THREE YEAR STUDIES ON PARTICULATE MATTER (PM_{10} & $PM_{2.5}$) TRENDS IN INDUSTRIAL AREA GAJRAULA (U.P), INDIA.

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ABSTRACT

Gajraula is a town and Nagar Panchayat in Amroha District in the state of western Uttar Pradesh, India. It is having a large number of industries thus there is an urgent need of ambient air pollution monitoring in this industrial area as residents of this city are exposed routinely to this air and odour pollutants load in the local air environment. Air quality monitoring ($PM_{2.5}$ and PM_{10} collected) was done two times in a week using Respirable Dust Samplers (RDS) and Fine Particulate Sampler (FPS) at three sites industrial (S1), commercial (S2) and residential (S3), representing different areas of the Gajraula. The results indicate the annual and seasonal variations of PM_{10} and $PM_{2.5}$ from March 2014- February 2017. The highest value of PM_{10} and $PM_{2.5}$ (242µg/m^3, 138 µg/m^3) was recorded at commercial site i.e. Indra Chowk (in winter season 2017) while lowest value (122µg/m^3, 56µg/m^3) at Town Basti (in the monsoon season of 2014) respectively. Eight heavy metals i.e. Pb, Cd, Cu, Zn, Cr, Fe, Al and Ni were also observed at all the sites. Multivariate statistical analyses were adopted including; correlation, principal component analysis (PCA) and cluster analysis (CA) to identify the major sources of air pollutants in the industrial area. Among the metals highest concentration was recorded at S1 and S2 (Raunaq Auotomotive and Indra Chowk) and lowest at S3 (Town Basti). Commercial site (Indra Chowk) is located nearby Jubilant Life Sciences, TEVA and railway station as traffic density remains high during the day and night.

Key words: Particulate matter (PM_{10}, $PM_{2.5}$) pollution trends, Trace metals, Seasonal trend, Statistical analysis (correlation, PCA, CA)

INTRODUCTION

Air pollution is worsening due to upward trends in power consumption, industrialization, vehicle use and scores of other developmental activities taken up by human beings (Cheng *et al.,* 2013 and Contini *et al.,* 2010). It has been estimated that vehicular pollution is the primary cause of air pollution in the urban areas (60%), followed by industries (20-30%) in India (Alharbi *et al.*, 2015). There are five major harmful substances released into the atmosphere in sufficient quantities as a result of natural events or by human activities. They are carbon monoxide, hydrocarbons, particulates, sulphur dioxide and nitrogen compounds (Wang *et al.,* 2013 and Popovicheva *et al.,* 2014b).

The sources of Particulate Matter can be divided into two categories i.e. Natural and anthropogenic, Natural sources –include soil dust, biological debris from natural precursors, organic matter from bioorganic volatile organic carbon (voc) etc while anthropogenic sources include industrial dust soot from fossil fuels, soot from biomass combustion, sulphates and nitrates from SO_x and NO_x respectively (Givehchi *et al.,* 2013 and Tiwari *et al.,* 2013).

Airborne pollutant such as Respirable Suspended Particulate Matter (PM_{10} and $PM_{2.5}$) is considered as a worldwide concern because they are associated with serious human health affects i.e. chronic, respiratory problems and mortality (Kumar *et al.*, 2015). The coars fraction (PM_{10}), consisting of particles with an aerodynamic diameter of up to 10µm, usally spends no more than a few hours suspended after emission before being removed from the atmosphere by sedimentation or precipitation processes, whereas the fine particles, of 2.5µm diameter ($PM_{2.5}$) or less (PM_1). Analysis of heavy metals from particulate matter (PM_{10}) find out by International Agency of Research on Cancer, most of the heavy metals are harmful to human, and some even have the carcinogenic effect. Pb and Cd are known to have the adverse effect on cardiovascular health where as the Cr, Cu and Zn are the important nutrients of food but inhalation of these metals may damage the lungs (IARC, 2013). Studies revealed that the current level of atmospheric particulates may have serious effect on health, especially in some urban and industrial areas (Tau *et al.*, 2013) due to the presence of heavy metal in it.

Thus, the objective of this study was to identify the possible source and determination of Particulate Matter (PM_{10} and $PM_{2.5}$) the concentration of heavy Metals (Pb, Cd, Cu, Zn, Cr and Ni) in respirable dust (PM_{10}) during summer and monsoon season at all sampling sites (Bourotte *et al.*, 2011). In this paper, therefore, efforts have been made to analyze and determine the present level of Suspended Particulate Matter and their trace metal contents in the industrial city Gajraula in Western U.P. India, over the three year period, i.e. 2014-2017 (Terzi et al., 2010).

MATERIALS AND METHODS

Gajraula is a town and Nagar Panchayat in Amroha district in the state of Uttar Pradesh, India; it is located on NH-24, 4-lane highway connecting Lucknow and Delhi and at latitude 28.85 N and longitude 78.23 E. It has an average elevation of 257 meters (879 feet). According to Indian census, 2011 Gajraula had a population of 55048. Due to establishment of a large number of industries there is an urgent need of ambient air pollution monitoring in Gajraula industrial area. Various types of Industries such as Chemicals, Fertilizers, Pesticides, Insecticides, Sugar Plants, Paper mills and Automobiles are located over here. Now people have started to take serious note of ill effect of particulate matter, therefore detailed study and control measures are required to amount the ill health effects.

Site Selection

Raunaq Automotive (S1): It is a Automotive Industry and the site is established on the roof of the building of this Industry located near NH-24.

Indra Chowk (S2): It is a residential area having commercial activities. A large number of shops and workshops are situated near this site and the distance of Gajraula railway station is 500 meters.

Town Basti (S3): This site is located in southern part of the city and around 2 km away from the Railway station. It is low density residential, agriculture based area and almost free from pollution.

Sampling and Analysis of Particulate Matter

Standard Gravimetric method of respirable dust sampling was used to measure the mass concentration of PM_{10} and $PM_{2.5}$. The instrument employed was respirable dust sampler (RDS) (Envirotech, New Delhi: APM-460). The operating flow rate of the machine is 0.8-1.2 m^3 min^{-1} with minimum detectable concentration of 1µg/m^3 (CPCB, 2015).

Gravimetric method was also used for the measuring the mass concentration of $PM_{2.5}$. The instrument employed was fine particulate matter (FPS) (Envirotech, New Delhi, Model: APM-550). The operating flow rate for the machine is depending on dry gas meter (DGM). This separates particulate with larger diameter. The particle fraction of 10-2.5µm diameter was separated at an impector surface of glass fibre filter (Whatman GF/A 37 mm dia) wetted with silicon oil. The $PM_{2.5}$ fraction escaping the impactor was collected on a Teflon membrane filter (Whatman of 47 mm dia). Dividing the difference between initial and final weight of the Teflon membrane filter by the total volume of air sampled gives the mass concentration for $PM_{2.5}$ (CPCB, 2015). All gravimetric measurements were taken precisely in a digital balance (Sartorius, Model: TE214S Max= 210g and d= 0.1M/g).

Analysis of Heavy Metal

A known portion of the fiber filter paper was covered by particulates digested by nitric acid and perchloric acid on a 140^0C hot plate. Residues were then re-dissolved by 0.1m hydrochloric acid and a blank was also prepared using the same area of unexposed glass fiber filter paper and by treating the same procedure. These were cooled, filtered and made to 50 ml by distilled water. Concentrations of heavy metals were analyzed by Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES; Spectro Analytical Instruments, West Midlands, UK) from samples collected for each site (Pal *et al.*, 2014).

QUALITY CONTROL

The quality control, during the filter paper numbering, pre conditioning, weighing, handling, monitoring, post weighing and recording was the thrust. For maintaining the quality control all instrument used during monitoring such as balance, Respirable dust sampler (RDS), fine particulate sampler (AFPS), Gas leakage checker, Plasma-Optical Emission spectrophotometer were calibrated on regular interval and recorded. The instruments performance check, data validation, temperature, humidity control and standard monitoring protocol were followed at all stages. The complete analytical procedures were provided by central pollution control board, Delhi. For analysis of heavy metal absorbing solution were store in amber color bottle and fresh solution were prepared once in every week. The outlier values have been removed during the validation of data and recording.

RESULTS AND DISCUSSION

The experimental investigation on air pollution with special reference to annual average of particulate pollutants revealed that the PM_{10} and $PM_{2.5}$ over Gajraula were reported just above the permissible limit sponserd by CPCB, MoEF (CPCB, 2015) in Commercial Area (S2) and Industrial Area (S1) whereas near the limit in residential area (S3) (Khodeir et al., 2012). The data was analyzed to study the seasonal variation of PM_{10} and $PM_{2.5}$ and the season wise classification of months adopted for the study is as follows: (i) Summer (March-June), (ii) Monsoon (July- October) and (iii) Winter (November- February). The lowest concentration was recorded at Town Basti (S3) in all the seasons and for all the years when compared to other areas. The PM_{10} and $PM_{2.5}$ concentration is very high in winter season and lowest in Monsoon season. The minimum concentration was found at Town Basti in the monsoon season of 2014-15 and it may be due to washout effect of this season while the maximum concentration at Indra chowk in the winter season of 2016-17 in table 1.

Particulate matter contributes to air pollution as size of these suspended particles directly linked to their potential for causing several health problems mainly respiratory diseases. An analysis of the data of the year 2016-17 in Fig. 1 shows that lowest concentration at S3 the range of PM_{10}

concentration was found between 34-312µg/m^3 with a yearly average of 178µg/m^3 and highest concentration at S2 the range of PM_{10} concentration was found between 64-495µg/m^3 with a yearly average of 206µg/m^3. Comparision with national ambient air quality standard we were found that the concentration of PM_{10} 2 to 3 times higher at S1, S3 and 3-4 times higher at S2.

Analysis of the data of the year 2016-17 for $PM_{2.5}$ shows the lowest concentration at S3. The range was found in between 18-145µg/m^3 with a yearly average of 87µg/m^3 while the highest concentration was found at S2. The range in between 34-225µg/m^3 with a yearly average of 117µg/m^3. While compressing with national ambient air quality standard the concentration of $PM_{2.5}$ 2 to 3 times higher at S1, S3 and 3-4 times higher at S2 in Fig 2.

Heavy metal such as Pb, Cd, Cu, Zn, Cr, Fe, Al and Ni concentration for the year of 2016-17 was also observed in PM_{10}. Annual mean and their standard deviation are presented in Table 2 and are reported in ng/m^3. Among the three monitoring sites, the highest concentration of Pb (973 ng/m^3), Cd (615 ng/m^3), Zn (1711 ng/m^3), and Ni (97 ng/m^3) are reported at S2, and Cu (812 ng/m^3), Cr (607 ng/m^3), Fe (2950 ng/m^3), Al (2673 ng/m^3) at S1 which falls in commercial area and industrial area due to Jubilant life science, Raunaq Automotives and many other kind of industry i.e. such as paper mills, milk Industry, Teva, Sugar industry and traffic density on NH-24 Line Highway as well as railway station.

Correlation coefficient (Table 3) of heavy metal concentration in PM_{10}: The Pearson's correlation coefficient (r) was calculated from the elemental concentration in order to predict the possibility of a common source of PM_{10}. The significant positive correlation was found between Pb-Cd (r=0.970), Pb with Zn (r=0.996) and Ni (r=0.990), Cd with Zn (r=0.987) and Ni (r=0.995), Cu with Fe (r=0.987) and Al (r=0.972), Zn with Ni (r=0.998), Cr-Al (r=0.923) and Fe with Al (r=0.982) in the year March 2016 to February 2017, respectively. Similarly, moderate positive correlation were found between Pb with Cr (r=0.726), Cd with Cr, Fe and Al (r=0.866, 0.534 and r=0.608), Cu- Cr (r= 0.823), Zn- Cr (r=0.779), Cr with Fe and Ni (r= 0.878 and r=0.814) and Al with Ni (r=0.531) during same duration of year. It may be due to the industrial and anthropogenic activities like vehicular emission and burning of industrial activity. There were also found non significant correlation between Pb- Al (r=0.410), Cd with Cu (r=0.432), Zn- Al (r=0.481) and Fe- Ni (r=0.450) in a complete year of 2016-2017. Based on the correlation study, it may be concluded that Pb, Cd, Cu, Zn, Cr, Fe, Al and Ni were contributed by some common sources, probably by stack of industries, vehicular and anthropogenic sources etc.

The principal application of factor analysis is to reduce the number of variables. This method focuses on cleaning up the factors. PCA (principal component analysis) was applied to determine the correlation between pollutants and to identify the source profile of heavy metals in PM_{10} (Table 4). The results of PCA that was performed to identify common sources of heavy metals with their variance in PM_{10} during one year sampling time. PCA results of trace metals in PM_{10} for last one year showed three factors accounting for 99.942 % of the overall variance. Factor 1 had high loadings for Pb, Cd, Zn and Ni which explained 74.576 % of the total variance. This factor is associated with Industries and traffic emission (Chang et al., 2009). Thus, factor 1 can be identified as mixed sources of industrial activities (such as burning and heating Boiler in Industries, Boiling of Stack and Production on the basis of Acid Base reaction) and traffic emissions. Factor 2 explained 25.178% of the total variance and correlated with high loadings on Cu, Fe and Al. This factor represented the use of Cu and Zn for molding purpose in making brassware items and other utensils. Another possible source of Zn and Cu is road traffic (diesel engine and wearing of brakes). Factor 3 explained 0.188% of the total variance mainly derived from the rural activities.

Most of the industrial emissions from Indra Chowk (around 500 meter distance industry and traffic interceptions) were adjoining residential area of the city and this exposing the urban and rural population released from the industries. Another interesting finding of the present study is that Fe and Zn have several sources in the rural atmosphere of Gajraula Nagar Panchayat, as these elements revealed strong significant loading to almost all the PCs. The cluster of Cd and Pb is fairly weak, supporting the above statement. The PCA findings are in agreement with the CA results (Fig. 4)

CONCLUSION

Assessment of air quality monitoring data around industrial areas showed significant spatial and seasonal variations in concentrations of PM_{10} and their heavy metal content depending on pollutant emission or formation and pollutant dispersion mechanisms, which are also influenced by meteorological conditions. Wind speed, relative humidity, temperature and rainfall were the governing parameters of seasonal variations in air pollutant concentrations in the area (Tao et al., 2014). Overall site specific assessment of PM_{10} and $PM_{2.5}$ data represent that Indra Chowk is the most polluted area in terms of particulate matter with highest mean concentration of 206 and 117μgm^{-3} during the year 2017 and lowest at Town Basti 177 and 87μgm^{-3}. The concentration of PM_{10} in winter was found higher than monsoon. The PC I for summer (74.576%) is characterized by Pb, Cd, Zn and Ni which represents Industrial activities, anthropogenic activities and road traffic. The PC II (25.178%) is associated with Industrial activities along with road traffic (i.e. Cu, Cr and Al). The PC III i.e. 0.188% is identified as agricultural activity. So industrial activities, wind-blown dust, traffic emission as well as anthropogenic activities are the major causes of air quality deterioration of Gajraula Industrial area. The outcome of this study may provide a comprehensive catalogue for outlining a proper scheme for required mitigative or preventive measures are the other causes of air quality.

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