IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 12, Issue 9 Ver. I (September. 2018), PP 16-23
www.iosrjournals.org

Investigation of PM_{10}, $PM_{2.5}$ and PM_1 during Pollution Episodes: Fog and Diwali Festival

AnkitaMangal,AparnaSatsangi, Anita Lakhani, K. MaharajKumari*
Department of Chemistry, Faculty of Science, Dayalbagh Educational Institute, Dayalbagh, Agra 282005, UP, India
**Corresponding author:K. MaharajKumari*

Abstract: *The present study focuses on the high loading of PM_{10}, $PM_{2.5}$ and PM_1 mass during the episodic events i.e. Diwali and fog at the campus site of Dayalbagh Educational Institute, Agra. During Diwali the mass concentration for PM_{10}, $PM_{2.5}$ and PM_1 were 2.8, 4.7 and 6.8 times higher than the mass observed during normal days due to burning of firecrackers. In addition, trace gas (O_3, NO_2 and CO) levels were also high during Diwali. During the fog event also high mass concentration of PM_{10}, $PM_{2.5}$ and $PM_1$was observed probably due to less dispersion of pollutants as a consequence of low mixing height, low temperature and high relative humidity. On the basis of correlation analysis and HYSPLIT backward trajectories high mass concentration during the two pollution episodes may be mainly attributed to firecrackers during Diwali and anthropogenic activities and local meteorological condition during fog.*
Keywords:*Pollution episodes; PM_{10}; $PM_{2.5}$; PM_1; O_3; Fog; Diwali*

Date of Submission: 21-08-2018 Date of acceptance: 04-09-2018

I. Introduction

Particulate matter (PM) exerts a serious effect on visibility, climate and human health (Li et al., 2015). PM emissions originate from industries, vehicles, re-suspended soil dust etc. (Nishanth et al., 2012). Various primary and secondary sources affect the levels of aerosols and other pollutants at a particular site, however, sudden increase in emission sources and/or favorable meteorological conditions may lead to episodic levels of pollutants resulting in poor air quality.

Fog is composed of tiny water droplets of micrometers size (Herckeset al., 2007) having high concentration of fine particles such as $PM_{2.5}$ and PM_1. They act as condensation nuclei to enhance the condensation of water vapor and increase the growth of the fine particles (Liu et al., 2016). Studies conducted in Indo Gangetic Plain (IGP) and other regions report high concentrations of particulate matter and their chemical constituents (water soluble ions, Polycyclic Aromatic Hydrocarbons (PAHs), Organic Carbon (OC) and Black Carbon (BC) and metals) during fog (Singh and Gupta, 2016; Agarwalet al., 2017).

Diwali is celebrated in India byburning fire crackers for 5 days. This deteriorates the ambient air quality resulting in serious health effects(Pervez et al., 2016) and reduction in visibility. Several studies report high emissions from fireworks during festivals like New Year celebrations (Zhang et al., 2010), Lantern festival in China(Tsai et al., 2012) and Diwali festival in India (Chatterjeeet al., 2013). Firecrackers are composed of a mixture of many metals and release thick layers of smoke during combustion. Higher concentrations of trace metals in ambient PM_{10} and $PM_{2.5}$ have been reported by many researchers (Sarkaret al., 2010;Tsai et al., 2012). In Lucknow, elevated levels of PM_{10} were observed during Diwali days in comparison to normal days (Barman et al., 2008). Burning of crackers releases pollutants like SO_2, O_3, NO_2, CO_2, CO, etc. that causes serious health hazards (Attriet al., 2001; Pachauriet al., 2013).

The present study investigates emissions of PM_{10}, $PM_{2.5}$, PM_1 and trace gases during these major episodes.

II. Methodology

Sampling site: Agra (27.16ºN, 78.08ºE) lies in Uttar Pradesh in North-central part of India. Climate of Agra is semi-arid type and two-thirds of its boundary is surrounded by Thar Desert of Rajasthan. Sampling was done on the roof of Science Faculty building of the Institute (Fig. 1). It is situated in a sub-urban location of Dayalbagh. The road connecting the institute to the rest of the city has a vehicular density of about 10^4 vehicles per day. Agra is hot and dry during the summer with temperature and RH in the range of 25°C to 47°C and 14 to 50% respectively. However, during winter the weather is cold with low temperature (as low as 3°C) and high RH (23 to 90%). The detailed description of the site has been discussed elsewhere (Vermaet al., 2017a).

Figure 1: Map of sampling site (shown by star) at Dayalbagh Educational Institute, Agra, India

Sampling: Sampling for different pollution events was done during October (Diwali) and December 2016 to January 2017. 18 samples were collected for different episodes which were divided as: 5 during Diwali (including pre and post- Diwali days) and 8 for foggy and 5 for non-foggy days. Foggy and non-foggy days were classified on the basis of relative humidity (> 80%)(Agarwalet al., 2017).

PM_{10} and $PM_{2.5}$ samples were collected using Fine Particulate Sampler (Envirotech APM 550) operating at a constant flow of 16.6 liter per minute on pre-weighed 47 mm quartz fiber filters (Pallflex, Tissuquartz) and PM_1 samples were collected by using PM_1 particulate sampler Envirotech (APM 577) operating at a flow rate of 10 liter per minuteon a pre- weighed 47 mm quartz fiber filter (QM-A). Filters were pretreated in a muffle furnace at 800°C for 4 hour and for removal of organic impurities filters were desiccated for 24 hour. Before weighing, the filters were equilibrated in a desiccator for 24 hour to avoid the effects of humidity on gravimetric mass and then weighed on an electronic microbalance (Mettler, Toledo). The mass concentration of PM was obtained from the difference of weights of the filters.

In-situ measurements of O_3, NO_2 and CO were also recorded using continuously operating analyzers. The detailed description of the measurements has been discussed elsewhere(Vermaet al., 2017b) Meteorological data (Temperature (T), Relative Humidity (RH), Wind Speed (WS) and Wind Direction (WD) was recorded at the present site using Automatic Weather Station WM271 Data Logger at every 1 hour interval. Air-mass back-trajectories were simulated using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model (Draxler and Hess, 2004).

III. Results and Discussions

PM_{10}, $PM_{2.5}$, PM_1, CO, NO_2 and O_3during Diwali: Fig. 2 shows the variation in concentrations of PM_{10}, $PM_{2.5}$, PM_1, O_3, NO_2 and CO during Diwali (31.10.16), pre- Diwali (28.10.13) and post-Diwali (3.11.16). High levels of $PM_{10,}$ $PM_{2.5,}$ PM_1 and trace gases were observed during Diwali. The mass concentration for PM_{10}, $PM_{2.5}$ and PM_1 was 280µg/m^3, 260µg/m^3 and 240µg/m^3, respectively during Diwali days, however, 3 days before Diwali the mass concentration for PM_{10}, $PM_{2.5}$ and PM_1 was 100µg/m^3, 55µg/m^3 and 35µg/m^3, respectively while after 3 days it was 80 µg/m^3, 60 µg/m^3 and 50 µg/m^3 respectively (Fig. 2a). As a result of huge amount of firecracker burnt on Diwali day, PM_{10}, $PM_{2.5}$ and PM_1 were 2.8, 4.7 and 6.8 times higher than the mass concentration on normal day. Similar results were reported by Rao et al. (2012) at Nagpur in which they observed 2-3 times increase in mass concentration of PM_{10} and $PM_{2.5}$ during Diwali, $PM_{2.5}/PM_{10}$ ratio shows a gradual increase (varied from 0.5 to 0.9) from pre-Diwali to day after Diwali signifying dominance of fine particulate loading. Similar variation in $PM_{2.5}/PM_{10}$ ratio during Diwali has been reported earlier by Kumar et al. (2016) at Pune, Mumbai and Varanasi.Mass concentration of fine particles increase as the burning of crackers and sparkles during late evening and night causes increased emissions of metal oxides, metal salts and other inorganic species from firecrackers. In addition gas to particle conversion also causes loading of $PM_{2.5}$ particulates. To determine the sources of different particle size, correlation analysis was done between PM_{10}, $PM_{2.5}$ and PM_1 and the correlation coefficient was more than 0.9 indicating that the sources were similar. High PM levels can be attributed to fire cracker emissionsfavored by stable meteorology, as the average wind speed was 0.43 m/s and the average relative humidity was 60% during Diwali.

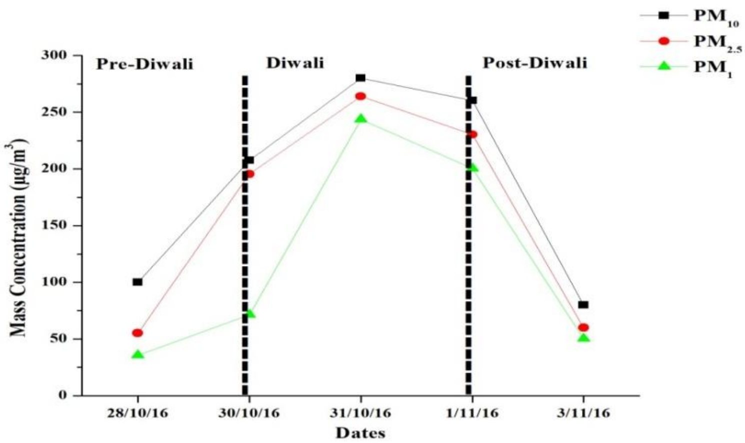

Figure 2 (a): Variation in PM mass concentration during Diwali

The enhancement in the PM mass concentrations during Diwali and their elevation times in the present study have been compared with the other locations in India and other fireworks festivals outside India (Table 1). PM_{10} concentration in the present study (280 µg/m^3) was found comparable (249 µg/m^3) with Tianjin, China (Tianet al., 2014) during New Year celebration and was slightly higher (223 µg/m^3) than those obtained at Hissar (Ravindra et al., 2003) during Diwali. $PM_{2.5}$mass concentration at the present site (264 µg/m^3) was similar to the concentration (271 µg/m^3) at Nagpur (Rao et al., 2012) during Diwali and higher than the concentration at China during New Year (165 µg/m^3; Tianet al., 2014) and Spring Festival (112 µg/m^3; Feng et al., 2016) and at Taiwan during Lantern Festival (112 µg/m^3; Tsai et al., 2012) respectively.However $PM_{10}$and $PM_{2.5}$ concentration at the present site were lower than those observed at Raipur (Nirmalkar et al., 2013) and Delhi (Tiwari et al., 2012) during Diwali. PM_1 concentration (243 µg/m^3) was comparable to the concentration (210 µg/m^3) at Raipur (Nirmalkar et al., 2013) during Diwali and concentration was lower than that observed at Delhi (Tiwari et al., 2012) during Diwali.

Table 1 Ambient PM concentrations (µg/m^3) reported during fireworks and their elevation times relative to non-fireworks period and their comparison with present study

Type of Festival	Site	Concentration			Elevation times			References
		PM_{10}	$PM_{2.5}$	PM_1	PM_{10}	$PM_{2.5}$	PM_1	
Diwali	Sector 15, Hissar	223	NR	NR	1.4	NR	NR	Ravindra et al. 2003
Diwali	NEERI, Nagpur	930	271	NR	2.0	2.0	NR	Rao et al. 2012
Diwali	Delhi	723	588	536	NR	NR	NR	Tiwari et al. 2012
Diwali	Raipur	555	395	210	2.6	3.0	4.6	Nirmalkar et al. 2013
Lantern Festival	Taiwan	NR	112	NR	NR	2.1	NR	Tsai et al. 2012
New Year	Tianjin, China	249	165	NR	1.9	1.8	NR	Tian et al. 2014
Spring Festival	Xinxiang, China	NR	112	NR	NR	NR	NR	Feng et al. 2016
Diwali	DEI, Agra	280	264	243	2.8	4.8	6.9	Present study

O_3 is a secondary pollutant which is photo-chemically formed from its precursors in the presence of sunlight. Fig. 2b and c shows diurnal variation of O_3, NO_2 and CO on normal day (3 days before and after Diwali) and Diwali day. During Diwali the concentration of NO_2 and CO were high during day as well as night than normal day. These high levels of CO may be attributed to burning of firecrackers which are composed of chemicals like potassium nitrate and carbon compounds (Holmes, 1983), therefore, when these firecrackers are burnt carbon monoxide and nitrogen oxide are released. O_3 follows a characteristic pattern; its concentration is high during sunlight hours and low during night. During Diwali, it followed the similar pattern characterized by high levels during day hours from 12:00 h to 18:00 h and was found maximum at 17:00 h (100 ppb). On this day, O_3 concentration was 1.3 times higher during day time than normaland 2-3 times higher during night. The high levels of O_3 during Diwali may be due to photochemical generation of O_3 from high levels of CO and NO_2 during pre-Diwali days due to metals present in firecrackers which emit UV radiation and these high energy UV radiations are absorbed by O_2 which generates atomic oxygen which on combination with O_2 and forms O_3 (Attriet al., 2001). Yadav et al. (2016) also reported an increase in O_3 and its precursors during Diwali.

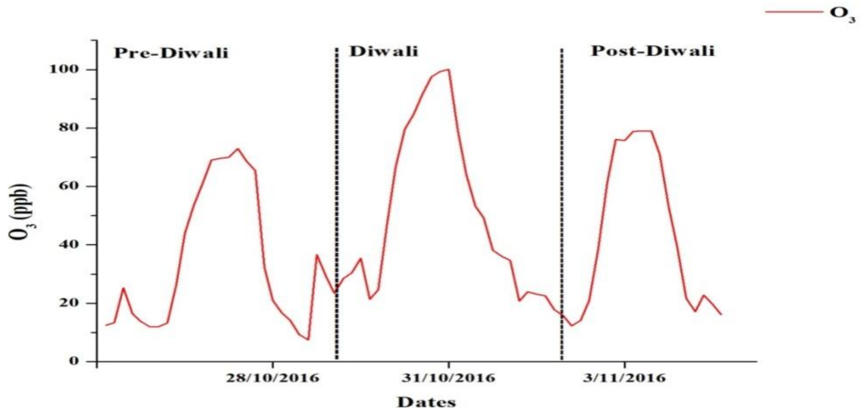

Figure 2 (b): Variation in O_3 concentration on pre- Diwali, Diwali and post- Diwali day

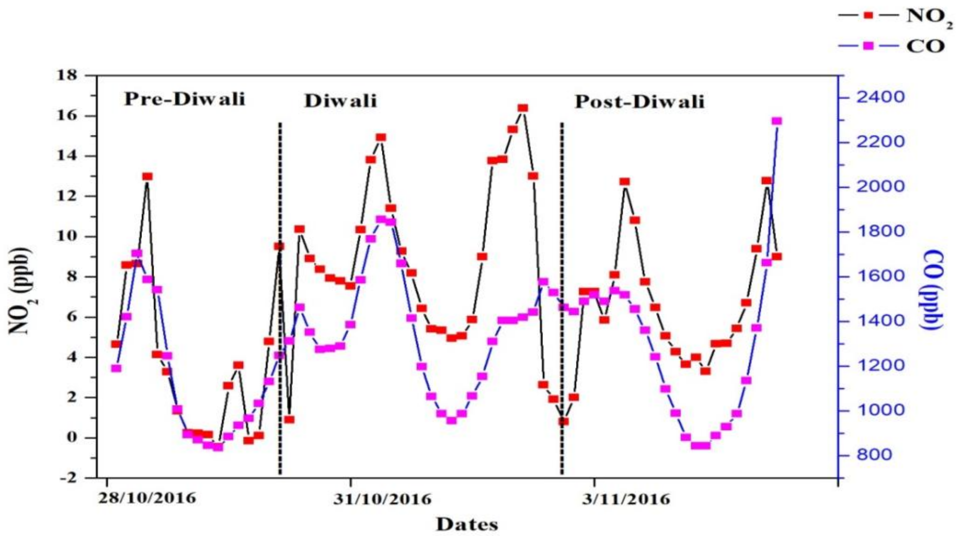

Figure 2 (c): Variation in NO_2 and CO concentration on pre- Diwali, Diwali and post- Diwali day

Air mass backward trajectory was determined using HYSPLIT to identify the path of transport of air mass (Fig. 3). The backward trajectory was plotted for day before Diwali and Diwali day. These trajectories were short and follow the same path during both days which suggests that high levels were not due to long range transport and were due to emissions from firecrackers.

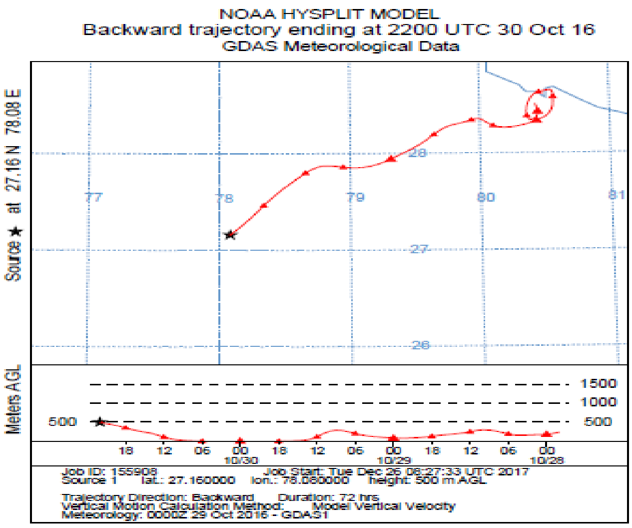

Figure 3 (a): Air mass back trajectory duringday before Diwali

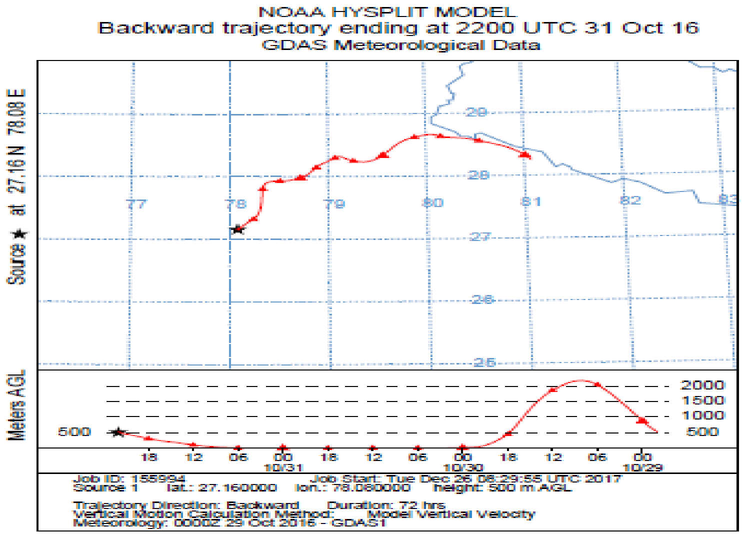

Figure 3 (a): Air mass back trajectory duringDiwali day

PM_{10}, $PM_{2.5}$ and PM_1 concentration during foggy events: Fig. 4 shows variation in average mass concentration of PM_{10}, $PM_{2.5}$ and PM_1 during foggy and non-foggy events. During foggy days the average concentration for PM_{10}, $PM_{2.5}$ and PM_1 was 290±62µg/m^3, 208±59µg/m^3 and 158±40µg/m^3 respectively and was 1.9, 2.0 and 2.3 times higher than non-foggy days. During non-foggy days the average concentration for PM_{10}, $PM_{2.5}$ and PM_1 was 149±12µg/m^3, 100±25µg/m^3 and 67±15µg/m^3 respectively. PM_{10} concentration was more than 2 times higher than the standard NAAQS value of 100µg/m^{3}and $PM_{2.5}$ was more than 3 times the standard NAAQS value of 60µg/m^3 (CPCB 2009).The high levels of particulate matter during foggy events may be attributed to low temperature, high humidity and accumulation due to low mixing layer height. During winter season, when temperature reached near dew point, the excess of water vaporin air condenses to form fog.The high relative humidity favors this process and forms an aqueous layer over aerosol particles which help the aerosol particles in scavenging water soluble gases. The low wind speed and low mixing layer height hinders dispersion of fog. Several studies (Li et al., 2015; Singh and Gupta, 2016; Agarwalet al., 2017) report that high mass concentration during fog period is associated with stagnant condition, low temperature, low wind velocity, high relative humidity and low solar heating of earth surface which results in slower dispersion of particulate matter and decrease in the boundary layer height (Agarwalet al., 2017). The average wind speed was 0.8±0.6 m/s and the average relative humidity was 81±11%. Fog formation takes place when the hygroscopic aerosols in the atmosphere act as cloud condensation nuclei on which water vapor condenses (Singh and Gupta, 2016). High PM mass concentration during foggy period may be attributed to an increase in accumulation mode particles as reported earlier by Gupta and Mandaria (2013). Low wind speed results in stagnant conditions which slow down the air convection and aggravate the pollutants (Huang et al., 2014).

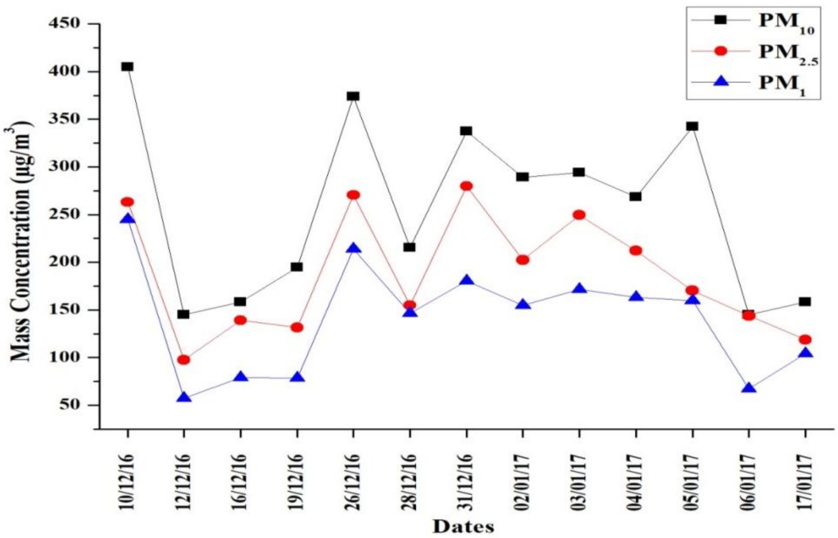

Figure 4: Variation in PM mass concentration during foggy and non-foggy event

Correlation coefficient between PM_{10}, $PM_{2.5}$ and PM_1 was higher than 0.87. A good correlation between PM_{10}, $PM_{2.5}$ and PM_1 indicates all the three particle sizes were associated with similar sources and meteorological conditions.
Air mass back trajectory was plotted for 05-Jan-17 (foggy day) at a height of 500 m AGL. Air masses were under the boundary layer and followed loop like pattern which suggested no contribution of long range transport.

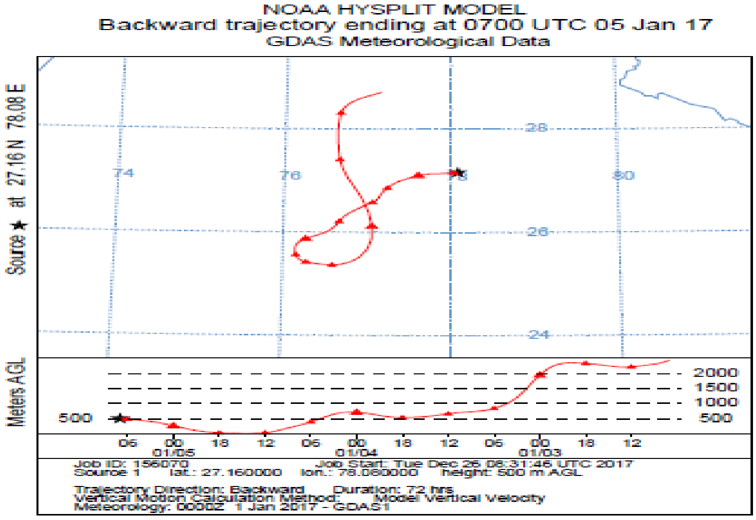

Figure 5: Air mass back trajectory during foggy event

PM mass concentrations observed at the present site were compared with other sites outside India and in India during fog-haze period (Table 2). It can be seen from the table that PM_{10} concentration at the present site (290 µg/m^3) was comparable to that observed at IIT Kanpur (273 µg/m^3; Ram et al., 2016) andBeijing, China (265 µg/m^3; Wang et al., 2015) during haze-fog. PM_{10} mass concentration was found slightly higher than those observed at Harbin, China (243 µg/m^3; Li et al., 2015) during haze-fogand 2.7 times higher than those observed at Taiwan (Chen et al., 2015) during episode. $PM_{2.5}$ concentration at the present site (208 µg/m^3) was found similar with those obtained at Harbin, China (208 µg/m^3; Li et al., 2015) during fog and found comparable to those observed at Beijing, China (188 µg/m^3; Wang et al., 2015). $PM_{2.5}$ concentration was found1.5 and 2.3 times higher than the concentration observed during winterat Xiamen, China (Zhang et al., 2013) and Korea (Park et al., 2013) during haze-fog respectively and PM_1 concentration at the present site (158 µg/m^3) was found comparable with those observed at Harbin, China (Li et al., 2015) during fog. PM_1 concentration was found 1.6 times higher than Beijing, China (Wang et al.,2015) during haze-fog. PM_1 mass concentration was found 1.3 times lower than IIT Kanpur (Singh and Gupta, 2016) during fog.

Table 2 Ambient PM concentrations (µg/m^3) reported during haze- fog episodes and their comparison with present study

Site	Concentration			References
	PM_{10}	**$PM_{2.5}$**	**PM_1**	
Korea	NR	88	NR	Park et al., 2013
Xiamen, China	NR	135	NR	Zhang et al., 2013
Taiwan	107	65	NR	Chen et al., 2015
Beijing, China	265	188	99	Wang et al., 2015
Harbin, China	243	208	195	Li et al., 2015
IIT, Kanpur	273	NR	NR	Ram et al., 2016
IIT, Kanpur	NR	NR	208	Singh and Gupta, 2016
DEI, Agra	290	208	158	Present study

IV. Conclusion

Pollution episodes Diwali and fog were studied at the campus site of Dayalbagh Educational Institute, Agra. During Diwali PM_{10}, $PM_{2.5}$ and PM_1 concentration was found 2.8, 4.7 and 6.8 times higher than normal days. $PM_{2.5}/PM_{10}$ ratio showed a gradual increase from pre-Diwali to day after Diwali, signifying dominance of fine particulate loading. Increase in fine particle concentration was due to burning of crackers and sparkles during late evening and night and gas to particle conversion. Average O_3 concentration was 1.3 times higher in day time and 2-3 times higher during night than normal days.

During fog average mass concentration of PM_{10}, $PM_{2.5}$ and PM_1 was 1.9, 2.0 and 2.3 times higher than non-foggy days. PM_{10} concentration was more than 2 times higher than standard NAAQS value and $PM_{2.5}$ concentration was found more than 3 times than standard NAAQS value. This may be due to anthropogenic activities andstable meteorological conditions(low temperature, low wind velocity, high relative humidity, low solar heating of earth surface resulting in slower dispersion of particulate matter and decrease in the boundary layer height). Air mass back trajectory followed loop like pattern which suggested no contribution of long range transport.

Acknowledgements

The authors are thankful to Director, Dayalbagh Educational Institute, Agra and the Head, Department of Chemistry for necessary help.

References

[1]. LiY, Zhao H and Wu Y, Characteristics of Particulate Matter during Haze and Fog (Pollution) Episodes over Northeast China, Autumn 2013,Aerosol Air Qual Res,2015,15, 853–864.
[2]. Nishanth T,Satheesh Kumar MK andValsarajKT, Variations in surface ozone and NOx at Kannur a tropical, coastal site in India, J AtmosChem,2012, 69(2), 101-126. doi:10.1007/s10874-012-9234-5
[3]. Herckes P, Chang H, Lee T et al. Air Pollution Processing by Radiation Fogs, Water Air Soil Pollut, 2007,181, 65 doi:10.1007/s11270-006-9276-x
[4]. Liu T, Zhuang G, Huang K, Lin J, Wang Q, Deng C and Fu JS, A Typical Formation Mechanism of Heavy Haze-Fog Induced by Coal Combustion in an Inland City in North-Western China, Aerosol Air Qual Res, 2016,17, 98-107.
[5]. Singh DK and Gupta T, Source apportionment and risk assessment of PM_1 bound trace metals collected during foggy and non-foggy episodes at a representative site in the Indo-Gangetic plain,Sci Total Environ, 2016,550, 80–94.
[6]. Agarwal A, Mangal A, Satsangi A, Lakhani A and Kumari KM, Characterization, sources and health risk analysis of $PM_{2.5}$ bound metals during foggy and non-foggy days in sub-urban atmosphere of Agra, Atmos Res, 197**,** 2017, 121-131.
[7]. Pervez S, Chakrabarty RK, Dewangan S, Watson JG, Chow JC andMatawle JL, Chemical speciation of aerosols and air quality degradation during the festival of lights (Diwali), AtmosPollut Res, 2016, 7(1), 92-99.
[8]. Zhang M, Wang X.M, Chen JM, Cheng TT et al. Physical characterization of aerosol particles during the Chinese new year's firework events,Atmos Environ, 2010,44, 5191-5198.
[9]. Tsai HH, Chien LH, Yuan CS, Lin YC, Jen YH andIe IR, Influences of fireworks on chemical characteristics of atmospheric fine and coarse particles during Taiwan's lantern festival,Atmos Environ, 2012,62, 256-264.
[10]. Chatterjee A, Sarkar C, Adak A, Mukherjee U, Ghosh S.K and Raha S, Ambient air quality during Diwali festival over Kolkata e a mega-city in India, Aerosol Air Qual Res, 2013, 13, 1133-1144.
[11]. Sarkar S, Khillare PS, Jyethi DS, Hasan A, and Parween M, Chemical speciation of respirable suspended particulate matter during a major firework festival in India, J Hazard Mater, 2010, 184(1-3), 321-330.
[12]. Barman SC, Singh R, Negi MPS and Bhargava S.K, Ambient air quality of Lucknow city (India) during use of fireworks on Diwali festival, Environ Assess, 2008, 137**,** 495-504.
[13]. Attri AK, Kumar U and Jain VK, Microclimate: formation of ozone by fireworks, Nature, 2001,411**,** 1015.
[14]. Pachauri T, Singla V, Satsangi A, Lakhani A andKumari KM, Characterization of major pollution events (dust, haze, and two festival events) at Agra, India, Environ SciPollut Res, 2013,20(8), 5737-5752.
[15]. Verma N, Satsangi A, Lakhani A andKumari KM, Low molecular weight monocarboxylic acids in $PM_{2.5}$ and PM_{10}: Quantification, seasonal variation and source apportionment, Aerosol Air Qual Res, 2017(a), 17(2), 485-498.
[16]. VermaN, Lakhani A and Kumari KM, High ozone episodes at a semi-urban site in India: Photochemical generation and transport, Atmos Res, 2017(b), 197, 232-243.
[17]. Draxler RR and Hess GD, Description of the 4 modeling system In: Technical Memorandum ERL ARL-224 NOAA Air Resources Laboratory, Silver Spring MD, 2004, Available online at: http://www.arl.noaa.gov/ready/4.html
[18]. Rao PS, Gajghate DG, Gavane AG, Suryawanshi P, Chauhan C, Mishra S, Gupta N, Rao CVC andWate SR, Air quality status during Diwali festival of India: A case study, Bull Environ ContamToxicol, 2012, 89(2), 376-379.
[19]. Kumar M, Singh RK, Murari V, Singh AK, Singh RS and Banerjee T, Fireworks induced particle pollution: a spatio-temporal analysis, Atmos Res, 2016, 180, 78-91.
[20]. Ravindra K, Mor S, and Kaushik CP, Short-term variation in air quality associated with firework events: a case study, J Environ Monit, 2003, 5(2), 260-264.
[21]. Tiwari S, Chate DM, Srivastava MK, Safai PD, Srivastava AK, BishtDS, and Padmanabhamurty B, Statistical evaluation of PM_{10} and distribution of PM_1, $PM_{2.5}$ and PM_{10} in ambient air due to extreme fireworks episodes (Deepawali festivals) in megacity Delhi. Nat Hazards, 2012, 61(2), 521-531.
[22]. Nirmalkar J, Deb MK, Deshmukh DK, and Verma SK, Mass loading of size-segregated atmospheric aerosols in the ambient air during fireworks episodes in Eastern Central India, Bull EnvironContamToxicol, 2013, 90(4), 434-439.
[23]. Tian YZ, Wang J, Peng X, Shi GL, and Feng YC, Estimation of the direct and indirect impacts of fireworks on the physicochemical characteristics of atmospheric PM_{10} and $PM_{2.5}$, AtmosChemPhys, 2014, 14(18), 9469-9479.
[24]. Feng J, Yu H, Su X, Liu S, Li Y, Pan Y, and Sun JH,Chemical composition and source apportionment of $PM_{2.5}$ during Chinese Spring Festival at Xinxiang, a heavily polluted city in North China: fireworks and health risks, Atmos Res, 2016, 182, 176-188.
[25]. Holmes HH, 1983, The Encyclopedia Americana, Int. edn. American Corp., New York.
[26]. Yadav R, Sahu LK, Beig G andJaaffrey SNA, Role of long-range transport and local meteorology in seasonal variation of surface ozone and its precursors at an urban site in India,Atmos Res, 2016,176–177, 96–107.
[27]. CPCB, 2009, Central pollution control board, India National ambient air quality standards (NAAQS) Gazette notification, New Delhi, 18 November 2009.
[28]. Gupta T andMandariya A, Sources of submicron aerosol during fog-dominated winter time at Kanpur, Environ SciPollut Res, 2013, 20(8), 5615-5629.
[29]. Huang K, Zhuang G, Wang Q, Fu JS, Lin Y, Liu T, Liu T, HanL and Deng C, Extreme haze pollution in Beijing during January 2013: chemical characteristics, formation mechanism and role of fog processing, AtmosChemPhys Discuss, 2014,6, 7517-7556.

[30]. Park SS, Jung SA, Gong BJ, Cho SY, and Lee SJ, Characteristics of $PM_{2.5}$ haze episodes revealed by highly time-resolved measurements at an air pollution monitoring Supersite in Korea, Aerosol Air Qual Res, 2013, 13(3), 957-976.

[31]. Zhang F, Chen J, Qiu T, Yin L, Chen X and Yu J, Pollution characteristics of $PM_{2.5}$ during a typical haze episode in Xiamen, China, Atmospheric and Climate Sciences, 2013, 3(04), 427.

[32]. Chen YC, Hsu CY, Lin SL, Chang-Chien GP, Chen MJ, Fang GC, and Chiang HC, Characteristics of concentrations and metal compositions for $PM_{2.5}$ and $PM_{2.5-10}$ in Yunlin County, Taiwan during air quality deterioration, Aerosol Air Qual Res, 2015, 15, 2571-2583.

[33]. Wang YH, Liu ZR, Zhang JK, Hu B, Ji DS, Yu YC, and Wang YS, Aerosol physicochemical properties and implications for visibility during an intense haze episode during winter in Beijing. AtmosChem and Phys, 2015, 15(6), 3205-3215.

[34]. Ram K, Singh S, Sarin MM, Srivastava AK, and Tripathi SN,Variability in aerosol optical properties over an urban site, Kanpur, in the Indo-Gangetic Plain: A case study of haze and dust events. Atmos Res, 2016, 174, 52-61.

AnkitaMangal "Investigation of PM10, PM2.5 and PM1 during Pollution Episodes: Fog and Diwali Festival "IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) 12.9(2018): 16-23.