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Semi-Decadal Spatio-temporal variation of gaseous pollutants over a Part of a National Capital Region, India

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ABSTRACT

Air pollution occurs when fumes (or smoke) and dust particle gases are introduced into the atmosphere in such a way that endangers animal and plant. Air pollution harms the health of living beings on our planet. It causes acid rain and smog, which cause respiratory diseases and cancer, depletes the ozone layer, and contributes to global warming. Current study examines gaseous observations, which is a measure source of the air pollution, in an urban National Capital Region of India.The concentration of gases was measured at air quality monitoring stations (AQMS) located throughout Delhi. The collection is from a five-year period of real-time data observation. Gas variations were interpolated in a geographic information system (GIS) to generate digital elevation models (DEMs). The current study investigated the role of gaseous pollutants in increasing overall pollution levels in Delhi NCR, as well as the variation of gaseous pollution across Delhi's different stations. Temporal interpolation of observations based on the concentration of gases depicted on the Z-axis. During the winter and monsoon seasons, distinct clusters of high values are depicted, indicating specific natural and anthropogenic activities. Summer months, on the other hand, indicate low values, indicating steady atmospheric conditions. Such information can play a critical part in enhancing the government's developmental initiatives and planning to lower the degree of pollution that our country requires.

Key words : *Gases, Geographic Information System (GIS), NCR, Air pollution, Atmosphere.*

Introduction

The greatest problem human race facing in 21st century is the climate change. This is well portrayed by the phenomena of global warming and sea level rise. Extensive research has demonstrated that there is a significant contribution of anthropoid element towards global warming by the way of introducing a noteworthy amount of greenhouse gasses and Particulate Matter (PM) to the lower atmosphere. The concentration of these gases beyond a threshold makes the atmosphere polluted which is now well observed at urban epicenters, particularly the Delhi-National Capital Region (Delhi-NCR) of India. The National Ambient Air Quality Monitoring Program (NAAQMP) of the country recognizes Nitrogen Dioxide (NO_2) and Sulfur Dioxide (SO_2) as the second and third major gaseous pollutants in India after Particulate Matter (PM) size less than 10 µm (PM_{10}). Higher concentration of gaseous pollutants in the atmosphere is cardinally attributed to increased population, intensified industrialization and concentrated urbanization. All these factors are directly or indirectly responsible for the loss and diminution of an array of natural resources. Notable among these are the agricultural and pasture lands and increased combustion of bio and fossil fuels across these lost territories (Agrawal *et al*., 2011; Andreae and Merlet, 2001; Badrinath *et al*., 2009; Goyal *et al*., 2013; Sun et al., 2011). Trace gases and greenhouse gases are responsible for the energy imbalance of earth's climate which is growing more rapidly from local to global scale (Logan *et al*., 1981; Mage *et al*., 1996;Montzka *et al*., 2011; Seinfeld and Pandis, 1998; Fenger, 2009; Gupta and Kumar, 2016). Atmospheric traces gases are one of the challenging environmental issues in urban and industrial areas (Cohen, 2006; Garg *et al*., 2001; Goyal *et al*., 2013).Urban air pollution is also influenced by various meteorological parameters. Ambient water vapor raises the removal rate of free radical product (HO_2, HO) in lower NOx environment (Chameides *et al*., 1973; Ghude *et al*., 2008; Lelieveld et al., 2004; Mavroidis et al., 2012; Monks, 2005; Sun et al., 2011; Sumesh et al., 2017). Ventilation coefficient which is the product of wind speed and mixing layer height, defines the pollution potential over a particular region (Walcek *et al*., 1995). The lifetime of NOx species are short varying from hours to days depending on the photochemical environment and its further oxidization to HNO_3 (Chameides and Walker, 1973). NO_2 and SO_2 play a major role in the formation of corrosion and acid rain in the atmosphere (Ghude *et al*., 2008). Carbon monoxide (CO) also plays a significant role in the oxidizing capacity of lower atmosphere by acting as a sink when large amount of reactive hydroxyl (OH) radical available in the troposphere (Ghude *et al*., 2011; Logan *et al*., 1981; Zahn and Brenninkmeijer, 2003). Biomass burning, Oxidation of methane, emission from fossil or bio fuel combustion and non-methane hydrocarbon (NHMC) are the major source of emission of CO (Gore *et al*., 2014; Marvroidis et al., 2012; Sun et al., 2011; Sateesh *et al*., 2018; Gogikar *et al*., 2018). CO has relatively longer lifetime. So, for long range transported pollutant it is a good tracer to identify its effect on emission of Ozone (O_3) from anthropogenic source (Ahammed *et al*., 2006; Badrinath et al., 2009; Beig *et al*., 2007; Chelani, 2012; Chin *et al*., 1994).. Guttikunda and Calori (2013) have estimated emissions reaching to 37,000 tons of SO_2, 376,000 tons of NO and 1.42 million tons of CO for the base year 2010 across NCR. Jayaraman and Nidhi (2008) have established interlinkage between air pollutants such as particulate matter (PM), NO_2, SO_2, CO, $O_3$and respiratory suspended particulate (RSPM) matter with adverse health effects for Delhi region with varying lags. Siddique *et al*. have pointed to significant influence of air pollutants on increased prevalence of various lung function deficits among young children (9-17 yrs) in Delhi-NCR. The research of Kandlikar (2007) has pointed to strong annual and biannual cyclic nature of SO_2, NOx, CO and PM_{10} for Delhi-NCR. Samal *et al*. (2012) have found indoor air pollutant concentration exceeding that of the ambient air for India Habitat Center parking area micro-environment, Delhi.However, the trends and cyclic nature of the air pollutants were influenced by the significant rulings of the Supreme Court of India during early part of this century (2002-2005). Cardinal rulings include (1) conversion of commercial vehicles to Compressed Natural Gas (CNG) technology and (2) closing of polluting industries in "non confirming areas" (Jayaraman and Nidhi, 2008). However, recent trends portray a consistent increase in pollution across the Delhi-NCR region. Recent studies have indicated a significant rise in air pollutants for the past few years which have a direct interrelationship with the growing impervious surface across the Delhi-NCR region (Garsa *et al*., 2019). This synthetic surface growth is also an indication of the increased vehicular traffic as well as expanding urban and industrial activity. The present study investigates the semi-decadal spatio-temporal dynamics of air pollutants, namely, NO_2, SO_2, CO and $PM_{2.5}$ across three observing stations of DelhiNCR from 2014 to 2018.

Observational Site

Delhi NCR is located in the Northern part of India. It is bounded by Rajasthan state on the Southwest, Haryana on Northwest and Uttar Pradesh on the east. Physiographically the metropolitan city is primarily classified into three parts such as the Yamuna flood plains, Delhi ridge and the Gangetic plains. The ridge is an extension of the Aravali Hill range encircling along the northwest, northeast and south through to west of the city. The flood plains lying north to the ridge consist of fertile and rich soil that makes agriculture suitable. Within NCR, Delhi covers an area of 1484 Km^2, Rajasthan contributes7829 Km^2 , Uttar Pradesh 10853 Km^2 and Haryana 13413 Km^2 area. The overall Population of Delhi NCR is 13,782,976. The metropolitan city is a preferred tourist attraction and has an attractive real estate market. It is one of the major centers of growth of India with respect to trade, commerce and many service sectors as well. The landscape has been witnessing exponential growth setting up large industrial hubs contributing significantly to air pollution. This is exactly why, the Central Pollution Control Board (CPCB) has established a number of air quality monitoring stations (AQMS) to observe the activity of various air pollutants. Current study takes into account the observations of $PM_{2.5}$, PM_{10}, NO_2, SO_2 and CO at three such monitoring stations namely, Delhi Milk Scheme, Shadipur (DMS), Institute of Human Behaviour of Allied Sciences (IHBAS) and Netaji Subhash Institute of Technology, Dwarka (NSIT) from 2014 to 2018 to appreciate the semidecadal spaio-temporal dynamics of the pollutants. The monitoring stations are carefully chosen wherein they represent high vehicular traffic as well as dense population within the NCR. Among the three stations DMS and NSIT region are newly developing territories in NCR whereas IHBAS is a well developed urban center of the metropolitan city. The former two are witnessing significant construction activity with respect to roadways, drainage and real estate development. On the other hand, the landscape around IHBAS boasts of a number of industrial hubs, primarily related to plastic and steel factories.

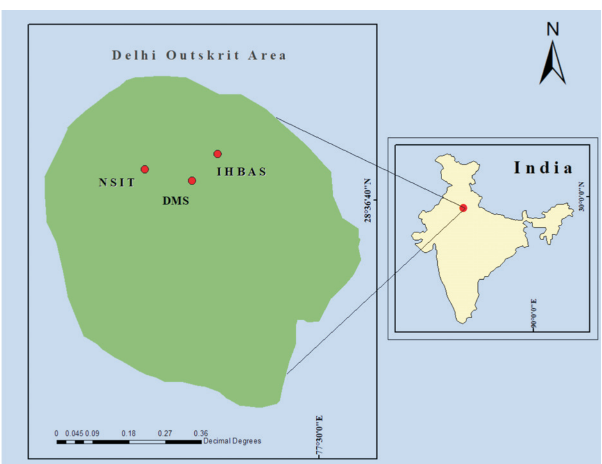


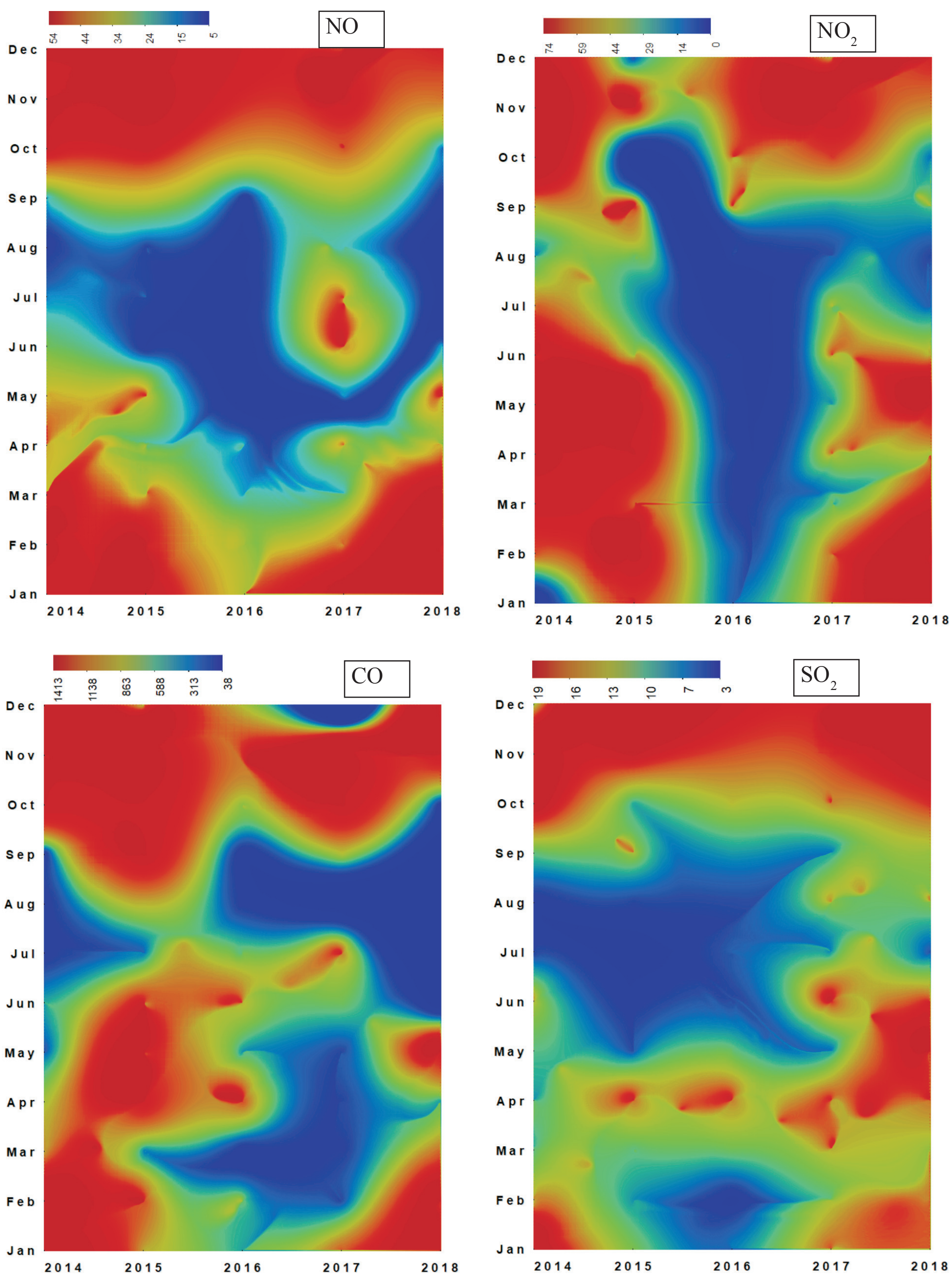
Fig. 1. Observational Site.

Data and Methods

Observation of air pollutants at AQMSs is carried out real time with 15 minute resolution. This real time observation is averaged out for hourly, daily, monthly and yearly mean for further analysis, manipulation and interpolation. Current study takes into account the observation of air pollutants such as $PM_{2.5}$, NO, NO_2, SO_2 and CO from 2014 to 2018 for their spatio-temporal analysis. However, there is absence of $PM_{2.5}$ data for the year 2014. Hence, the research involves the analysis of PM_{10} for the year 2014 instead of $PM_{2.5}$ (Supplementary data-2). The methodology adopted for the present study is geostatistical and geospatial investigation of air pollutants. Geostatistical examination involves the descriptive characterization of pollutant concentrations and their interrelationship. Temporal variations of pollutants are looked into on a yearly basis to interpret the extent of pollution as well as the individual contribution of each pollutant. The statistical analysis plots gaseous pollutants NO, NO_2 and SO_2 on primary Y-axis whereas the particulate matter is plotted along the secondary Y-axis. During analysis SO_2, NO_2 and NO are plotted together against particulate matter whereas CO is plotted separately owing to the disparity in concentration. The statistical investigation also involves the regression of gaseous pollutants against ambient particulate matter. In a similar way the investigation analyzes NO, NO_2 and SO_2 combinedwhereas CO is investigated separately. Geospatial investigation for the present research involves the interpolation and interpretation of the contaminant concentrations in spatial and temporal coordinates. The analysis takes into account geographical coordinates of the AQMS for spatial interpolation of observed concentrations of pollutants. For temporal interpolation, the pollutants are examined within a time coordinate where the larger time unit represents the X-axis and smaller one the Y-axis. Hence, current analysis depicts year on X-axis and Month on Y-axis. Within both the analyses the examination treats pollutant concentration as z-axis and identifies hot spots of pollution spatially as well as temporally. The interpolation technique follows ordinary kriging method based on histogram equalization stretching. For standardization of output all the maps are displayed in stretched form wherein blue represents lower activity and red higher concentration.

Results and Discussion

As mentioned in earlier section (Data and Methods) the research lacks $PM_{2.5}$ data during 2014 for the stations. To decipher the influence of particulate matter on air pollution, the research analyzes the concentration of PM_{10} for the above year. A peek into the interrelationship between the two particulate matter activities of ambient air for April 2018 establishes a very strong linearity for the background station AUH. Analysis portrays co-relationship exceeding 95% between $PM_{2.5}$ and PM_{10} for the month as well as above 82% for a single day (30th April 2018, Figure 2). Therefore, $PM_{2.5}$ is modeled from the PM_{10} observations to infer the aerosol concentration of ambient air. $PM_{2.5}$ concentration for the study region has witnessed a steady increase since 2014. The data portrays noteworthy concentration of $PM_{2.5}$ (modeled) for the year 2014. The concentration of aerosols takes a dip during 2015 after which there has been a steady increase in their activities. However, the activity of these aerosols displays again takes a downward turn during 2018. While DMS and NSIT indicate a drop during 2018, IHBAS displays a lowering of $PM_{2.5}$ concentration from 2017. Overall, the data exhibits two peak concentrations of PM activities during 2014 and 2016. It may be attributed to the



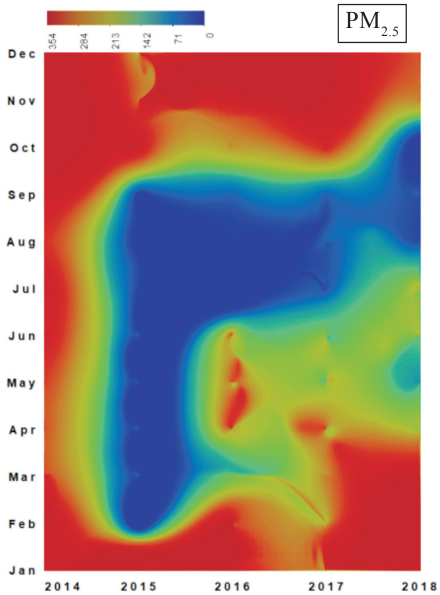
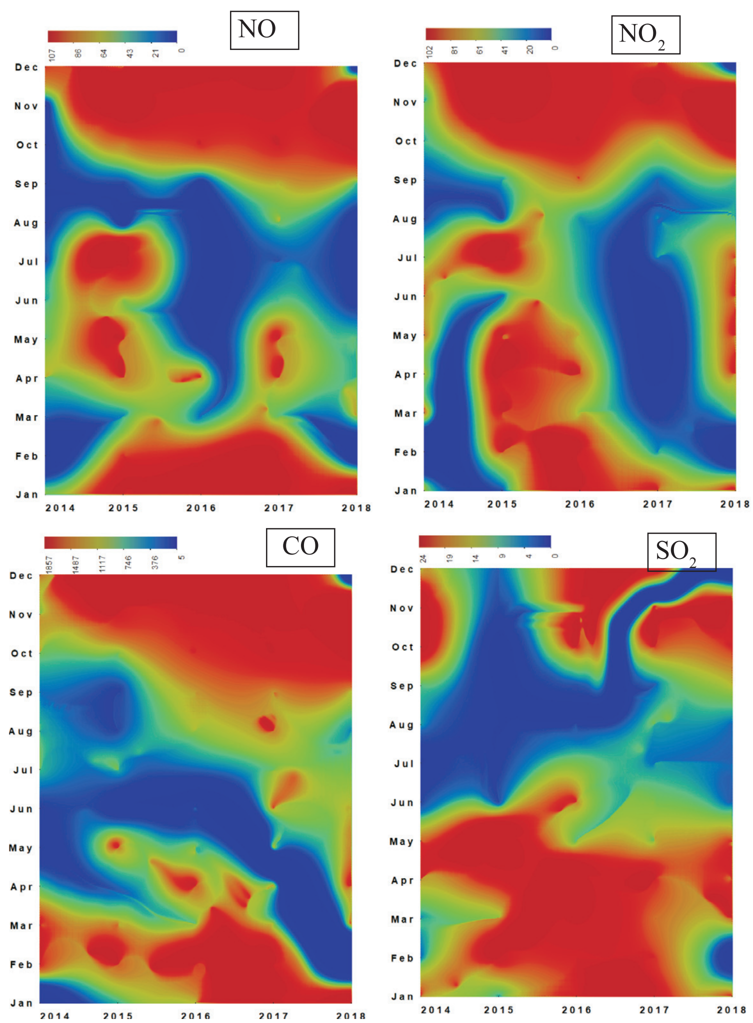


Fig. 2. NSIT parameters data.

extreme heat wave conditions during summer (April-July) of 2016. Delhi-NCR also witnessed a very below average rainfall during 2014 (370.8 mm against long term average of 648.9 mm) whereas the metropolitan city gauged 672.3 mm and 770.6 mm of above average rainfall in 2017 and 2018 respectively (Indiatoday report, 2019). Spatially NSIT and DMS reveal a general higher aerosol activity than IHBAS (Figure 3). While, construction and developmental activity around DMS and NSIT attributes greater PM ambient air concentration, heat wave conditions hampered these activities severely during 2016 and hence a higher PM$_{2.5}$ activity around IHBAS. In a nut shell, it can be concluded that lower rainfall and greater drier climatic conditions have led to noteworthy PM pollution of air in 2014 and 2016. However, a steady increase of PM activity across the landscape is observed due to below average rainfall (524.1 mm and 515.3 mm during 2015 and 2016 respectively) and continued enhanced ur-



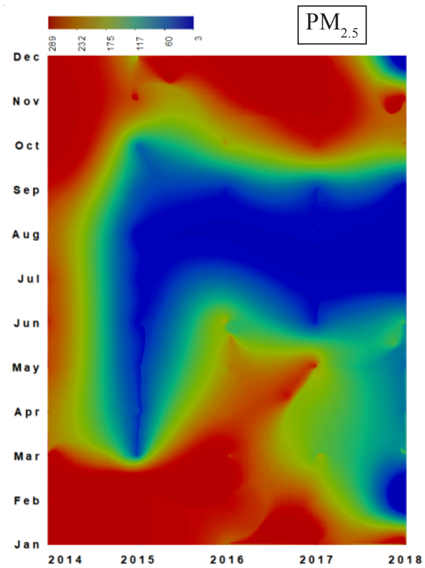
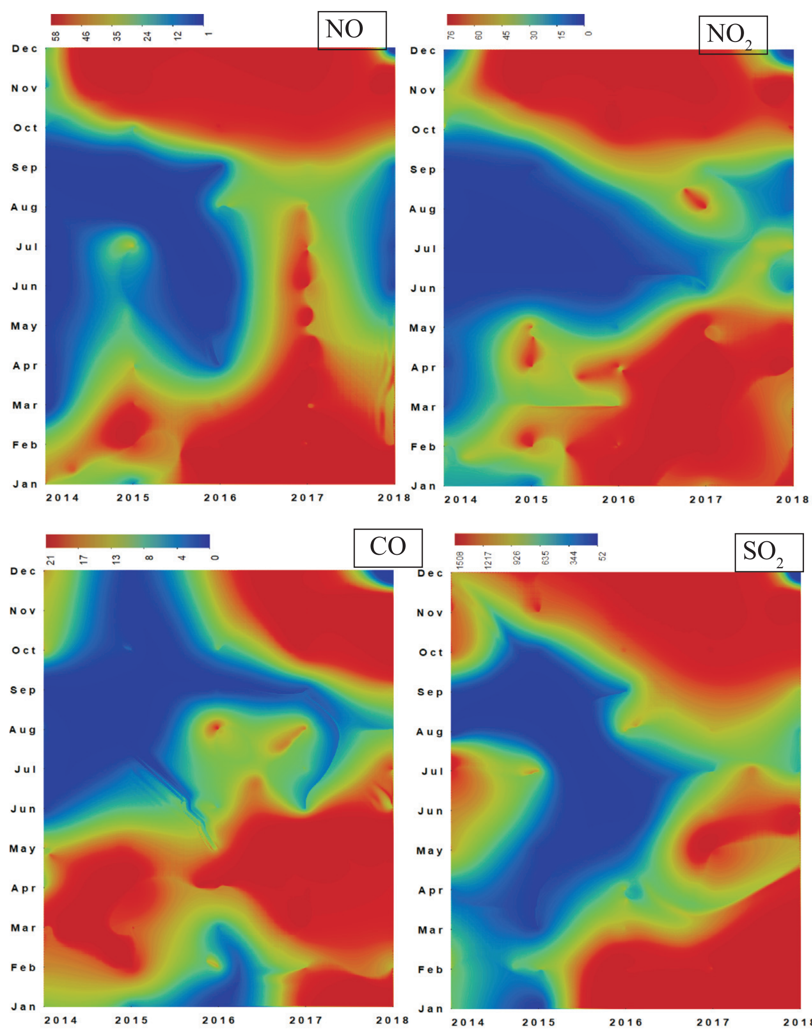


Fig. 3. DMS parameters data.

banization (around 4% - 6% of vehicle number growth, Planning Department, Govt. of Delhi, 2019). During the analyzed last half decade of data, it is noteworthy that all the monthly averages of $PM_{2.5}$ concentration for all the stations exceeded the threshold annual limit of (40 µg/m^3) put forward by National Ambient Air Quality (NAAQ) except September 2018 in NSIT region. This indicates a consistently prevailing moderately polluted to poor air condition across the Delhi-NCR.In contrast to the PM concentration of ambient air, IHBAS and DMS exhibit greater activity of Gaseous pollutants in comparison to NSIT surroundings (Figure 4). This can be attributed to the greater number of industries, particularly the plastic and steel industries as well as the greater quantity of garbage produced from the more dense population of the landscape. Among the three stations, NSIT exhibits the lowest gaseous pollution of air due mainly to the absence of



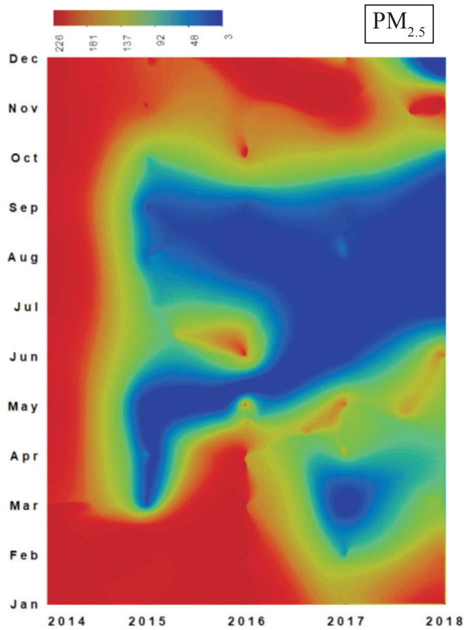


Fig. 4. IHBAS parameters data.

any industrial activity (Figure 4). Among the gaseous pollutants NO_2 exhibits a consistent greater concentration exceeding the NAAQ standard for all the stations. Out of the analyzed years for the past decade two (2014, 2015), four (except for 2017) and four (except for 2014) of the five years for NSIT, DMS and IHBAS respectively exceed the NAAQ threshold annual limit of 40 µg/m^3. In other words, the inhabitants of the study experienced NO_2 polluted ambient air 80% of the time for the last half decade. With respect to the gaseous pollutants of SO_2 and CO, the data portrays a cleaner and safer environment. However, it is

Noteworthy that DMS region, due to its greater construction activity, portrays a consistent higher polluted air both with respect to gaseous as well as particulate matter.

Conclusion

Present research took into account the concentrations of pollutants such as CO, NO, NO_2, SO_2 and $PM_{2.5}$ to investigate the health of Delhi-NCR ambient air for the past half-decade. Geostatistical and geospatial investigation leads to a consistent greater particulate matter activity for the above time period. With a look into the prevailing temperature and rainfall conditions of the landscape, the findings point towards a direct relationship between scanty rainfall and higher temperature to greater particulate matter pollution of the surrounding air. This is evident from a noteworthy greater pollution during 2014 (scanty rainfall) and 2016 (heat wave condition during summer). Among the analyzed three monitoring stations, DMS and NSIT surroundings portray increased $PM_{2.5}$ pollution in comparison to IHBAS owing to greater construction and developmental activities. Contrastingly, IHBAS points towards a greater gaseous pollution due to larger industrial activity. However, it should be noted that the data acquired for the study relates to the past half-decade with many data gaps. Hence, the authors strongly believe continuous analysis and evaluation of air pollutants will help us better appreciate the origin, dynamism and cyclist, if any, of Delhi-NCR air pollution. Acknowledgement the authors sincerely acknowledge the support and facilities provided by the Amity Centre for Ocean-Atmospheric Science and Technology, Amity University Haryana (AUH) and data provided by Central pollution Control Board (CPCB) for carrying out this project. On behalf of all authors, the corresponding author states that there is no conflict of interest.

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