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SPATIO-TEMPORAL VARIABILITY OF AMBIENT TRACE GAS POLLUTANTS AND THEIR PCA PREDICATION: A COMPREHENSIVE REVIEW

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ABSTRACT

This review work is intended to serve as an in-depth analysis of national and international spatial and temporal variation of ambient air pollutants patterns like SO_2, NO_2 and diurnal variation of surface O_3 and CO are taken into consideration. The gaseous pollutants vary from city to city. As the local people's life style influences a lot in their emission. It is found that in most of the city SO_2 is under permissible level, Whereas NO_2 is somewhere seen to have high concentration as well as somewhere low concentration. Vehicle emission is the main source of NO_2. Similarly, CO pollution is also dependent on vehicle emission. The secondary pollutant surface O_3 are found in different parts of India and abroad. It is found that in most of the places it has not exceeded its prescribed standard limits, but its formation is not only dependent on its precursors but also on the prevailing meteorological condition. For validation of the result and for predicting and identifying the major source Factor analysis and PCA have also been used. A few mentionable research works on monitoring of the trace gas pollutant in the ambient air are as follows.

Keywords: Spatial; Temporal; Gaseous Pollutant; National; International; Secondary Pollutant; PCA; Sources

INTRODUCTION

Clean and unpolluted air have so far been treated as unlimited and free natural resource. Pollution of the atmosphere has been an uninvited spin off of humanoid activities probably since the cavemen first lit fires. Atmospheric pollution is defined as any environmental condition where certain substances are present in such amount and duration that they may produce harmful effects on his environment. These amounts, or concentrations vary widely depending on the sources and their distribution, local meteorological conditions and the topographical condition of the sampling location. Sources of air pollutants may be through natural occurrences for example, volcanic eruptions, sand storms, forest fires, dispersion of plant pollen, wind, soil erosion, etc.; But, man-made activities also introduced pollutants are mainly from manufacturing, industrial and motor vehicle operation. The activities are mainly concentrated in cities and other urban areas, and according to report these cities expected to be held nearly 50% of the total World's population[1]. As modernization and robust industrial activities have further increased the use of fossil fuels and their byproducts, predominantly in developing countries leading to the emission of gaseous pollutants[2]. In urban areas the transportation sector causes the most pollution not only that the Industry, power plants and the burning of municipal and household solid waste also add to the pollution load.

A meteorology study plays a crucial role in air pollution. In fact, there is a variable and strong seasonality in the meteorological factors, which regulate the environmental pollutant quality levels. The important meteorological variables are wind speed (WS) and wind direction (WD), amount of rain and its duration, atmospheric air temperature, and relative humidity (RH). Micrometeorology has a key role to play in air pollution. There is a strong correlation between micrometeorology and dispersion of air pollutants which essentially involves wind in the widest sense.

Gaseous pollution may cause several respiratory and other health complications. It impacts economic productivity, reduces agricultural production, harms property and building and causes ecological disturbances that increase the risk of environmental disaster. On human, air pollution is now associated with acute and deep alveoli respiratory such as asthma, lung cancer and eye diseases like

conjunctivitis, especially in the young child and older person.[3,4] One of the secondary pollutant known as acid rain, which has been responsible for damage to fertility of soil, fish resources and natural vegetation, often very far away from the birthplace[5]. Air pollution is also responsible for smog formation, which leads to the reduction in visibility which scatters light by airborne particles present in the atmosphere. It may also cause offensive odors in addition to soiling monuments and buildings for example, Taj Mahal in Agra. However, by far, the most serious long-term soon threaten the very existence of human life, especially in the seashore and coastal and highland regions. There is a great concern about global warming led to the famous Kyoto Protocol of 1997, in which nearly 100 countries undertook to reduce their emissions of certain pollutant gases to the significant level.[6, 7]

Spatio-Temporal variability of ambient trace gas pollutants

SO_2 and NO_2 : National level Status

SO_2 released from the Mathura refinery, its concentration effect and consequences were studied on the Taj Mahal (the monument which is adjudged as) in Agra, India[8]. A study on NO_x at Nineteen highly traffic cross cutting points within the city of Kolkata was performed and had observed that there have been the significant seasonal deviations with winter, having the maximum concentration and minimum during peak monsoon[9]. The behavior of oxides of nitrogen (NO_x: NO, NO_2) was observed in Mumbai. The monitoring results showed that at a larger distance from the road the level of NO decreased, but the concentration of NO_2 remained the same which was very harmful[10].

Sub-regional and percentage SO_2 and NO_x sectorial emissions inventories of all 466 sectors in India had been estimated for using base data for the years 1990 and 1995. Total SO_2 and NO_x emissions for the year 1990 from all India districts were 3542 and 2636 Gg respectively, and for the year 1995 4638 and 3462 Gg respectively, growing by 5.5 % per annum. The sectoral composition indicated for SO_2 emissions are predominantly due to the electric power generation sector, which is 46 % and Power and transport sector emission equally dominated NO_x emissions contributing nearly 30 % respectively[11].

Studied had been done to know the concentrations of SO_2 in Delhi. The average monthly concentrations of SO_2 were in the range of 16.15- 34.44 $\mu g/m^3$ and showed regular seasonal variations with the highest concentrations in winter and lowest in monsoon season. It has been analyses that higher concentrations of SO_2 were generally associated with the directions of wind blowing from WNW–NW. It was noticed that the wind pattern in the northern part of India including Delhi revealed that the wind blew from the western region of India subcontinent to Bay of Bengal (BOB) during most of the season except in the season of monsoon months (June-September) where the direction of the wind gets reversed[12].

The gaseous pollutant concentration Measurement has been done for the Raniganj - Asansol. It has been recorded that at any of the monitoring stations values of SO_2 levels did not exceed in it's the 95^{th} percentile than the reference level. The 95^{th} percentile value of NO_x was found to be exceeding the limit (80 $\mu g/m^3$) at some sites, but is within the prescribed limit of 120 $\mu g/m^3$ at a site. It was observed that the annual average of SO_2 values was minimum and almost an equal at all the Sampling monitoring study sites and were below the reference levels of 80 $\mu g/m^3$ at the site. The winter average SO_2 levels were relatively high when comparison done with date of the summer and monsoon study. The annual average NO_x concentration levels did not cross the reference levels of 80/120 $\mu g/m^3$ at any of the four sampling sites. Vehicles were the dominant transportation and emission source of NO_x in this region. Monitored high concentration of NO_x at all these sites (annual average 56.85–60.42 $\mu g/m^3$) was mainly due to the fact that the two sites (RGC and BBC) were near to the Grand Trunk Road, one of the busiest National Highways[13].

In summer and post monsoon seasons, the concentrations of SO_2 and NO_x were within the prescribed limits except at a few sites in summer. Winter data showed the levels of SO_2 were exceeding the limits at one residential site in Visakhapatnam[14]**.** Contribution of pollution different emission source, identification and concentration estimation had been made for Jamshedpur city, also known to be as the steel city of India[15]. In-depth zone-wise analysis of the above indicated that for effective air quality management, the priority should be given highest to the industrial source emissions, followed by vehicle and domestic sources in Jamshedpur region. The results of the modeling exercise revealed that in the sampling study area, the concentration levels of SO_2 and NO_2 would be relatively high[16, 17].

Due significant seasonal variations these trace gaseous concentrations were highly dynamic in nature

with characterized levels high in winter and low in monsoon[18]. Daily average concentrations of SO_2, NO_2 and NH_3 in the study area were found to be within the permissible limit of NAAQS (National Ambient Air Quality Standards) as limit set by the Central Pollution Control Board, India[19]. The daily average concentrations of SO_2 and NO_2 were observed to be 12.3±9.2, and 32.5±14.2, at the residential site, with 21.3±15.7 and 49.9±9.8 μg/m^3 at the industrial site, respectively. The 8h average corresponding values of the commercial site were 15.5±11.9 and 39.9±17.3 μg/m^3 respectively.

SO_2 and NO_2 : International level Status

Depending upon their experimental results the major air pollutants were SO_2, CO, NO_2, HC, O_x and PM. Among these, two types of concentrations exhibited by the pollutants, whether they were photo chemically reactive (PCR) (NO_x, SO_2, HC and O_x) or non-photo chemically reactive (NPCR)[20]. The variation corresponding to NPCR reactive pollutants showed two maxima, one in the morning at 8:00 am and secondary in 8:00-9:00 pm in the evening. However, PCR pollutants exhibited only a single maximum at about noontime or early afternoon. Inventories have been done for some selected years to estimate the concentration of SO_2 and NO_x for 25 Asian countries [21].

The substantial concentration monitoring of NO_x generated during cooking hours due to gas burning had been done. The measured concentration of NO_2 was almost 4000 μg/m^{3}after using a gas cooking range consisting of four rings for 75 min with full power in a laboratory of volume 70 m^3. Diurnal means SO_2 concentrations varied from 9 μg/m^3 (2–6 am) to 12 μg/m^3 (6–10 pm) with a maximum value observed in May (30 μg/m^3) and a minimum in November (1.5 μg/m^3) [22].

Investigation of the ambient SO_2 levels in four residential locations within the capital region of Egypt has been done. The results indicated that the average ambient SO_2 concentrations were above the permissible limit of the national as well as international monthly average exposure, without the influence of the type of local activity[23]. SO_2 levels were investigated in Erzurum during the periods of 1990-2000, the heating season to assess air pollution level. It was found that emission values of SO_2 had increased dramatically to 1994–1995 winter season; emission values of SO_2 and NO_2 pollutants were higher than the permissible limit in 1992– 1993 winter periods[24]. Air quality concentrations of SO_2 were also found in parallel with emission values of these pollutants. The decreases in emissions of pollutants were explained in this manner that after 1995, we started high quality coal instead of low quality lignite and both emission and air quality values of SO_2 decreased.

There has been monitoring of the status of gaseous pollutant in greater Dhaka. The overall average values of SO_2 at five sampling locations were 48 μg/m^3, which was very close to the annual average of the WHO guideline values for the EU (European Union WHO 2000: 50 μg/m^3). The highest concentration (76.8 μg/m^3) of SO_2 was found in the commercial and heavy traffic areas at the sampling sites of BCIC Bhaban, Motijheel, while the lowest concentration (20.7 μg/m^3) was found in the semi-urban area of the sampling sites of Jahangirnagar University campus, Savar. The reason for high concentration of SO_2 in the city center was probably due to the high content of Sulphur in fossil fuel. Medinava hospital recorded the highest concentration of NO_2 (40 μg/m^3) and the sampling site was Dhanmondi, having medium traffic, whereas Jahangirnagar University campus recorded the lowest concentration (5.0 μg/m^3) at, Savar, which is a semi urban location[25].

Weather conditions strongly affect the concentrations of SO_2 and also varied distinctively with the seasons. It has been noticed that during the winter (heating period) the concentrations of SO_2 were higher because of the burning of high-Sulphur coal and lower in summer than other seasons. In contrast, due to increase in the industrial growth and its activities, industrial pollution has been increasing at an alarming rate, but in recent years, the concentration of SO_2 in Beijing during the summer had been cut down, obviously due to control following of its industrial management, policy and frameworks. The PCR activity led to an obvious decrease of NO_x (NO and NO_2) the data recorded for daytime[26].

NO_2 and SO_2 concentration measurements were done in Pakistan and observed that the concentration of NO_2 was found in the range of 0.02–0.08 ppm. The reason for high concentration of NO_2 at this location could be the presence of large chemical manufacturing plant adjacent to the road. The NO_2 concentration at some sampling locations was higher than the USEPA limit of 0.05 ppm, but some sampling sites recorded very well within the limit of USEPA ambient air quality standards. Similarly the concentration of SO_2 was found in the range of 0.02–0.07 ppm and concentrations at all the sampling locations were within limits of USEPA ambient air quality standards. The concentration of

SO_2 was found highest at a sampling point where it was in the range of 0.05–0.07 p.m., Due to presence of industrial activity near the road[27]. Traffic- related air pollutants like nitrogen oxides (NO_x) were monitored near major roads at 10 sites in Japan[28].

CO and O_3: National level Status

According to the worked done, O_3 being a secondary pollutant, found that O_3 did not show any linear correlation with the traffic density[29]. Measurements of CO concentrations in different seasons were performed at the different sampling sites of New Delhi 2002[30]. Surface O_3 had been measured at Tranquebar a tropical rural coastal site on the Eastern coast (Bob) of Southeast India, and the period of the sampling were for nearly 3.5 years i.e. From May 1997 to October 2000[31]. A significant diurnal cycle of average O_3 has been recorded by the measurements showing with a maximum concentration (33±4ppbv) in the afternoon and average minimum O_3 (11±2 ppbv) at sunrise. O_3 also was found to have higher concentration (23±9 ppbv) in May and lower concentrations were recorded in the month of October (17±7 ppbv) at this site.

According to the estimation done for the surface O_3, seasonal and diurnal variation having a preliminary analysis of its critical concentration levels has been done at semiarid monitoring sites of India. According to their data they found that monthly average O_3 mixing ratios ranged between 8-40 ppb having annual average of 21 ppb. They also found that O_3 exposure in their study were lower than the critical level of O_3 and suggested that the level O_3 had not any impact on reduction in crop yields[32].

There has been the investigation for RH, concentrations of surface O_3, WS, NO_x and WD during the summer of 2005 at five sampling sites in Chennai. The different climatic conditions study had dealt with the characteristics of hourly and daily mean surface O_3, such as temperature, RH, WS and WD and other pollutant concentrations. It has been recorded that on 17th May hourly O_3 the maximum concentration reached 53 ppb, whereas the ground level O_3 concentration at the different sampling sites were at a range of 2 and 53 ppb but NO_x and O_3 concentration were below the prescribed limits. The mean O_3 concentration in all sites had been observed to be higher in the wind flow from SSE and S than that of the SSW and WSW. It had also been observed that the surface O_3 concentration increased with the increase in temperature and decreased with increase in RH[33].

There has been Observation of surface O_3 with its precursors namely, CO and NO_x simultaneously on the diurnal scale in Pune. According to their findings the maximum O_3 reached as high as 85–90 ppbv during February, whereas a minimum of 10- 15 ppbv was observed during the monsoon month of August. They revealed that a time lag of 5-7 hour was required for most of these precursor gases to photo chemically produce O_3 to its maximum potential[34].

An attempt has been made to examine rural site surface O_3 formation in the governing photochemical processes. For this purpose, measurements of surface O_3 and selected meteorological parameters had been monitored at Anantapur, a semi-arid zone in India for 2 consecutive years (2002-2003). The annual diurnal average variation of O_3 showed maximum concentration 46 ppbv at noon and minimum 25 ppbv in the morning. The average seasonal variation of O_3 mixing ratios was observed to be maximized (about 60 ppbv) during summer and the minimum (about 22 ppbv) in the monsoon period. The monthly day time and night time average surface O_3 concentration showed maximum in the month of march were (55 ±7; 37±7.3 ppbv) and minimum in august (28±3.4; 22±2.3 ppbv) during the study period. The monthly average high O_3 were observed at noon in March was due to the possible increase in precursor gas concentration by anthropogenic activity i.e. Man-made and the local meteorological parameters influence. The mixing ratio of O_3 started increasing at about 7:30 am and it reached a maximum value at about 4:00 pm[35]. The O_3 variation was not only controlled by solar radiation, but also by dynamics atmospheric influences. Photochemical O_3 productions are most favored on conditions at high temperature, high solar intensity of radiation, and the most important should be of sufficiently high concentrations of NO[36]. Surface temperature was highest (43- 44°C) recorded during the months of March and April which favor and leads to higher photochemical production. On the other hand, RH, which was higher during the rainy season, showed negative correlation with temperature and O_3 mixing ratio.

The surface level measurements of O_3, CO, CH_4 and light Non CH_4 hydrocarbons (NMHCs) were made at rural sites of eight different sampling sites in the central India during the month of February, 2004. They reported that the O_3 average mixing ratios were, founded in the range of 60–90 ppbv,

were significantly higher compared to the typical values reported for urban sites of India[37]. Emission characteristics of O_3 related stress gases of a semi urban site in the Indo-Gangetic plain was also studied. In their study, elevated levels of O_3 were observed when CO and NO_x were in the range of 200-300 ppbv and 20-30 ppbv respectively.

Aerosol mass concentrations of CO, O_3 and black carbon (BC) were analyzed over tropical urban environment of Hyderabad from January–December, 2008[38]. Higher concentration of BC, CO and O_3 was observed before monsoon, after monsoon and winter and the minimum concentrations exhibited during monsoon season[39].

CO and O_3: International level Status

It was well known fact that O_3 forming capacity due to precursor emissions was highly dependent on the amount of NO_2 and HC (Hydrocarbon) and both of these precursors were closely related to traffic and estimated the tropospheric air pollution[40-45]. A complex VOC-NO_x chemistry for O_3 control was discussed in this study. In addition OH, NO_3 and O_3 were shown to play a crucial and important role in the production and fate of environmental born toxic chemicals, mutagenic PAH and fine particles.

The research has been done on the prediction of O_3 formation in air pollution. They intended to test the performance of the O_3 formation prediction schemes. The prediction results of O_3 formation were compared to the real data. From the comparison, it could be predicted that the scheme based on the parameter estimation method gave a reasonable accuracy with limited prediction horizon[46].

The diurnal and seasonal concentration variations in CO, NO and NO_2 pollutants were presented and meteorological conditions during an intense pollution episode were analyzed in the context of the characteristics of the main sources of pollution. The high levels of CO concentrations were associated with high pressure systems, temperature inversions on surface and low wind speeds[47].

An attempt has been made to allocate anthropogenic pollutant emissions over space toward managing O_3 pollutions. The two precursors of ground level O_3 viz. VOC and NO_x were estimated in this study. According to the resulting inventory revealed approximately 50 % of VOC and NO_x emissions annually due to the cause of traffic, transportation and road motor vehicles. The traffic, transportation and road motor vehicles and residential wood combustion were the largest VOC sources in the summer and fall month's respectively[48].

Monitoring and analysis has been done for O_3 and NO_x variability along with BC and PM_{10}. NO_x and PM_{10} particles were anti-correlated with O_3, with noticeable O_3 destruction during peak hours (mean ~ 6 and 9 ppbv at 7 am and 8 am respectively) when NO_x and PM_{10} concentrations had exhibited maximum values[49].

It has been analyzed that the pesticide impact on air quality, especially surface O_3, and observed that different pesticide's had the potentiality to O_3 formation in troposphere[50]. As, for example, organo-phosphorous insecticides (Dimithocite) decomposition and degradation were found to be an effective hydrocarbon precursor for stratospheric and surface O_3.

The work had been carried on O_3 modeling, according to this study, the impacts of the background concentration of O_3 on regional scale model results were analyzed during the summer smog episode in Europe. It was found that depending on the weather situation, moderately modified assumptions of background O_3 concentrations revealed an uncertainty of near surface O_3 concentration of 5-15 %[51].

Throughout the world, several attempts are made to predict the tropospheric O_3. The work has been performed in Mexico City in the year 2003. They attempted to find the liquefied petroleum gas (LPG) effect on O_3 formation. In their experimental study of outdoor smog chamber due to burning of LPG was carried out to determine its effect on maximum O_3. They performed eight smog chambers by introducing 60 % additions of commercial LPG and 60 % propane + 40 % butane mixture of the initial concentration into a morning ambient air of Mexico City metropolitan area (MCMA). The final results showed that by increasing 60 % in the air of MCMA and associated compounds to LPG or diminishing 50 % of the mixture, and had not an appreciable influence. One of the major effects on O_3 formation is determined by total NMHC contained in the atmosphere, being the maximum of O_3 formed in the eight smog chambers, and the result was that on the average it diminished a 55 %[52].

An attempt had been done on investigation of O_3 budget and its dependence on NO and rate of free radical production. The photochemical box model was applied to calculate local O_3 production and loss rates for the arctic free troposphere. This model concluded that there were increased by O_3 production rates by a factor of 28 in the 1 - 3 km layer and in the distance 3- 6 km layer by the factor

of 7 between February and May. For NO_x mixing ratios Gross O_3 production rates were calculated which increase linearly with up to ~ 300 and ~ 500 pptv in February and May respectively[53].

In the USA the investigation of O_3 exposures and implications for vegetation in rural areas of the central Appalachian Mountains, USA has been done. Response of vegetation to O_3 in these areas was determined using the combination of sigmoidally weighted exposure index, number of hours that average concentrations ≥ 0.01ppm (N100), and the occurrence of droughts at the level of moderate or more extreme. In general, sigmoidally weighted exposure index and N100 data it has been suggested that negative vegetation growth responses over most of the 12 year would have been minimal for most sites, even if the value of O_3 exceeding O_3 standards[54].

It has been observed that there is a strong spatial and temporal variability of traffic related air pollution roadside. According to their observation the highest CO and NO_x concentrations during the past few years has been monitored in the capital region of France ie. Paris[55].

In greater Dhaka CO values were wide-ranging between semi-urban sampling site, industrial sampling site and urban sampling sites. The highest concentration (334 $\mu g/m^3$) of CO was observed at the industrial monitoring site (Novarties, Tejgaon), and the minimum value (42 $\mu g/m^3$) was found in the semi-urban sampling area (Jahangirnagar University, Savar). The maximum concentration of CO at the industrial sampling sites was presumably due to the incomplete conversion of fossil fuel at operation of different mechanical and industrial processes. The total average concentrations of CO and O_3 were 166.0 and 28 $\mu g/m^3$, respectively[25].

The peak value of O_3 appeared between 11am and 6 pm local time (maximum appears at 2 pm local time) when the solar radiation intensity was recorded maximum in the noontime at Beijing, the capital of china[26].

The CO monitored data in Pakistan were in the range of 1.5- 6.1 ppm that was under the prescribed limit according to USEPA Ambient air quality standards. The comparison of CO at nine locations showed that the highest values were seen at a site having high load of traffic congestion and emission volume of traffic pollutants were high[27].

The CO daily mean concentration recorded was 2.25 mg/m^3 with the range of 0.72×3.46 mg/m^3, by the observed data which was lower than the NAAQ[26].

According to the analysis done for the tropospheric O_3 concentration in Spain. They had studied temporal and spatial variations of O_3 at different scales; daily, weekly, seasonal and annually. In this study the link between elevated O_3 concentrations and high values of the recirculation factors (r = 0.7 - 0.9) had shown the importance of recirculation flows on the local air pollution episodes[56].

Shipboard measurements of NO_2, HNO_2, HNO_3 and O_3 in the eastern Mediterranean Sea were done. According to their study HNO_2 and HNO_3 acids revealed to be the most important for the transport of N_2 of marine biota in busy shipping lanes[55]. Identified NO_x and O_3 episodes to estimate O_3 by statistical analysis. O_3 concentration had been forecasted by time series modeling[58].

Typical annual, weekly and diurnal cycles of the ground-level O_3 analyzed, assessment and measurement at two stations in Tehran has been done. O_3 as a pollutant showed that the O_3 level concentrations were below the WHO guidelines in Tehran during 2000- 2003. It was also found that the diurnal cycles of O_3 were typical for stations that were strongly influenced by motor traffic. The research indicated that the O_3 level was also affected (positively or negatively) by meteorological parameters, e.g. RH, solar radiation, temperature, WS and WD[59].

Principal components analysis (PCA) and (FA) factor analysis for predicting the sources of air pollution

Factor analysis and principal component analysis have a wider application in identifying the major source of air pollution. From the literature, it is found that these sources have varied from place to place. However, mainly different anthropogenic activities like industrial process, transpiration activities, biomass burning, coal combustion, etc. And some natural source like soil resuspension are major contributors of gaseous as well as particulate pollution. The literatures are as follows.

PCA has been used for the investigation and analysis of databases of atmospheric pollutants. The data set was made of nearly 400 measurements of 26 gaseous pollutants and meteorological observation. The sampled measurements were carried out at four different places in the Netherlands. PCA was considered as a simple way to display visually most of the total variation in a few dimensions. It was also considered very helpful in the identification and recognition of sources and the investigation of

meteorological effects[60].

PCA had been applied for the identification of the major sources of $PM_{2.5}$ and PM_{10}. Three major sources were identified, namely emissions from the transportation and vehicle, industrial output and soil resuspension for PM pollution and heavy metal present in it[61].

PCA was also carried out using the measured elements and had identified soil and sea salt spray as the main sources for the SPM at all the floors in Mumbai[62]. By Application of PCA it has confirmed that vehicular traffic and industrial emission as the major contributors of metals in Delhi[61]. According to the study, the properties of PCA were a robust method of investigation of pollution source in environmental studies[62]. These properties were considered and discussed with the examples of using methods of factor analysis in atmospheric, hydrology and lithospheric ecological systems.

On application of PCA for their research, they came to the conclusion that three factors were responsible most out of the 7 observed variables, which were the 84 % of the variance. The results showed that local emissions, dominated the concentration of SO_2, NO_2, NH_3 and PM_{10}. Mobile sources were the major emissions sources affecting the urban area beside the contributions due to emission from industrial sources and discharge, coal-fired power plants and domestic heating[18].

PCA also revealed that source of pollution were resuspension of road soil, dust due to vehicular and traffic emission, solid waste burning and emission from the industrial discharge at an urban site whereas resuspension of road soil, dust due to vehicular and traffic emission, construction related activities and windblown dust carrying industrial emission, were common sources at rural sites[65].

CONCLUSION

From PCA few sources of air pollution are identified. In premonsoon one natural source of pollution, i.e. Soil resuspension and two anthropogenic sources viz. Vehicle and traffic emission, by combustion of coal or fossil or biomass and solid waste burning is identified as a major source of air pollution. In post monsoon one geogenic source i.e. Soil resuspension and other anthropogenic source like vehicle emission along with combustion of biomass and waste material are identified as a major source of air pollution in the study area, whereas in winter like other two seasons, one gigantic pollution source i.e. Soil resuspension along with anthropogenic sources viz. Vehicle and traffic emission and combustion of coal and waste are identified.

All the monitoring sites have high observed value of SO_2 in the winter season than premonsoon and least recorded value in the post monsoon season. Precipitation driven washout may lower down the post monsoon value of SO_2. The concentration of SO_2 was comparatively lower in all the seasons than the NAAQS prescribed standard in all the monitoring sites. So, this scenario is quite safe.

The NO_2 level was very high throughout. All the sensitive sites have exceeded its standard of 30 $\mu g/m^3$ in all season. The residential site is also having a tendency to cross the set limit of NO_2 almost in all season excerpt a few sites. High vehicle density may cause such elevated level of NO_2. To explain the above finding it could be said that NO_2 was not only dependent on rainfall, but emission of these gaseous pollutants also dependent on vehicle density and the distance of the monitoring site from the road.

The concentration of O_3 is not the only function of its precursor viz. CO but also a function of prevailing meteorological conditions. It is observed that the concentrations of O_3 increase with the decreasing concentration of its precursors and vice versa. A time lag of 5-7 hour is required for most of these precursor gases to photo chemically produce O_3 to its maximum potential. This is also found that on diurnal scale, these precursor pollutants of O_3 are built up in the early morning hours along with a maximum in noon or afternoon. Comparing with its latest standard (NAAQS) so far average CO value has crossed the limit. On the other hand O_3 is again far below the standard. The CO being a threat to the study area needs proper management strategies to check down its value and O_3 is quite safe so far.

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