 2011

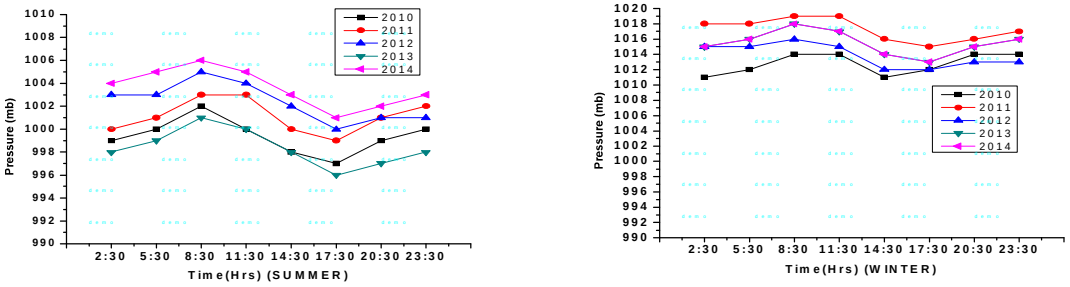

Fig 9:Diurnal Variation of Pressure in Agra City in Summer and Winter Season from year 2010 to 2011

5.1 Meteorological phenomenon during summer and winter seasons in Agra

Meteorological factors play an important role in air pollution studies particularly in pollutant transport irrespective of their entry into the environment. Fig 6 describes the diurnal variation of temperature in both summer and winter seasons from 2010 to 2014 years in Agra city. Maximum temperatures recorded 40^0C to 47^0C in summer and minimum temperatures of 8^0C to 10^0C temperatures. The city experiences high temperatures in summer and low

temperatures with fog in winter season. Wind speeds during both seasons are shown in Fig 7 Hence it is understood that dry air observed in summer seasons. Calm winds are observed throughout the night in both seasons and in day time wind speed increase due to unstable atmosphere in summer season. Whereas in winter low wind speeds are observed during daytime not exceeding 4m/s. Low relative humidity in summers and high relative humidity (RH) in winter is observed as shown in Fig 8. In summer below 10% RH and in winter 60 to 80% RH is observed. Diurnal variation of pressures are observed in Fig which shows low pressures 1006 mb during day time and pressure increasing in night time and high pressure levels 1020 mb are observed during winter season due to low temperature and stable conditions of the atmosphere. Diurnal variation of wind direction is shown in Table 1. Winds are observed westerly, northwesterly in summer and easterly north easterly in winter. The monitoring stations used in the study are located in the east side of the city, so when winds are easterly and southeasterly all the pollutants released will be moved inside the city leading to severe health problems. When winds are westerly or north westerly the pollutants move towards rural areas causing damage to agriculture and health of the rural people. The concentrations are maximum in winter months and are lower during summer season. Summer season comprises of unstable atmosphere, high temperatures and low relative humidity values. During winter, there is increased atmospheric stability, which in turn allows for less general circulation and thus more stagnant air masses. Stagnant air masses allow more accumulation of pollutants in any given area. During the winter, atmospheric dispersion is typically at a minimum and therefore the pollutants will not be as widely dispersed. The winter months are relatively much calm than other months. The prevailing calm conditions facilitate more stability to atmosphere and consequently slow dispersion of pollutants generated and help in build up of pollutants in vicinity of the pollutant sources.

SUMMER					
Time/Year	**2010**	**2011**	**2012**	**2013**	**2014**
2:30	SW	WSW	NW	N	NNW
5:30	SW	WNW	WNW	N	NW
8:30	W	WNW	WNW	NNE	WNW
11:30	WNW	NW	WNW	NW	WNW
14:30	W	NW	WNW	NW	WNW
17:30	WSW	NW	WNW	NNW	NW
20:30	SSW	NW	WNW	N	NW
23:30	WSW	NW	W	ENE	WNW
WINTER					
Time/Year	**2010**	**2011**	**2012**	**2013**	**2014**
2:30	N	NE	NNW	E	ESE
5:30	NW	ENE	NNW	ENE	ESE
8:30	NW	ENE	NW	E	E
11:30	NW	ENE	NW	E	E
14:30	NW	ENE	NW	E	E
17:30	NW	NE	NW	ESE	ENE
20:30	NW	NE	NW	ESE	ENE
23:30	NW	NE	NW	SE	NE

Table 1.Wind movements in Agra City in Summer and Winter Season from year 2010 to 2011

VI. CONCLUSIONS

The study describes the analysis of concentration of various pollutants at 4 locations of Agra city i.e., Taj Mahal, Itam-ud-daulah, Rambagh and Nunhai areas. It concludes that SO2 and NO2 levels are less compared to RSPM and SPM pollutants which are in acceptable limits of NAAQS standards, whereas RSPM and SPM levels exceeded the standards of NAAQS at all monitoring stations. It is observed the pollutant concentrations are high in all years of winter season compared to summer season due to stable atmospheric conditions. Also high concentrations of NO2, RSPM and SPM pollutants are observed in Rambagh and Nunhai stations as compared to Taj Mahal and Itam-ud-daulah stations. SPM is recorded highest in winter followed by summer. The high value of SPM in winter was due to increase in use of biomass, fossil fuels for heating purposes.

Hence the study concludes that air pollutants not only affect the vegetation near the point sources and urban centers, but depending on the meteorology, specially wind pattern may spread in suburban and rural areas, affecting the

crops. Air pollutants cause deleterious effects on physiology and metabolism of plants due to their oxidizing potential. Responses of plants vary between different species and their cultivars. Responses of plants to air pollutants also depend on type of pollutants, concentrations duration and its magnitude. There is a need to screen out sensitive and tolerant cultivars in India and establish the exposure indices of all the important crops to reduce the crop loss. Also implementation of environmental regulations by the Government to reduce bad air quality is required along with awareness programs for the people to reduce anthropogenic emissions.

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