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Monitoring of Ambient Air Particulate Matter during Diwali Festival at an Urban Industrial Area in Eastern Central part of India

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Abstract : Bursting of firecrackers during festive occasion can cause short term air pollution. The effect of firecrackers on ambient air quality was assessed by monitoring particulate matter concentration during Dushehara and Diwali, major festivals celebrated every year in India during the month of October and November with lot of bursting of firecrackers. To assess the impact of bursting of fire crackers during festival times total suspended particulate matter, PM_{10} and $PM_{2.5}$ were monitored during October and November of 2015 in an urban location in eastern-central part of India. The concentration levels of particulate matter on festival days during Dushehara were found to be higher by 1.75, 2.28, 1.27 times and during Diwali by 1.30, 2.19, 2.26 times, respectively for TSPM, PM_{10} and $PM_{2.5}$, than during the respective non-festive days average values. On the day of Dushehara festival, TSPM, PM_{10} and $PM_{2.5}$ concentration levels have been recorded as 395.70, 319.29, 193.89 μgm-3 respectively and on the Diwali day 501.26, 305.20, 229.78 μgm–3, respectively. The relationship between meteorological factors and particulate matter concentrations was studied and a clear inverse relationship between $PM_{2.5}$ and wind speed (r = –0.26) and PM_{10} and wind speed (r = –0.21) was found. The diurnal variation in the TSPM and PM_{10} showed peak concentrations occurring during night hours for both, the festival and non-festival days; festival peak values being consistently higher than non-festival concentrations.

Keywords : Ambient air quality; Dushehara; Diwali; Firecrackers; Particulate matter; TSPM, PM_{10} and $PM_{2.5}$

1. INTRODUCTION

Diwali is an important festival of India, in which bursting of lot of firecrackers takes place almost in every part of country during the month of October and November. According to one estimate, the Indian Fireworks industry boasts of about 90.19 million USD worth of annual turnover, at an annual growth rate of about 10 percent. The bursting of firecrackers releases significant amount of gaseous and particulate air pollutants, which can cause adverse impact on human beings. In India several researchers have investigated the ambient air quality status during festivals [1]-[5]. In [6] morphological study of ambient air aerosols reported metals (56.95%), black carbon (1.98%) and aromatic organics (1.11%) during Diwali festival at Delhi. Sustained higher concentration of $PM_{2.5}$ and PM_{10} (about 8 to 9 times than regulatory standards), for two days, during Diwali at Nagpur during November 2014 have been reported [7]. Similarly, in [8] measured higher level of SPM and RSPM on festive day as compared with non festive day at Udaipur city, Rajasthan, during November 2014. In another study [9] reported 1.3 to 4.0 times increase in PM_{10} and 1.6 to 2.5 times increase in total suspended particulate matter on the Diwali day as compared with pre-Diwali month at Delhi.

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As per the WHO in the year 2014 and 2016, Raipur ranked fourth and seventh place in the world associated with $PM_{2.5}$ aerosol. According to the WHO, death toll due to joint effect of air pollution in the year 2012 was 13700 people in high income countries of the Eastern Mediterranean Region, 2274500 people in South East Asia and 7054600 people in the world (WHO press release, 25 March 2014) [10]. During the month of October and November, any additional source contributing to particulate matter may make the air pollution scenario at ground level critical or severe, due to favorable meteorological condition.

In the current study, TSPM, PM_{10} and $PM_{2.5}$ aerosol mass concentration are monitored to observe the short term effect of firecrackers bursting during celebration of Dushehara and Diwali festival in the year 2015 in Raipur city, an urban industrial area situated in eastern central part of India.

2. METHODOLOGY

A. Study Area

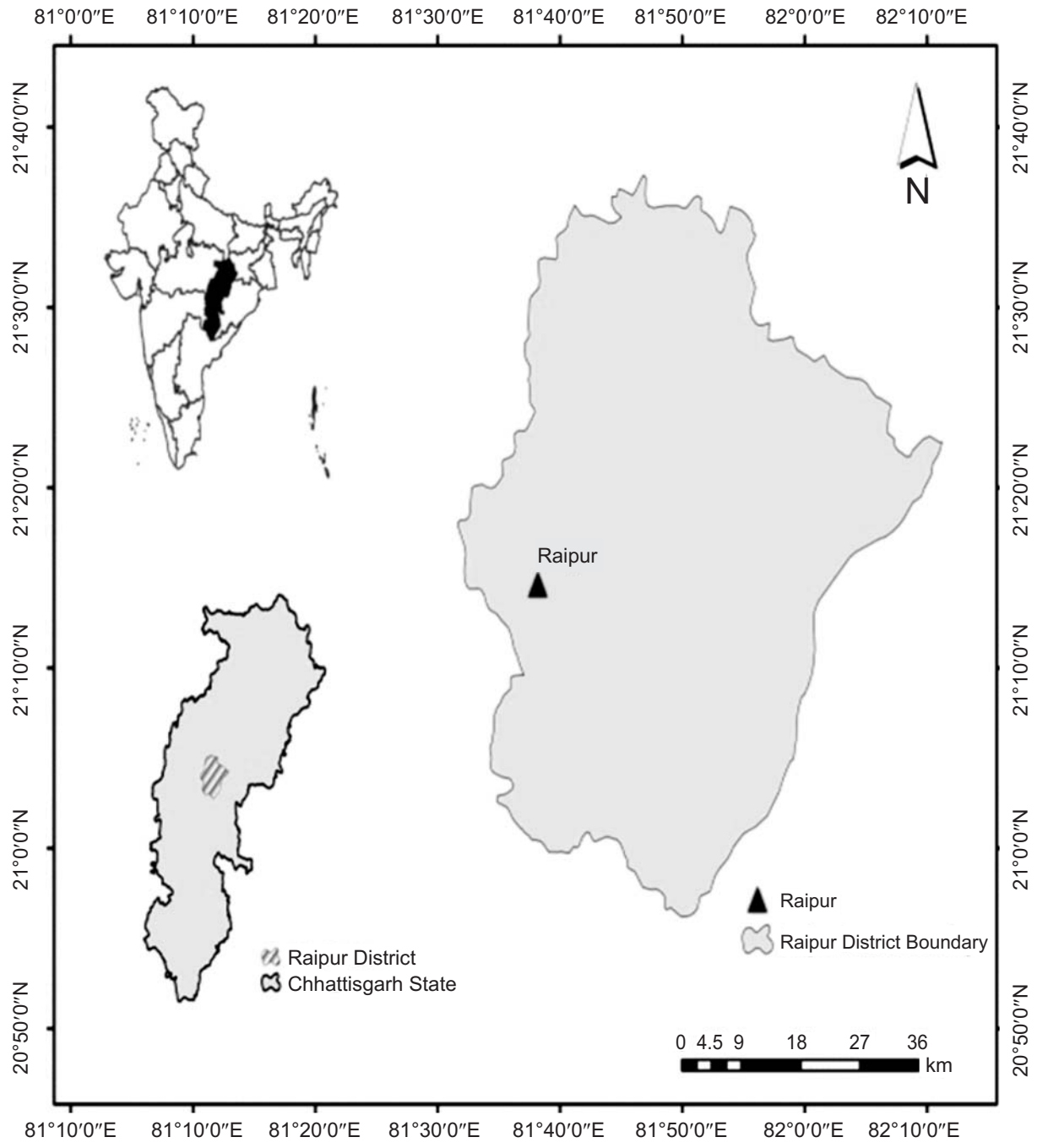

Figure 1: Site Map

The study area Raipur is the capital city of Chhattisgarh state situated in eastern-central part of India. Raipur city is one of the leading industrial and commercial cities of central India. Coal based thermal power plants, steel and sponge iron industries, agriculture based industries such as rice mills, other metal based industries, and cement industries etc. are the main industries in Raipur district. Raipur has a tropical wet and dry climate, with moderate temperature except from April to June, during these month highest temperature can be 46 to 48 ºC. Winter season falls during November to January months; minimum temperature can fall to 5ºC. Ambient air aerosol sampling was performed during festival time, on the roof top (21°15ˈ00ˈˈN, 81°36ˈ16.50ˈˈE, and 303.360 m a. m.s.l.) of main building of National Institute of Technology Raipur. Sampling site was at a height of 14 meters from the ground level, and industrial clusters like Gogaon, Urla and Siltara are located in north-east and north-west at about 08 km. Site map is provided in Fig.1.

B. Instrumentation and Sampling Techniques

TSPM, PM_{10} and $PM_{2.5}$ aerosol sampling was conducted simultaneously during (festival) October-November of 2015, on the roof top of main building (14 m above the ground level) inside the campus of National Institute of Technology Raipur, situated in Raipur. Sampling of aerosol was carried out using high volume sampler, respirable dust sampler (PM_{10}) and $PM_{2.5}$ sampler, to have the broad aerosol size distribution. Samplers were operated for 24 hours (8-hour cycles for TSPM and PM_{10}) during festive days and non-festive days. Aerosol samples were collected on Whatman glass fibre filter (8 × 10 inch) and Teflon (2 µm PTFE) filter of size 46.2 mm effective diameter. For conditioning, the filter papers were placed in desiccators for 24 h before and after sampling. The desiccated filter papers were weighed using balance (Precisa-92SM-202A) with 0.01 mg resolution. Aerosol concentrations were determined gravimetrically by dividing the difference in weight of the filter paper before and after the sampling with the volume of air sampled. Instrumentation and other details are given in Table 1.

Table 1
Instrumentation and Sampling Techniques

Sampler	*Model/Make*	*Particulate Size*	*Flow Rate*	*Sampling*	*Filter*
High Volume Sampler	APM 430/ Envirotech	10 µm – 50 µm	0.9-1.1$m^{3/}m^{-1}$	8 hr interval	Whatman Glass Fibre Filter (8 × 10 inch)
Respirable Dust Sampler	APM460DXNL/Envirotech	Aerodynamic Diameter (d) ≤ 10 µm	0.9-1.1$m^{3/}m^{-1}$	8 hr interval	Whatman Glass Fibre Filter (8 × 10 inch)
$PM_{2.5}$ sampler	APM 550/Envirotech	Aerodynamic Diameter (d) ≤ 2.5 µm	16.67 l pm	24 hr interval	Teflon PTFE (2 µm pore size), 46.2 mm

C. General Meteorology

Local Meteorological parameters such as air temperature, relative humidity, and wind speed and wind direction were obtained from the archives of Weather Underground (*http://www.wunderground.com*). Temperature during study period varied between 18ºC to 35ºC, with higher values during the day time than evening and morning times. Relative humidity during study period varied between 20% to 90% with lower values during noon time, and higher values during evening and morning. Wind speed remained calm during night and evening, and varied from 0.28 ms^{-1} to 4.05 ms^{-1} during the day time.

3. RESULTS AND DISCUSSION

A. Variation in particulate matter concentration

Table 2
Air Quality Standards

Air Quality Parameter	*CPCB (NAAQS, 2009)*		*USEPA*		*WHO*		*EU*	
	Annual	*Daily (24 Hr)*	*Annual*	*Daily (24 Hr)*	*Annual*	*Daily (24 Hr)*	*Annual*	*Daily (24 Hr)*
TSPM (μgm^{-3})	140*	200*	–	–	–	–	–	–
PM_{10} (μgm^{-3})	60	100	–	150	20	50	40	50
$PM_{2.5}$ (μgm^{-3})	40	60	–	35	10	25	25	–

* As per earlier (NAAQS-CPCB, India)

Table 3
Particulate Matter Concentration during Study Period

Day	*Date*	*Particulate Matter Concentration (μgm^{-3})*			*Meteorological Parameter*	
		TSPM	*PM_{10}*	*$PM_{2.5}$*	*RH (%)*	*Temp (°C)*
Before Dushehara	03-10-2015	346.33	146.00	128.15	70.25	29.62
	10-10-2015	168.23	139.90	138.63	59.75	28.12
	12-10-2015	128.59	102.00	NA	57.00	28.75
Dushehara	22-10-2015	395.70	319.29	193.89	54.62	28.25
After Dushehara	23-10-2015	252.90	187.70	190.99	55.12	27.75
	31-10-2015	233.77	122.91	NA	71.62	23.37
Before Diwali	02-11-2015	314.77	106.43	111.68	65.62	25.75
	09-11-2015	344.82	119.34	90.20	58.00	25.50
	10-11-2015	456.62	205.11	111.60	60.62	25.00
Diwali	11-11-2015	501.26	305.20	229.78	55.87	25.12
After Diwali	18-11-2015	420.95	143.43	119.12	57.87	23.87
	27-11-2015	385.03	120.07	73.85	46.37	24.56
Average of non festive days (Dushehara)		226.11	140.30	152.66		
Average of non festive days (Diwali)		385.58	139.36	101.67		

Ambient air quality standards by different agencies for particulate matter concentration have been summarized in Table 2. The temporal variations of TSPM, PM_{10} and $PM_{2.5}$ concentrations and meteorological parameters during festive and non festive days have been summarized in Table 3. On Dushehara, we observed higher values of 1.75, 2.28 and 1.27 times of non-festive day average values, respectively for TSPM, PM_{10} and $PM_{2.5}$. Concentration of PM_{10} and $PM_{2.5}$ rose to 319.29 μgm^{-3} and 193.89$\mu g\ m^{-3}$ on Dushehara and 305.20 $\mu g\ m^{-3}$ and 229.78 μgm^{-3} on Diwali, respectively, being 3.05 and 3.82 times higher than the daily average limit prescribed by the Central Pollution Control Board (CPCB), India. The peak values were observed during festival days of Dushehara and Diwali festival than non-festival, normal

days. On Diwali, we observed higher values of TSPM, PM_{10} and $PM_{2.5}$, of about 1.30, 2.19 and 2.26 times of non-festive day average values, respectively. The diurnal variation in the TSPM and PM_{10} concentration was high during the night hours for the festival and non-festival days both, festival peak values being consistently higher than the non-festival concentrations (fig. 2). Usually, the bursting of fire crackers is more on Diwali nights, however, we observed higher PM_{10} concentration on Dushehara night as compared with Diwali night; it may be due to burning of huge effigies of demon Ravana and brothers at many places in the city (hindu mythology) causing lot of associated biomass burning and firecrackers bursting. However, $PM_{2.5}$ concentrations were more on Diwali. We have observed negative correlation of $PM_{2.5}$ and PM_{10} mass concentration with wind speed (r = –0.26 and –0.21, respectively) during study period.

B. Comparison with other studies

Similar ambient air quality studies have been carried out during festivals and specific firecracker bursting periods at different locations. These studies have reported similar pattern of short term air quality degradation. In [11] reported three times higher $PM_{2.5}$ concentration (464.02μg m^{-3}) during firecrackers period than average value (113.92 μg m^{-3}) observed during non-firecrackers period at Jinan, China, during celebration of Chinese New Year (2008). In [12] reported about 35 times PM_{10} concentration on Diwali day than normal day before Diwali at Vadodara, India, during three consecutive years 2009 to 2011. In [13] reported higher concentration of respirable suspended particulate matter and suspended particulate matter on Diwali (312.50 μgm^{-3}, 618.31 μgm^{-3}, respectively) than the day after Diwali (107.00, 214.67μgm^{-3}, respectively) at Jhansi, India during November 2013. Similarly in [14] reported 6.44, 7.16, and 5.33 times high concentration of SPM, PM_{10} and $PM_{2.5}$ respectively during Diwali of 2007 than other days at Kolkata, India. In [15] found elevated levels of PM_{10} (142.0 μgm^{-3}) and $PM_{2.5}$ (106.0 μgm^{-3}) during Diwali than other days before and after Diwali at Jabalpur, India during 2012. Chhattisgarh Environmental Conservation Board (CECB, 2013) has monitored ambient air quality at different locations of Raipur City, India, during festival and non festival days in the year 2013 and found about 1.6 times higher PM_{10} concentration on Diwali than the day before Diwali [16]. In a Central Pollution Control Board (CPCB, 2014) ambient air quality study in Chhattisgarh state, India, PM_{10} concentration were reported to range between 73 and 167.0 μgm^{-3} on normal days and consistently higher values of PM_{10} ranging between 127 and 260.0 μgm^{-3} were reported on festival day. The Maximum PM_{10} concentration (260.0μgm^{-3}) was reported on festival day at Raipur City. Central Pollution Control Board (CPCB, 2014) has also monitored ambient air quality at different cities in India during the festival of Diwali in the year 2014 and found significant increase in particulate matter concentration in almost every part of India, except one location (Rajaji Nagar) in Bangalore city [observed lower PM_{10} value (213.00μgm^{-3}) on Diwali than normal day (231.00 μgm^{-3})] [17].

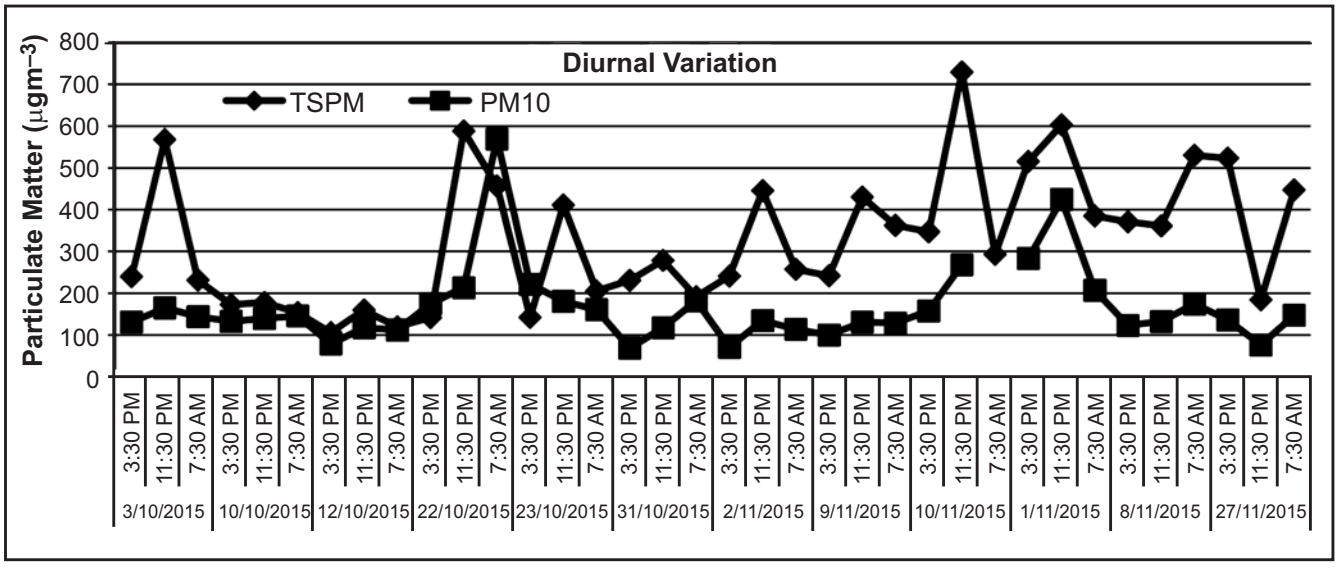

Figure 2: Diurnal Variation during Study Period

4. CONCLUSION

Dushehara and Diwali are the main festivals in India and are celebrated in the winter season, generally in the month of October-November, with lot of fire crackers bursting, leading to short term degradation of ambient air quality. The present study investigates the impact of festival fireworks on urban air quality at an urban industrial area in eastern-central part of India, Raipur city. The concentration of TSPM, PM_{10} and $PM_{2.5}$ were found to be very high on Dushehara and Diwali day as compared with normal days. On Dushehara and Diwali day, TSPM, PM_{10} and $PM_{2.5}$ concentration levels were recorded respectively as 395.70, 319.29, 193.89 μgm^{-3} and 501.26, 305.20, 229.78 μgm^{-3}. Clear negative correlation of $PM_{2.5}$ and PM_{10} mass concentration with wind speed as (r = –0.26) and (r = –0.21) during study period were observed. Diurnal variation of TSPM and PM_{10} concentrations showed peak values during night time. The use of firecrackers during festivals significantly increased the particulate matter concentrations and may cause adverse impact on human health particularly during winter nights. The use of firecrackers needs to be controlled to improve the air quality.

5. ACKNOWLEDGMENT

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