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A case study on air pollution during Diwali festival at Visakhapatnam, India

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ABSTRACT

This study focuses o**n** the variation in air quality assessed from mass concentrations of air pollutants [PM_{10}, $PM_{2.5}$, SO_2 and NO_2] for Pre-Diwali, Diwali and Post-Diwali days (October, November) in Visakhapatnam for two consecutive years, 2018 and 2019. For the first time, study about firework episode was carried out in this region. The results indicate that fireworks during Diwali festival affected the ambient air quality adversely due to emission and accumulation of $PM_{2.5}$, PM_{10}, SO_2 and NO_2. The effect is less in 2019 than 2018, due wash out of pollutants by rain water.

Key words*: Diwali, Particulate matter, Fireworks, Air pollution*

Introduction

Particulate Matter (PM) continues to be among the top environmental concern. The main sources of PM are vehicular emissions, power plants and episodic events such as fireworks. Fireworks are used commonly during cultural and religious festivals. In India, Diwali (Ajit *et al*., 2019; Neelam *et al*., 2018) the festival of lights is celebrated with a custom of firing crackers. The festival falls during the period October-November every year.

The major components of fireworks are oxidizing components, metals (containing colors), fuel, and binders (Jingyan *et al*., 2017). The fireworks generate pollutants and smoke. The high levels of noise associated with fireworks can affect wild life and hearing loss (Billock *et al*., 2017). The chemicals released from fireworks can affect surface water. The sudden rise in pollutants can trigger variety of health effects like skin burn, eye allergies, respiratory, cardiovascular and deterioration in visibility (Yangyang Zhang *et al*., 2017). The fireworks release air pollutants like particulate matter and gases nitrogen oxides NO_X, sulphur dioxide SO_2 and carbon monoxide CO.

The impact of firework emissions is analyzed by most of the studies (Cinzia *et al*., 2011; Venkata Swamy *et al*., 2013) measuring pollutants during Pre-Diwali, Diwali and Post-Diwali days. The studies reported that the concentrations increased by 2 to 8 times than normal days. As fireworks take place during evening hours after sunset higher concentrations are reported during evening hours after 8 PM.

The present study focuses on impact of firework emissions in the port city of Visakhapatnam (17.6868° N, 83.2185° E) located on the east coast of India. The variation in air quality is assessed from mass concentrations of air pollutants [PM_{10}, $PM_{2.5}$, SO_2 and NO_2] for Pre-Diwali, Diwali and Post-Diwali days during October-November in Visakhapatnam for two consecutive years, 2018 and 2019.

Materials and Methods

Study area

Visakhapatnam city (17.6868° N, 83.2185° E) located on the east coast of India. The city is studded with 14 major industries located within a distance of 13 km from the coast. The city with an area of about 680 km^2 is surrounded on three sides by mountains and the Bay of Bengal on the fourth it is effectively shielded from many winds, with only marine air moving into the basin.

Methodology

The real time hourly mass concentrations of $PM_{2.5}$, PM_{10}, NO_2 and SO_2 were recorded by National air quality index of Central Pollution Control Board compiled for each city under the Ministry of Environment, Forests and Climate Change, India. The instruments measuring the mass concentrations are located in the central point of the city. The mass concentrations of $PM_{2.5}$ and PM_{10} are measured using beta attenuation method. The gas pollutants NO_2, and SO_2, are measured using the gas phase chemiluminescence method and ultraviolet fluorescence method respectively. The data are publicly accessible and data used in this paper were obtained from the website.

Sampling protocol

The main festival day was on 7th November, 2018 and 27th October, 2019. Thus 6th and 8th November, 2018 and 26th and 28th October, 2019 were considered as Pre and Post Diwali days. Data were collected for 12hr day (6 A.M-6P.M) and night (6P.M-6A.M) time and 24 hrs taking mean values of pollutants.

Results and Discussion

The study was aimed at comparing the concentration levels of various pollutants in Visakhapatnam city during Pre Diwali, Diwali day and Post Diwali periods and to find out whether the concentration levels are within the recommended permissible standards. The meteorological conditions can influence air pollutants through mechanisms such as strong surface winds and convection. These can dilute firework emissions. Meteorological parameters viz. temperature, relative humidity and wind speed for monitoring periods were taken from https://app.cpcbccr.com/ccr/#/caaqm-dashboard-all/caaqm-landing/caaqm-data-availability as presented in Table 1. The parameters during monitoring periods were almost identical. Large differences in parameters are not seen, whereas in 2019 rainfall was recorded before and after Diwali were tabulated in Table 2.

The 24 hr average, day (6 A.M-6P.M) and night time (6P.M-6A.M) concentrations of PM_{10}, $PM_{2.5,}$ SO_2 and NO_2 during Pre, Diwali and Post Diwali days are depicted in Table 3 and Figure 1.

SO_2 and NO_2 showed evening peaks during Diwali night which show they have common resources. As vehicular emissions decrease on account of public holiday and hence increase in concentrations could be attributed to fireworks. When compared to 2018 the gaseous concentrations in 2019 were low which could be possibly due to rainfall recorded.

According to the National Ambient Air Quality Standards (NAAQS), the 24 hr average limit for PM_{10} and $PM_{2.5}$ are 100 $\mu g/m^3$ and 60 $\mu g/m^3$ respectively. In the year 2018, On Diwali Day (night) the average concentrations of sampling site for PM_{10}, and $PM_{2.5}$ were found to be 331.2 $\mu g\ m^{-3}$, 412.7 $\mu g\ m^{-3}$ which are 3.46 and 6.13 times higher than their respective daytime levels. In 2019, the night time average concentrations site for PM_{10} and $PM_{2.5,}$ were found to be 161.23 $\mu g\ m^{-3}$, 230.9 $\mu g\ m^{-3}$ which are 1.75 and 5.22 times higher than their respective day-

Table 1. Meteorological parameters recorded during festivity period

Year	Day	Monitoring Date	Temperature °C	Relative Humidity (%)	Wind speed (m/s)
2018	Pre Diwali	6th November	28±2	74±5	1±1
	Diwali	7th November	28±2	70±8	1±1
	Post Diwali	8th November	28±2	70±4	2±1
2019	Pre Diwali	26th October	33±6	77±5	2±1
	Diwali	27th October	42±10	76±6	1±1
	Post Diwali	28th October	30±0	78±5	2±1

time levels (Table 2). After two hour of firework the particulates PM_{10} and $PM_{2.5}$ (Figure 3) reached higher concentrations 500 µg $m^{-3}$and remained high until 5:00 PM of the next day in 2018.

According to the National Ambient Air Quality Standards (NAAQS), the limit for NO_2 and SO_2 is 80 µg/m^3. The ambient SO_2 andNO_2 levels (µg/m^3) measured is shown in Figure 2. The NO_2 and SO_2 levels were found to be below the permissible limit as prescribed by NAAQS except on the day of Diwali night in 2018, NO_2 exceeded the limit. The concentrations of NO_2 are higher than SO_2 on all measured days. In the year 2018, On Diwali Day (night) the average concentrations of SO_2 and NO_2 were found to be 61.7 µg m^{-3} and 83.5 µg m^{-3} respectively which are 8.69 and 2.39 times higher than their respective daytime levels. In 2019, the night time concentrations, SO_2 and NO_2 were found to be 31.5 µg m^{-3} and 43.1 µg m^{-3} respectively which are 1.53 and 1.2 times higher than their respective daytime levels.

In 2019, the concentrations of PM_{10} and $PM_{2.5}$ reached 500 µg m^{-3} and lasted only for 2-3 hrs respectively. The pollutants were washed out quickly due to rainfall recorded in 2019. The presence metals, binder, fuels and oxidizing components could have contributed to higher values of PM_{10} and $PM_{2.5,}$ even if rain impacted in reducing SO2 and NO2. The sudden raise in particulate matter could trigger health issues. The adults and infants are most sus-

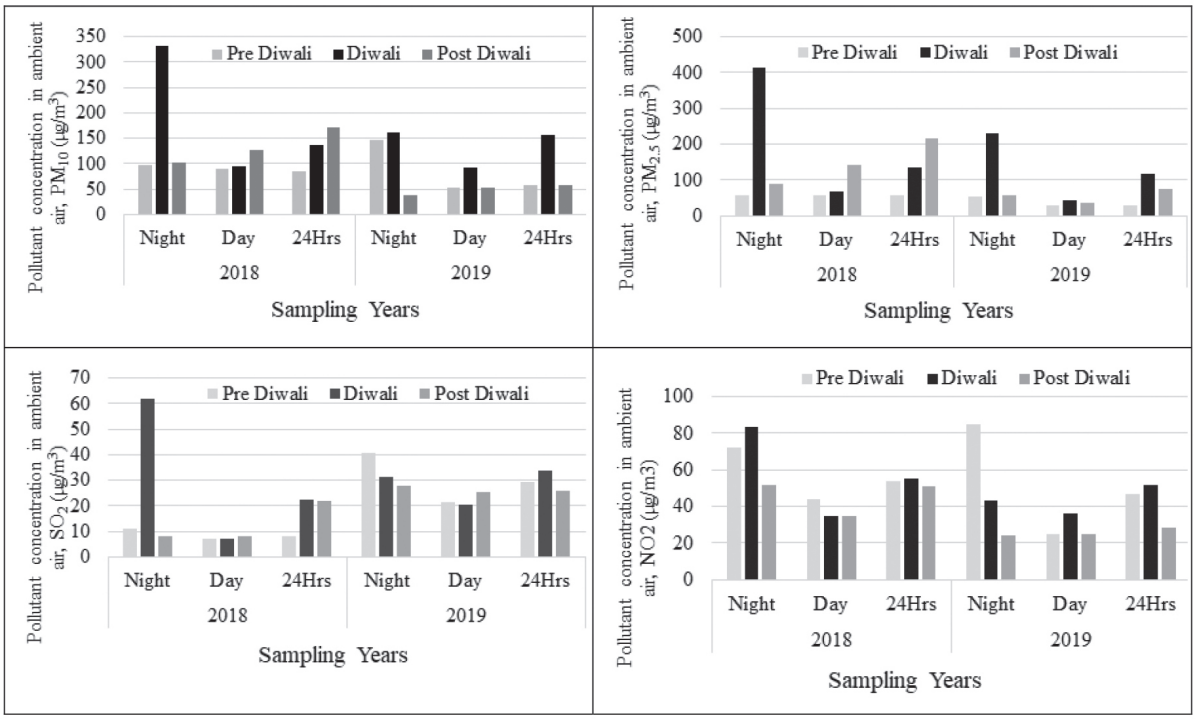

Fig. 1. Day, night and 24 hr mean concentrations of particulate matter and pollutants before, during and after Diwali festival

Table 2. Rainfall recorded three days before and after Diwali festival

Year	Date	Maximum Rain fall (mm)	Year	Date	Maximum Rain fall (mm)
2018	4th November	0	2019	24th October	4
	5th November	0		25th October	0.5
	6th November	0		26th October	0
	7th November	0		27th October	0
	8th November	0		28th October	1
	9th November	0		29th October	0
	10th November	0		30th October	0

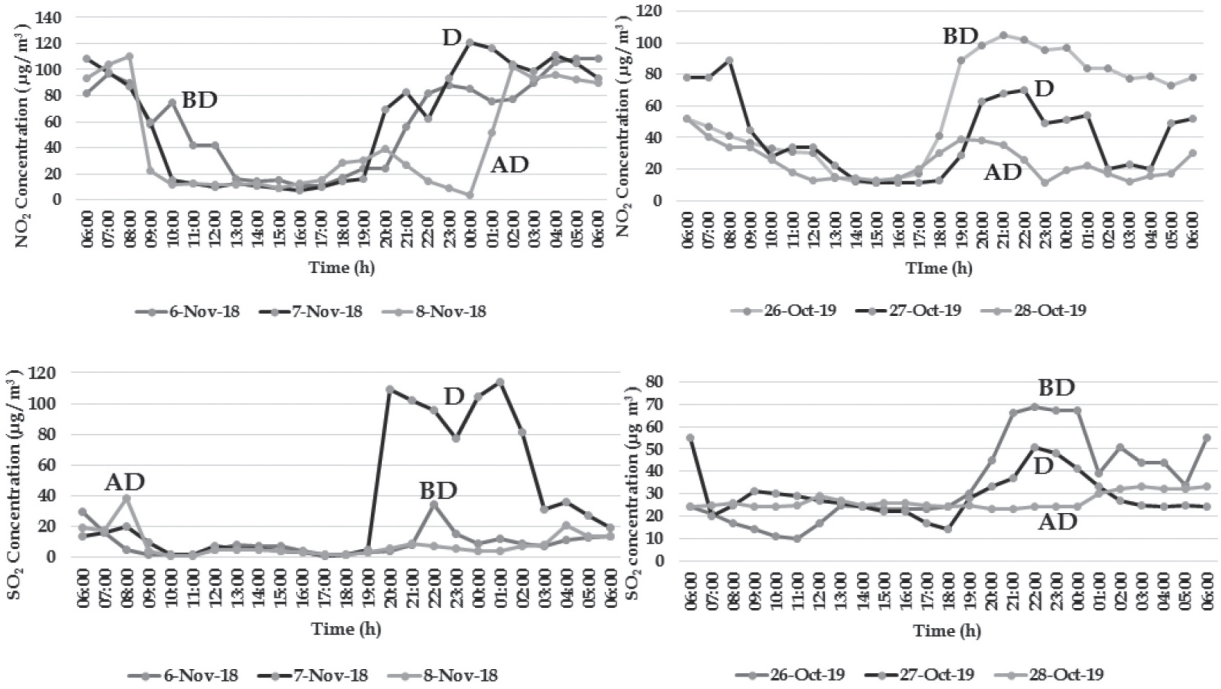

Fig. 2. Variability in concentrations of SO_2 and NO_2 during and after firecracker burning event

Table 3. Diurnal Patterns of various pollutants during the festival

Pollutant concentration in ambient air (µg/m^3)	Day	2018			2019		
		Night	Day	24 Hrs	Night	Day	24 Hrs
PM_{10}	Pre Diwali	96.7	89	83.6 ± 43.5	146.6	52.8	56.4 ± 46.6
	Diwali	331.2	95.5	137.6 ± 106.9	161.23	92.0	155.4 ± 152.5
	Post Diwali	103.23	126.6	170.3 ± 148.3	38.6	51.9	57.5 ± 43.2
$PM_{2.5}$	Pre Diwali	59.3	58.2	57.1 ± 29.7	55.1	30.6	30 ± 18
	Diwali	412.7	67.3	134.3 ± 152.9	230.9	44.2	118.4 ± 157.5
	Post Diwali	90.1	142.5	215.6 ± 200.6	56.6	35.3	75.5 ± 88.5
SO_2	Pre Diwali	10.8	7.0	8.2 ± 8.0	40.8	21.4	29.2 ± 17.5
	Diwali	61.7	7.1	22.6 ± 33.5	31.5	20.5	33.7 ± 16.6
	Post Diwali	8.07	8.2	22.1 ± 31.7	27.6	25.3	26 ± 3.7
NO_2	Pre Diwali	72.3	43.8	53.6 ± 29.2	84.7	24.7	46.7 ± 31.9
	Diwali	83.5	35	55 ± 38.3	43.1	35.9	51.6 ± 28.9
	Post Diwali	52.07	35.1	51.3 ± 43.9	24	24.7	28.6 ± 13.4

Night : 6 P.M. to 6 A.M.
Day : 6 A.M. to 6 P.M.
24 Hrs average with standard deviation

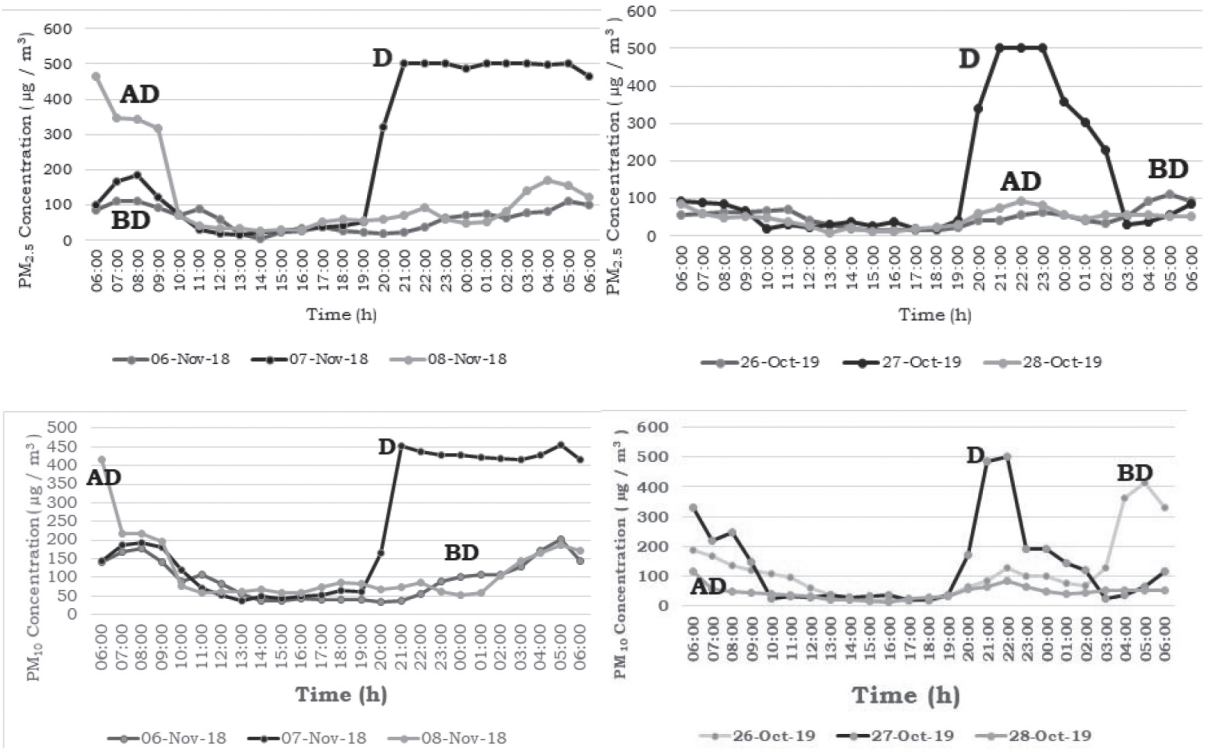

Fig. 3. Variability in concentrations of particulate matter during and after firecracker burning event

ceptible to mortality with short term acutely raised pollution concentrations (Qian Di *et al*., 2017).

Conclusion

The present work investigates the influence of Diwali fireworks on air quality at Visakhapatnam city. The increase in concentrations of pollutants during night time during Diwali day can be attributed to firework emissions and day time decrease in values during Diwali day might be due to decrease in vehicular emissions on account of public holiday and no contribution from fireworks. The averaged concentrations of pollutants remained high during morning hours of post Diwali which means the cleansing of pollutants after burning of crackers need time.

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