Seasonal Trends and Source Apportionment Study of RSPM, $PM_{2.5}$, NO_2 and SO_2 in Ambient Air of Jammu City, Jammu & Kashmir

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Abstract-

Clean air is the foremost requirement to sustain healthy lives of mankind and those of the supporting ecosystem which is turn effect wellbeing. Release of particulate matter and various gaseous emissions has been on rise due to rampant industrialized growth. The ambient air quality is being deteriorated day by day due to various natural as well as anthropogenic sources. The pollutant data (RSPM, $PM_{2.5}$, NO_2 and SO_2) from State Pollution Control Board for period June 2017 to May 2018 has been used for this study . The study reveal that sampling site with heavy traffic density/load recorded the higher concentrations of RSPM, $PM_{2.5}$, NO_2 and SO_2 in all the seasons. Higher concentration of RSPM (178.0 µg/m^3) and $PM_{2.5}$ (51.2 µg/m^3) were observed in summer season at all the sites whereas striking feature of higher concentrations observed in case of gaseous pollutant NO_2 (24.6 µg/m^3) and SO_2 (5.1 µg/m^3) in winter season at all the sites. Lowest concentrations of all the pollutants observed in Monsoon season at all the sites. Factor analysis was carried out using Principal Component Analysis for all the four pollutants. The major sources identified in the study which were responsible for the higher concentration of pollutants are Vehicular emission (from petrol and diesel driven vehicles) and crustal re-suspension. Some contributions are from wood and leaf burning and coal combustion.

Keywords: Ambient air quality, RSPM, Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2) &Principal Component Analysis.

1. Introduction:

   Air which we breathe constitute aerosol particles or suspended particulate matter which has been a matter of public concern due to its direct implications on human health (Spengler&Thurston 1983; Orisini et al, 1986; Dockery et al, 1993, Alias et al. 2007; Hung 2013), affecting visibility and their role in Global Climate Change (Seinfiel and Pandis 1998). Some substances generated from the natural sources while others are caused by human activities. Emissions from industries and auto exhausts are responsible for rising discomfort, increasing airborne diseases and deterioration of an artistic and cultural heritage in urban and industrial. Size of the aerosols provides information about the chemical and physical processes effecting aerosol as they are transported into the environment. The degree of respiratory penetration and retention is a direct function of the aerodynamic diameter of the particle. In general, particles smaller than 10µm in diameter get respired inside our body (McCarnac 1971) and particles with diameter < 5µm are filtered in the nose for most of part, while those < 1-2 µm in the diameter predominantly get deposited in the alveolar region of the lungs (Gupta et al, 2007).

In India, almost all the cities are suffering due to increase in concentration of particulate matter (PM) in air along with gaseous pollutants.

Particulate matter (PM) is currently considered to be the best indicator for health effects of ambient air pollution (Burnett et al., 2014, WHO, 2014). Many human activities contributing to ambient PM are further contributing to climate change, and are therefore associated with additional health impacts. In order to take actions to reduce exposure to air pollution, and hence the associated health impacts, it is essential to know the sources and activities contributing to local levels of pollution (Karagulian et al., 2015). Studies identify high ambient concentration of PM 2.5 in India originating largely from anthropogenic activities such as fossil fuel combustion in power generation, industrial processes, road transport and solid fuel use in traditional resident cooking (CPCB, 2011; Guttikunda et al., 2014; Pant et al., 2015; Amann et al., 2017; Chowdhary et al, 2016., Gorden et al., 2018; Venkatraman et al., 2018 &). Many studies have demonstrated a close relationship between particulate matter (PM_{10}) pollution and deterioration in human health. The key properties of airborne particles are generally considered to be the size of aerosols and the associated capacity for penetration into the human respiratory system (Sharma et al, 2014). Gaseous pollutants have health effects of their own and may act in concert with PM to cause health effects. Any consideration of the health effects of different components and sources of PM must consider how gaseous pollutants may affect the toxicity of PM constituents (Adams et al, 2014).

Like other parts of our country, air pollution in Jammu and Kashmir is also increasing with the number of vehicles. The main source of air pollution in Jammu city is vehicular traffic which goes on increasing year by year (Sharma and Raina, 2012; Sharma and Raina 2015). Numbers of vehicles registered in Jammu city upto 2017 was 422972 represented in the table 1, which indicates that rate of registration is increasing every year. At least 15 lakhs vehicles are playing on the roads in J&K, making it one of the most vehicle populated state in the country.

Urban atmospheric conditions has deteriorated more and at a faster rate as compared to rural condition and Sulphur dioxide (SO_2) and Nitrogen Dioxide (NO_2) are considered as major gaseous pollutants in a city. SO_2 has been recognized as a major pollutant emitted from anthropogenic sources e.g burning of fuels, smelting of metal sulphides and other industries facilities. NO_2 is a ubiquitous urban air pollutant whose major source is exhaust of both petrol and diesel fuelled engines, stationary combustion in boilers fired by coal, oil or gas. Ambient SO_2 and NO_2 are possible factor causing chronic obstructive pulmonary disease in humans, contribute to the formation of acid rain and deteriorate air quality (Sharma and Raina, 2015).

Continuous emission of pollutants from vehicular traffic is a matter of grave concern because of their adverse effect on ambient air quality as well on human being. The alarming vehicular growth rate, frequent traffic jams and improper roads has resulted in a significant rise in the total suspended particulate matter (TSPM) level of Jammu city. However vehicles continues to be the biggest contributor to the ambient TSPM level, significant contributors from other pollution sources (Srivastava and Jain 2005: Srivastava & Jain 2007) Particulate matter from various sources may contains hazardous pollutant and can have carcinogenic and mutagenic effect (Srivastava et al, 2008). Hence identification of the source and estimate of their contributions are important.

Various methods are used to estimate the source contributions, including Principal Component analysis (PCA) or Factor analysis, multiple linear regression analysis (MLR) and the Chemical Mass Balance receptor model.

In the present study, we have applied PCA for the source apportionment of RSPM, $PM_{2.5}$, NO_2 and SO_2 in the ambient air of Jammu city. PCA method focuses on cleaning up the factors, it also produce factors that have high correlation with one smaller set of variables and little or no correlation with another set of variable (Steven, 1996; Srivastava et al., 2008). PCA is often used as an exploratory tool to identify the major sources of air pollutants (Thurstan & Spengler, 1998; Bruno et al., 2001, Marcazzan et al., 2003, Guo et al., 2004).

The major advantage of using PCA as a receptor model is that there is no need for a prior knowledge of emission inventories (Chio et al., 2004, Gupta et al., 2011). Henry and Hidy (1979) characterized the potential sources of particulate sulphates in four US cities by applying PCA to a mixture of air samples and meteorological variables.

The PCA techniques have also been used to assess the sources of gaseous atmospheric pollutants such as volatile organic compound (VOCs), Carbonyl, Nitrogen Oxides(NOx) and Carbon monoxide (Bruno et al., 2001; Miller et ., 2002)

The study on source apportionment of particulate matter, SO_2 and NO_2 using PCA are rather limited for the city of Jammu. In the present study an attempt has been made to identify and estimate the possible sources of RSPM, PM $_{2.5}$, NO_2 and SO_2 in the ambient aerosol particles of Jammu city.

2. Material and Method

2.1. Area Descriptions.

Jammu is located at 32.73^0 N amd 74.87^0 E. Jammu is the winter capital and the largest city in Jammu province of Jammu and Kashmir. Lying on the banks of Tawi river, the city of Jammu with an area of 26.64 Km^2 (10.29 Sq mi), is surrounded by the Himalayas in the north and northern plains in the South. Jammu like the rest of the north western India, features a humid subtropical climate (Koppen: Cwa(Climate Jammu with extreme summer high reaching 46^0 c (39^{0}F). June is the hottest month with average high temp of 41^{0}c (105^{0}F), while January is the coldest month with average lows reaching 4^{0}c (45^{0}F). Average yearly precipitation in about 42 inches (1:100mm) with the bulk of rainfall in the months from June to September, although winters can also be rather wet.

In summer, particularly in the month of May, extremely intense sunlight or hot winds can raise the mercury to 46^{0}c (115^0 F). Following the hot season, the monsoon lashes the city with heavy downpour along with thunderstorm: rainfall may total upto 669mm (26.3 inch) in the wettest month (Map, weather and Airports for Jammu India (http:/www.fallinngrain.com/world/In/12/Jammu. Htlm). The wind rose pattern of Jammu is shown in figure 2.

To carry out the present study, the data of RSPM, PM$_{2.5}$, NO_2 and SO_2 has been taken from the State Pollution control Board, Jammu which is available on their website. The state pollution control board has collected the data from three different locations in Jammu. The characteristics of sampling sites are depicted in table 2.

Site1. MAM stadium is considered to be busiest place as it is located nearby Jammu bus stand where interstate bus services are available 24 hrs which includes huge traffic flow during day time as well night.

Site2. Narwal (NW) is identified as residential area away from city and is characterized by low vehicular traffic.

Site3. Bari Brahmna(BB) is considered to be an industrial belt. These industries are involved in manufacturing mainly agricultural product, automobile spare parts, beer plant, pharmaceuticals, chemicals, transportation accessories and electronic, scientific and printing equipments.

3. Results:

The summarized monthly average concentrations of various pollutants i.e RSPM, PM $_{2.5}$, NO_2 and SO_2 are graphically depicted in figures 3.1 to 3.4 and similarly seasonal average concentrations of RSPM, PM $_{2.5}$, NO_2 and SO_2 at various sites are presented in figures 3.5 to 3.8.

At site 1,(Narwal) identified as residential area, the average concentration of RSPM varies from 140.3 µg/m^3 in summer and 103.3 µg/m^3 in monsoon whereas PM $_{2.5}$ varies from 30.6 µg/m^3 in summer and 20.1 µg/m^3 in monsoon. Similarly NO_2 varies from 14.0 µg/m^3 in winter and 8.6 µg/m^3 in monsoon whereas SO_2 varies from 3.2 µg/m^3 in summer and 2.0 µg/m^3 in monsoon.

The site observed to have lower concentration of all the pollutants as per the characteristics of the site being a residential area free from huge traffic flow.

The highest concentration of RSPM (178.0 µg/m^3) PM $_{2.5}$(51.0 µg/m^3), NO_2 (24.6 µg/m^3) and SO_2 (5.0 µg/m^3) are MAM stadium which is not unexpected due to its nature of heavy vehicular sites. The variation of concentration of pollutants at MAM and Bari Brahmana reveals that heavy traffic and industrial sites have persistent pollutant level.

It can seen from the tables, that higher concentrations of gaseous pollutants NO_2 & SO_2 can be attributed to interstate bus terminal, local bus stands, high traffic flow; commercial activities, use of generators during frequent power cuts, frequent traffic jams, slow vehicles contributes for the elevated concentrations of these pollutants.

Monsoon season resembles lowest concentration of all the pollutants at all the sites which may be attributed to heavy rainfall during this season which may washed out the ambient pollutant$_s$ concentrations from the atmosphere. During monsoon season large amount of precipitation and changes in wind direction takes place resulting low concentration of pollutants (Sharma & Raina ,2005). The absorption of gases and solid particles by cloud and washing down of raindrops during rainfall contributes to the cleaning of atmosphere. Higher relative humidity during monsson period also results in settling down of particulate matter and gases present in the ambient environment (Ravindra et al, 2003 Sharma & Raina, 2015).

The higher concentration of NO_2 & SO_2 observed to be higher in winter season at all the sites and that can be attributed to calm meteorological conditions which facilitate more stability to the atmosphere resulting in slow rate of dispersion. Removal of pollutants by wet scavenging is much reduced in winter season. Winter season received lesser rainfall as compared to other seasons high value of NO_2 & SO_2 in winter are also in tune with the findings of Sharma and Raina,2005, Ravinndra et al., 2003, Mamta and Bhasin, 2010).

Ambient RSPM, PM $_{2.5}$, NO_2 and SO_2 concentration measured lowest at Narwal (NW) residential areas as compared to MAM stadium and Bari Brahmana. Narwal have comparatively lesser no of inhabitants, less construction activity, lesser volume of vehicles, proper road and also adequate vegetation is present along road side which clearly shows the role played by foliage in absorbing the pollutants.

It has been revealed in various studies that meteorological factors such as wind speed, relative humidity, precipitation and ambient temperature play very vital role in the dispersion of air pollutants (Ravindra et al., 2003, Sharma and Parvez, 2003, Asrani et el.,2006, Karar et al., 2006, Chauhan et al., 2010. Meteorological parameters vary in different part of the year and also from place to place.

The concentration of $PM_{2.5}$ and gaseous pollutants (NO_2 and SO_2) has been found within the range of NAAQs (National Ambient Air Quality Standards) limits as stipulated by CPCB provided in the table 3.2

3.2. Source Apportionment method:

Principal Component Analysis (PCA) was executed by the vaimax rotated factor matrix method, to carry out the Source Apportionment; base on the orthogonal rotation criterion which maximize the variance of the squad element in the column at a factor matrix using a statistical package SPSS (version 22). The PCA is a statistical technique that can be applied to a set of variables in order to reduce their dimensionality. It allows the replacement of a large set of inter correlated variables with smaller number of independent variable.

Result of varimax rotated factor analysis carried out on RSPM, PM $_{2.5}$, NO_2 and SO_2 at three identified sites in Jammu and corresponding possible sources are presented in the tables 3.2.1 to 3.2.3

3.2.1. Source Apportionment at MAM stadium

The factor analysis results of RSPM, PM $_{2.5}$, NO_2 and SO_2 at MAM stadium have been presented in table 3.2.1. Two factors were found as significant in all pollutants which could explain most of the variance of data. Factor 1 explained ~75.2 % of the total variance of the data and had high loading of all the pollutants. This, with eigen value of 8.98 was identified as vehicular emission (diesel + gasoline) Omar et al., 2002; Fang et al, 2004). Traffic is a source category that includes different kinds of emissions from various vehicle types. In addition to primary PM emissions from exhaust, and the emissions of organic and inorganic gaseous PM precursors from the combustion of fuels and lubricants, vehicles emit significant amounts of particles through the wear of brake linings, clutch, and tires (Amato et al., 2009, Belis et al., 2013, Karagulian et al, 2015,). These are deposited onto the road and then re-suspended by vehicle traffic together with crustal/mineral dust particles and road wear material. The second factor with the eigen value 2.1 & percent of variance 24.6 identified as crustal re-suspension.

The site is major transportation hub of Jammu and motor vehicles emission at this site was responsible for the above results.

3.2.2. Source Apportionment at Narwal (NW)

The factor analysis results of RSPM, PM $_{2.5}$, NO_2 and SO_2 are depicted in table 3.2.2. Two factors were identified which could explain most of the data variance Factor 1 accounts for 65% of the total variance of data with eigen value 7.5. This factor was associated with emission from diesel and gasoline driven vehicles (Guo et al, 2004, Fang et al., 2004; Sharma et al, 2007). Factor 2 explained ~25% of the total variance with eigen value of 2.8 and this factor is recognized as wood and dry leaf burning (Halshall et al., 1997., Sharma et al., 2007; Khiwal et al., 2008). At this site, many labour class people resided who used wood and leaf burning for cooking their meal.

3.2.3. Source Apportionment at Bari Brahmna

Table 3.2.3 shows the factors analysis results of RSPM, PM $_{2.5}$, NO_2 and SO_2 at Bari Brahmna which is an industrial site. Three possible sources has been identified which explained most of the variance. Factor 1 was responsible for 60.2% of the total variance with eigen value 7.1. Similarly factor 2&3 were responsible for 28.5% and 11.5% of the total variance with eigen value 2.0 and 1.8. The factor 1 was associated with vehicular emission with high loading for all the four pollutant.

Factor 2 was identified as coal combustion and factor 3 as crustal re-suspension (road side paved dust). Bari Brahmna is an industrial site and movement of load carriers vehicles are more in this area which accounts for possible source of Diesel and gasoline emission from vehicles. Also industrial have many electroplating industries which used coal for their furnace. Industry is a heterogeneous category including mainly emissions from oil combustion, coal burning in power plants and emissions from different types of industries (petrochemical, metallurgic, ceramic, pharmaceutical, IT hardware, etc.) and from harbor-related activities. Industrial sources are sometimes mixed with unidentified combustion sources or traffic (Belis et al., 2013). Dust is characterized by elements abundant in the earth's crust rocks and the soil. These components of PM are associated with the re-suspension from fields or bare soils by local winds. When reported separately, road dust was included in the traffic source category in this study (Belis et al., 2013). Even though re-suspension of natural soils and road-dust emitted and re-suspended by vehicular traffic can be distinguished using markers of brakes, tires, and road wear, separating these two contributions may be challenging (Karagulian et al, 2015)

4. Conclusion

Based on the result obtained, it may be concluded that the most polluted area is MAM stadiun located centrally in Jammu, where the elevated concentrations of all the pollutants (RSPM, $PM_{2.5}$, NO_2 and SO_2) were observed in all seasons. Similarly lower concentration of al the pollutants were found at Narwal in almost all seasons.

The concentration of RSPM and $PM_{2.5}$ were observed to be highest in summers season all the three sites and lowest in monsoon season, whereas NO_2 and SO_2 concentration were found to be highest in winter season and lowest in monsoon season at all the sites.

The highest concentration at MAM stadium can be attributed mostly to local emission produced by high traffic density whereas observation of lowest concentration at Narwal is not unexpected as it a clean residential area with low traffic density.

Source apportionment carried out by PCA reveals major source as diesel and gasoline driven vehicles. At MAM, major sources are vehicular emission and Crustal re-suspension while vehicular emission and wood and leaf burning are the sources identified at Narwal. Three sources have been identified at Bari Brahman industrial area where emission from Diesel vehicles, coal combustion and crustal re-suspension played important role in the concentrations of pollutants.

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References

Adams, K., Greenbaum, D.S., Shaikh, R., Erp, A.M and Russel, A.G (2014). Particulate matter components, sources, and health: Systematic approaches to testing effects. Journal of Air and waste management, 65, 544-558.

Alias, M., Hamzah, Z. and Kenn, L.S. (2007). “PM10 and Total suspended particulates (TSP) measurements in various power stations.” The Malayasian Journal of Analytical Sciences, 11, 255-261

Amann, M., Purohit, P., Bhanarkar, A.D., Bertok, I., Borken-Kleefeld, J., Cofala, J., Heyes, C., Kiesewetter, G., Klimont, Z., Liu, J., Majumdar,D., Nguyen, B., Rafaj, P., Rao, P.S., Sander, R., Schopp, W., Srivastava, A., Vardhan, B.H (2017). Managing future air quality in megacities: a case study for Delhi Atmos. Environ. 161, 99-111.

Asrari, E., Ghole, V.S and Sen, P.N (2006). Study on the status of SO2 in the Tehran-Iran. Journal of Applied Sciences and Environmental Management, 10(2), 75-82.

Belis, C., Karagulian, L. Bo., P. Hopke (2013). Critical review and meta-analysis of ambient particulate matter source apportionment using receptor models in Europe. Atmospheric Environment, 69, 94-108

Burnett, C.A., Pope III, M., Ezzati, C., Olives, S.S., Lim, S., Mehta, H.H., Shin, G.,Singh, B., Hubbell, M., Brauer, H.R. Anderson, K.R., Smith, J.R., Balmes, N.G., Bruce, H. Kan, F., Laden, A., Prussustün, M.C., Turner, S.M., Gapstur, W.R., Diver, A Cohen (2014). An integrated risk function for estimating the global burden of disease attributable to ambient fine particulate matter exposure. Environment health Perspect. 10.1289/ehp.1307049

(http://en-climate-data.org/location/60044) climate data retrieved 29 Aug 2013)

Bruno, P., Caselli, M., Gennero, G., Traini, A., (2001). Source apportionment of gaseous atmospheric pollutants by means of an absolute principal component scores (APCS) receptor model. Fresenius' *Journal of Analytical chemistry*, 371, 1119-1123.

Chauhan, A., Pawar, M., Kumar, R., and Joshi, PC (2010). Aambient air quality status in Uttarakhand (India): A case study of Haridwar and Dehradun using Air Quality Index. Journal of American Science, 6(9), 565 – 568.

Chio, C.P., Cheng, M.T., Wang, C.F., (2004). Source apportionment to PM10 in different air quality condition for Taichung urban and coastal areas, Taiwan. *Atmospheric Environment* 38, 6893

Choudhary, S., Dey, S (2016). Cause specific pre mature death from ambient PM 2.5 exposure in India: estimate adjusted for baseline mortality. Environment International 91, 283-290.

CPCB (2011). Air quality monitoring, Emission Inventory, Source apportionment study for Indian cities. National summary, Central Pollution Control Board(CPCB), Ministry of Environment, forest and Climate change (MoEF &CC), New Delhi, India.

Dockery, D.W., Pope, C.A., 1993. Acute respiratory effects particulate air pollution. Annual Reviews of Public Health 15, 107-132

Fang, G-C, Chang, K-F, LuC, B.A, (2004). Estimation of PAHs dry deposition and BaP toxic equivalency factor (TEFs) study at urban , industrial park and rural sampling sites in Central, Taichung, *Chemosphere* 4, 55; 787-608

Gordan, t., Balakrishnan, K., Dey, S., Rajagopalan, S., Thurnburg, J., Thurston, G., Agrawal, A., Collman, G., Guleria, R., Limaye, S., Salvi, S., Kilaru, V., Nadukar, S (2018). Air pollution health research priorities for India: perpectives of the Indo –U.S. communities of researchers. Environmental International 19, 100-108.

Guo, H., Wang, T., Louie, P.K.K., (2004). Source apportionment of ambient non methane hydrocarbons in Hong Kong: application of a principal component analysis /absolute principal component source (PCA/APCS) receptor model. *Environmental Pollution* 129, 489-498.

Guo, H., Wang, T., Louie, P.K.K., (2004). Source apportionment of ambient non methane hydrocarbons in Hong Kong: application of a principal component analysis /absolute principal component source (PCA/APCS) receptor model. *Environmental Pollution* 129, 489-498.

Gupta, S., Kumar, K., Srivastava, A., Srivastava, A and Jain, VK (2011). Size distribution and source apportionment of polycyclic aromatic hydrocarbons (PAHs) in aerosol particles from the atmospheric environment of Delhi, India (2011). Science of the Total Environment, 409; 4674-4680.

Gupta. S., Kumar. K., Srivastava. A., Srivastava. A., and Jain. V.K (2011). Size distribution and Source apportionment Polycyclic aromatic hydrocarbons (PAHs) in aerosol particle samples from the atmospheric environment of Delhi, India. Science of the total Environment, 409, 4674- 4680

Guttikunda, S.K., Goel, R., Pant, P (2014). Nature of air pollution, emission sources, and management in the Indian cities. Atmospheric Environment. 95, 501-510.

Hallsall, C.J., Coleman, P.J., Davis, B.J., Burnett, V., Harding, J.P., Jones, K.D., (1994). Polycyclic aromatic hydrocarbons in U.K urban air. *Environmental ,Sciences and Technology* 28, 2380- 2386X.

Henry, R.C., Hidy, G.M., (1979). Multivariate analysis of particulate sulphate and other air quality variables by principal components – Part I. Annual Data from Los Angles and New York. *Atmospheric Environment* 13, 1581-1596.

Hung, H., MacLeod, M., Guardans, R., Scheringer, M., Barra, R., Harner, T., and Zhang, G. (2013). "Toward the next generation of air quality monitoring: Persistent organic pollutants." Atmospheric Environment, 80, 591-598.

Karar, K., Gupta, A.K., Kumar, A, and Biswas, A.K (2006). Seasonal variation of PM $_{10}$ and TSP in residential and industrial sites in an urban area of Kolkata, India. Environment Monitoring and Assessment, 118 (1-3) 369-381.

Khaiwal, R., Sokhi, R., Grieken, R., (2008). Atmospheric polycyclic aromatic hydrocarbons: Source attribution, emission factors and regulation. Atmospheric Environment 42, 2895-2921.

Mamta, P. and Bhasi, JK (2010). Analysis of ambient air quality using air quality index-A case study. International Journal of Advance engineering Technology I (II), 106-114

Marcazzan, G.M., Ceriani, M., Valli, G., Vecchi,R (2003) Source Apportionment of PM 10 and PM2.5 particulate matter in Milan (Italy) using receptor modeling. Science of total Environment; 317: 137-147.

McCornac, B.H., 1971. Introduction to the scientific study of atmospheric pollution – Reide Dordrect, Holland

Miller, S.L., Anderson, M.J., Doly, E.P., Milford, J.B., (2002). Source apportionment of exposure to volatile organic compounds, I. Evaluation of receptor model using simulated exposure data. *Atmospheric Environment* 36, 3629-3641.

Omar, N.Y.M.J., Abas, M.R.B., Ketuly, K.A., Tahir, N.M (2002). Concentrations of PAHs in atmospheric particles and roadside soil particles collected in Kaula Lumpur, Malaysia. *Atmospheric Environment* 36, 247-254

Orsini, C.Q., Tabacniks, M.H., Artaxo, P., Andrade, M.F., & Kerr, A.S (1986). Characterization of fine and coarse particles of natural and urban aerosols of Brazil. Atmospheric Environment, 20, 2259-2270.

Pant, P., Shukla, A, Kohli, S.D., Chow, J.C., Watson, J.G., Harrison, R.M (2015). Charcaterization of ambient $PM_{2.5}$ at a pollution hotspot in New Delhi, India and inference of sources. Atmosperic Environment. 109, 178-189.

Ravindra, K., S, Ameena, Kamyotra,J.S., Kaushik, C.P (2003). Variation in spatial pattern of criteria air pollutants before and during initial rain of monsoon. Environment monitoring and assessment 87, 145-153.

Sharma ,A & Raina, A.K (2012). Ambient air quality of Jammu City: A case study with reference to SO_2 and NO_2 content. International Journal of Environmental Sciences, 3. No.1 650-658.

Sharma ,A & Raina, A.K (2015). Ambient air quality of Katra Town (J&K): A case study with reference to SO_2 and NO_2 content. International Journal of Environmental Sciences, 6. 46-54.

Sharma, R and Parvej, S (2003). Seasonal variation of PM 10 AND SPM levels in ambient air around a cement plant Journal of Scientific and Industrial Research , 62, 827-833

Srivastava, A and Jain, V.K, (2007). Size distribution and source identification of total suspended particulate matter and associated heavy metals in the urban atmosphere of Delhi. *Chemosphere* 68, 579-587.

Srivastava, A., Gupta, S., Jain, V.K (2008). Source apportionment of Total Suspended Particulate Matter in Coarse and Fine size ranges over Delhi. Vol. 8 No.2 188-200.

Steven, J. (1996). c Applied multivariate statistics for behavioral sciences, 3rd edition. Eribaum, Majwah, NJ.

Thurston, G.D., Spengler, J.D.,(1985) A quantitative assessment of sourcecontributions to inhalable particulate matter. Pollution in Metropolitan, Boston. Atmospheric Environment 19, 9-25.

Venkataraman C., Brauer, M., Tibrewal, K., Sadaverte, P., Ma, Q., Cohen, A (2018). Source influence on emission pathways and ambient $PM_{2.5}$ pollution over India (2015-2050). Atmospheric chemistry physics. 18, 8017-8039.

WHO, Geneva (2014). Burden of Disease from Ambient Air Pollution for 2012, Description of Method, Version 1.3, The Global Health Observatory." Retrieved 01.03.2014,

S.No	No. vehicles registered upto 2016		No. of vehicles registered from 2016 to 2017 (Growth in a year)	
1	Light vehicles	33080	Light vehicles	38412
2	Medium vehicles	15619	Medium vehicles	17548
3	Heavy vehicles	40403	Heavy vehicles	42013
4	Two wheelers	282089	Two wheeler	301458
4	Others	19541	others	23541

Table 1. Source Regional Transport office Jammu

Site	Acronym	Site Character	Sampling period	No. of samples per month
MAM stadium	MAM	Heavy vehicular traffic	24 hr	8 samples per month
Narwal	NW	Residential	24 hr	8 samples per month
Bari Brahmana	BB	Industrial	24 hr	8 samples per month

Table 2. The characteristics of sampling sites

Pollutant	Time weighted average	Permissible limits (Concentration in µg/m^3)		
		Residential	Industrial	High traffic sensitive area
$PM_{2.5}$	24 hr	60	60	60
SO_2	24 hr	80	80	80
NO_2	24 hr	80	80	80

Table 3.1. National Ambient Air Quality Standards (CPCB)

Pollutant	Factor 1	Factor 2
RSPM	0 .89	0.52
$PM_{2.5}$	0.79	0.57
NO_2	0.90	0.46
SO_2	0.85	0.61
Eigen Value	8.98	2.1
Variance (%)	75.2	24.6
Cumulative (%)	75.2	69.0
Possible Source	Vehicular emission (Diesel+ gasoline)	Crustal re-suspension

Table 3.2.1. Varimax rotated factor loading matrix at MAM stadium

Pollutant	Factor 1	Factor 2
RSPM	0 .91	0.55
$PM_{2.5}$	0.99	
NO_2	0.93	0.60
SO_2	0.90	0.23
Eigen Value	7.5	2.8
Variance (%)	65.1	25.4
Cumulative (%)	65.1	89.0
Possible Source	Vehicular emission (Diesel+ gasoline)	Wood and dry leaf burning

Table 3.2.2. Varimax rotated factor loading matrix at Narwal (NW)

Pollutant	Factor 1	Factor 2	Factor 3
RSPM	0 .73	0.32	0.26
$PM_{2.5}$	0.82		0.21
NO_2	0.6	0.25	0.31
SO_2	0.73	0.21	0.20
Eigen Value	7.1	2.0	1.8
Variance (%)	60.2	28.5	11.5
Cumulative (%)	60.2	82.0	89.0
Possible Source	Vehicular emission (Diesel+ gasoline)	Coal combustion	Crustal Re-suspension)

Table 3.2.3. Varimax rotated factor loading matrix at Bari Brahmana

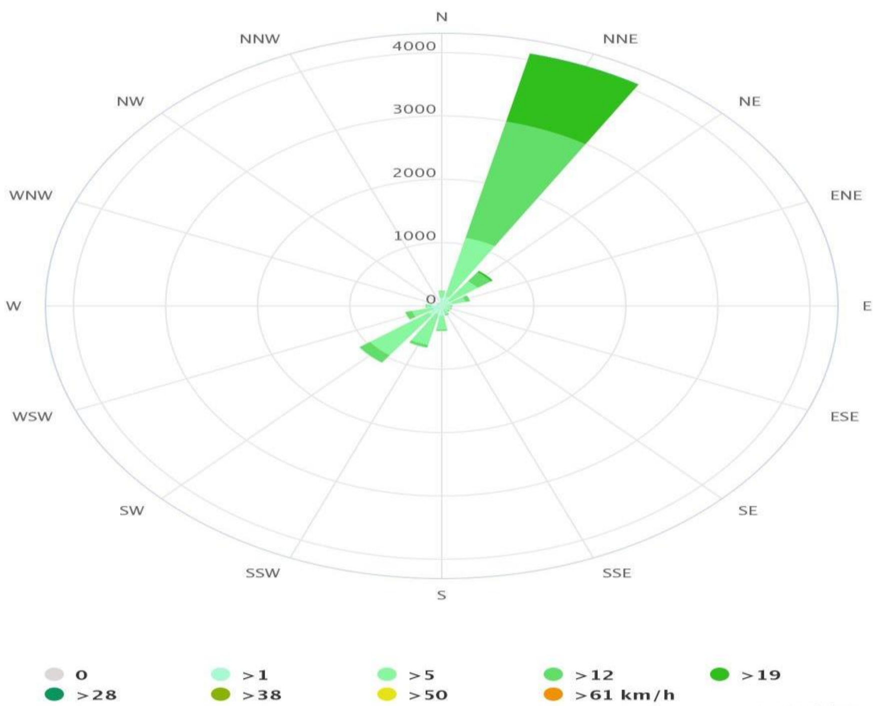

Fig. 2.The wind rose for Jammu shows how many hours per year the wind blows from the indicated direction

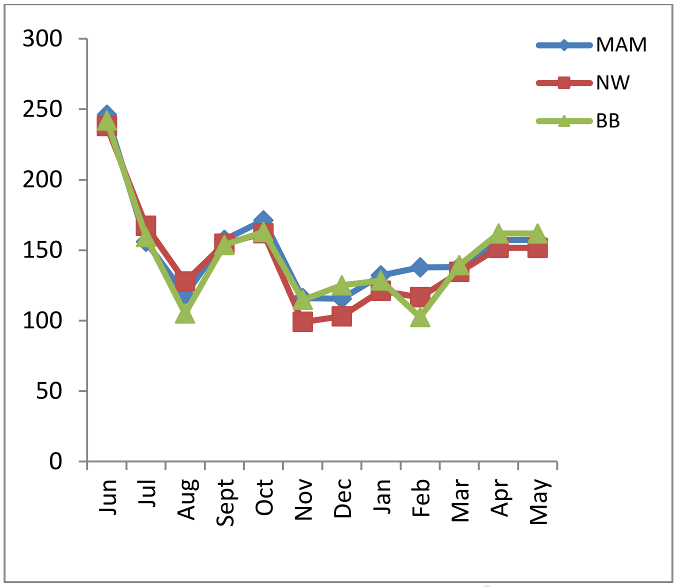

Fig. 3.1. Monthly average concentration (µg/m[3]) of RSPM at all the sites

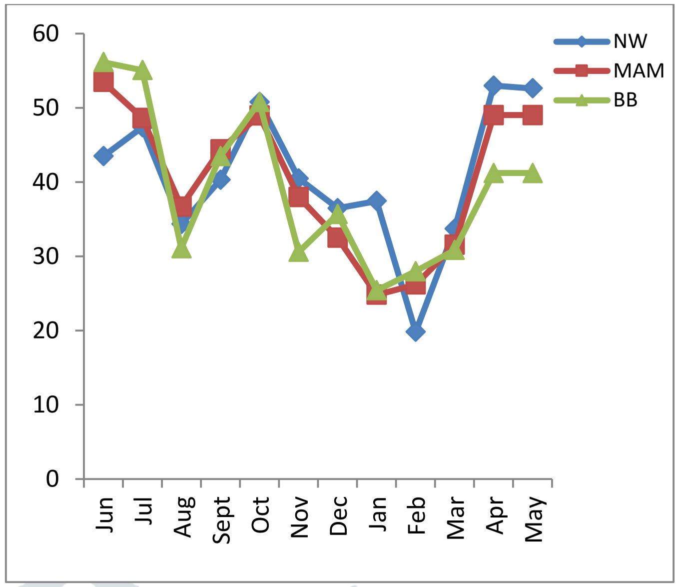

Fig. 3.2. Monthly average concentration (µg/m[3]) of $PM_{2.5}$ at all the sites

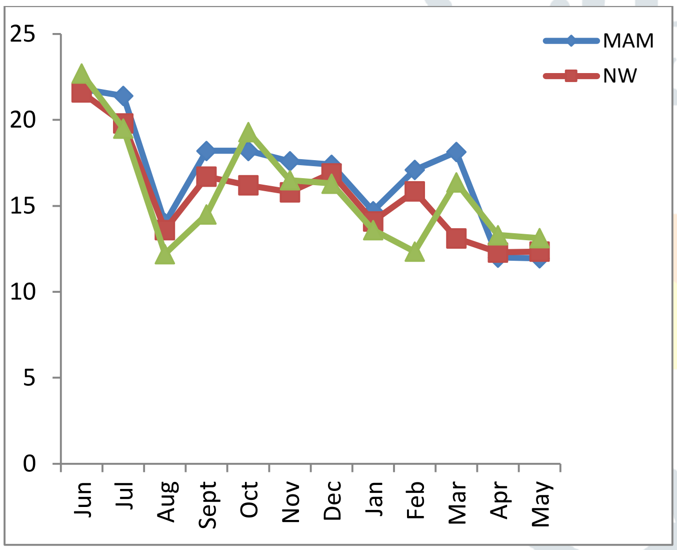

Fig. 3.3. Monthly average concentration (µg/m[3]) of NO_2 at all the sites

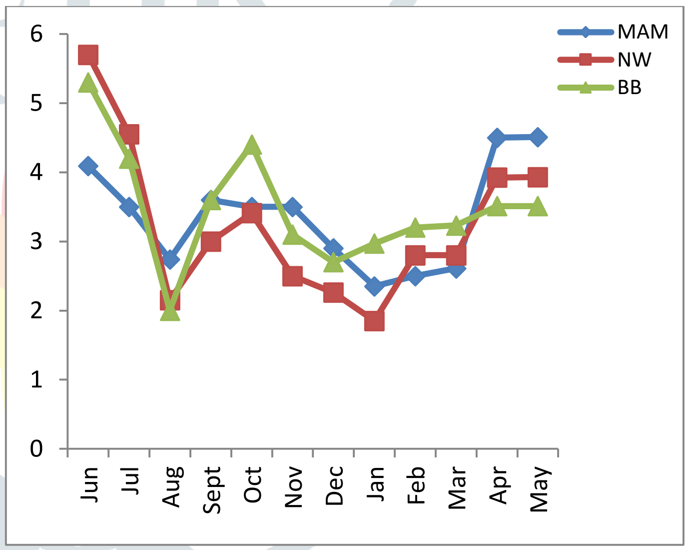

Fig. 3.4. Monthly average concentration (µg/m[3]) of SO_2 at all the sites

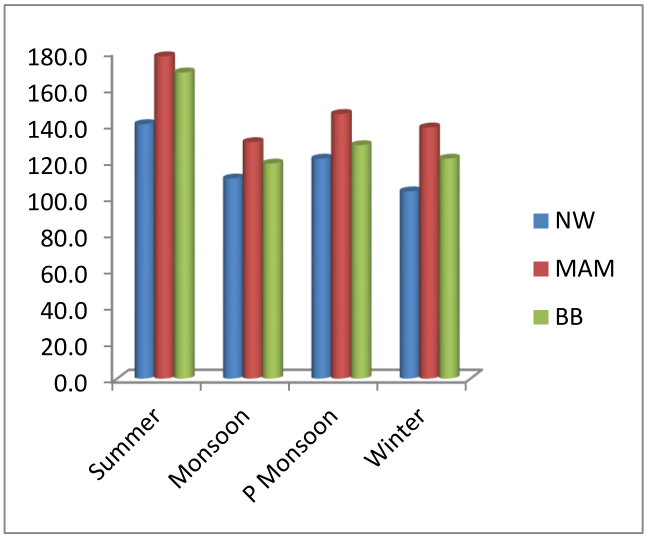

Fig.3.5. Average RSPM concentration (µg/m^3) at various sites in different seasons

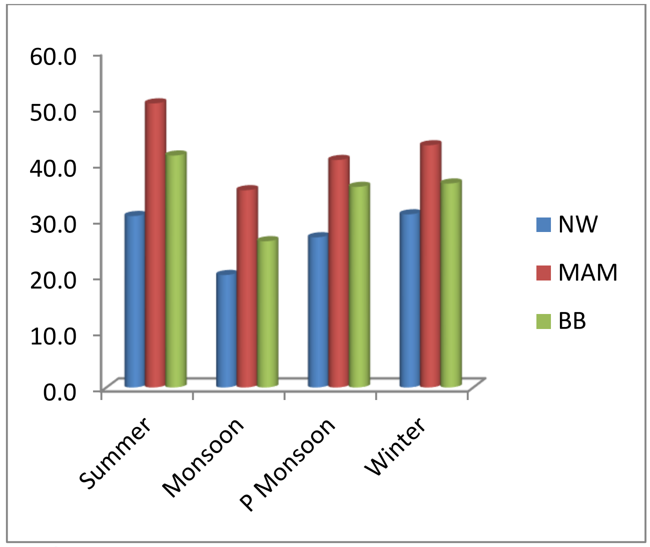

Fig.3.6. Average $PM_{2.5}$ concentration (µg/m^3) at various sites in different seasons

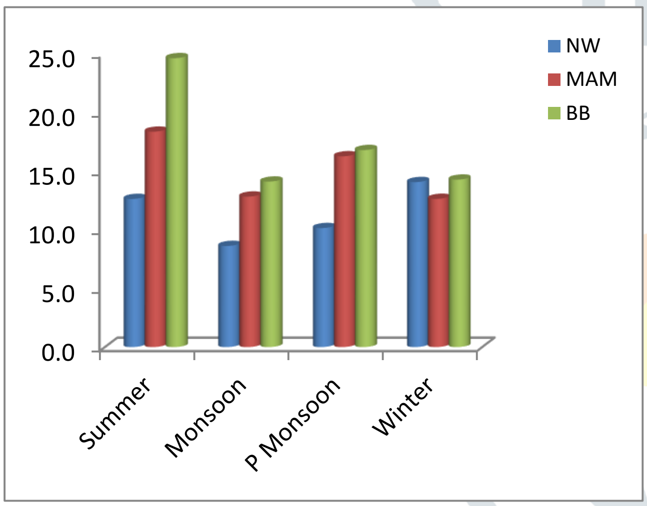

Fig.3.7. Average NO_2 concentration (µg/m^3) at sites in different seasons

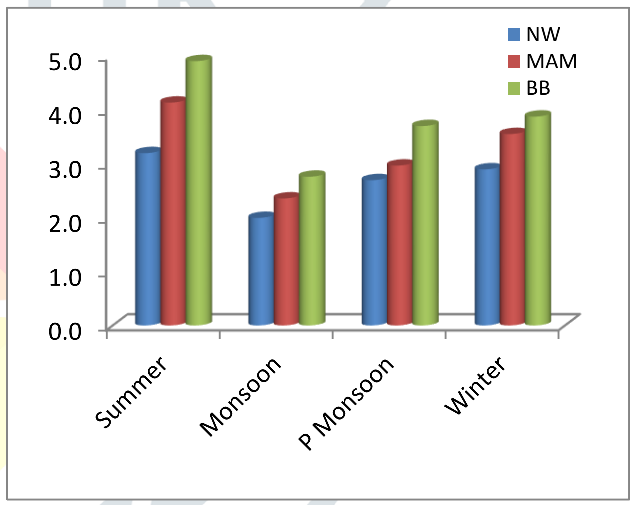

Fig.3.8. Average SO2 concentration (µg/m^3) various at various sites in different seasons