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Research Article

Festival of Light: Comparative Study of Pollutants with Meteorology on Ambient Air of a Central Urban Site Nagpur during two Successive Years

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Abstract

Diwali-the festival of light- is celebrated in India, every year in the month of October or November with the fascinating and extensive use of fireworks. The present study is conducted, for two successive years of 2014 and 2015. During study, to assess the impacts of air contaminations particularly the transitory and tremendous event of particulate matters (PM_{10} and $PM_{2.5}$) on ambient air quality. The concentration of air pollutants such as particulate pollutants (PM_{10} and $PM_{2.5}$) and gaseous pollutants (CO, NO_2, O_3 and SO_2) were observed for seven consecutive days during the festival in an intensely populated residential area of Nagpur district, India. It was observed that the concentration of air pollutants increases many folds during diwali festival as compared to normal days. On actual days of the festival, the concentration of PM_{10} and $PM_{2.5}$ accomplished its highest value of 950 µg m-3 and 900 µg m^{-3} in 2014 while 1000 µg m^{-3} and 975 µg m^{-3} in 2015, respectively. In the year of 2014, the concentrations of PM_{10}, $PM_{2.5}$, SO_2, and NO_2 were found 6.20, 5.15, 3.83, and 3.27 times higher than the concentrations in normal days. While in the year of 2015, the concentrations of these pollutants were also found 5.10, 3.45, 4.83, and 2.27 times higher than the concentrations in normal days. These figures demonstrate the enormous contribution of fireworks in ambient air pollution.

Keywords: Diwali; Particulate Matter; SO2; NO2; O3

Introduction

Cracker and fireworks are used to celebrate diwali festival, which release a lot of contaminating components that can possibly disintegrate ambient air quality in local or regional scale. In India, fireworks bursting is performed mainly in diwali, new age and wedding ceremonies. Diwali festival is one of the momentous celebrations of crackers blasting, which therefore leads to significant degradation of air environment in major and small Indian cities. Blasting of crackers releases a significant amount of chlorates and nitrates of potassium, sodium oxalate, charcoal, sulfur, manganese, etc. [1,2]. Various toxic fractions of gaseous and particulate air pollutants release in considerable quantity which ultimately worsen air quality as a whole. Several researchers reported about the deterioration of air quality during diwali festival to a substantial level. An observed increase of 2-10 times in PM_{10}, TSPM (Total Suspended Particulate Matter), SO_2 and NO_2 concentrations have been covered in the study areas of Hisar and Lucknow city [1,3]. Some surveys have been performed associated with diwali fireworks over different areas in India [3-5] and compared with normal days which show 3 times increase in concentration of black carbon. [6,7] reported an impact on ambient surface ozone during the festival of diwali. Researchers from other countries also accomplished studies to measure the essence of diwali pollution on air environment (Bach et al., 1975). Size distribution of aerosols had been studied by Drewnick et al. [8] during New Year's 2005 in Mainz, central Germany. Increased concentrations of some heavy metals had been reported by Vecchi et al., [9] during the celebration of the FIFA world Cup, in Italy in 2006. A study during lantern day festival in Beijing, on the status of air quality presumes that broadly blasting of firecrackers reports 57, 25 and 183% increase in SO_2, NO_2 and PM_{10} levels, when compared to the previous day. Besides these higher concentrations in the gentle wind, several health effects like cardiovascular diseases have been reported [10,11]. Fleischer and coworkers reported the concentrations of

organic toxic species, including octachlorinated dioxins, furans, and hexachlorobenzene, in the remains of fireworks [12]. Allergic bronchitis, acute exacerbation of bronchial asthma, chronic bronchitis, emphysema, COPD (Chronic Obstructive Pulmonary Diseases), allergic rhinitis, laryngitis, sinusitis, pneumonia, and common cold increase during these times [13]. Holding in view of the reviewed literature, the present work was carried out in order to monitor the condition of air quality by defining and comparing selected parameters such as PM_{10}, $PM_{2.5}$, Sulfur Dioxide (SO_2), Nitrogen Oxide (NO_2) Ozone, CO and NH_3 with meteorological parameters in the residential area in NEERI, Nagpur city, during the festival of lights in October 2014 and November 2015.

Method and Methodology

Study Area

The area for the study is NEERI (National Environmental Engineering Research Institute), Nagpur, which is a major part of residential site in Nagpur (Figure 1), situated, between 21° 7′ 9.25′′ N to 21° 7′ 33.84′′ N latitude and 79° 03′ 52.26′′ E to 79° 04′ 27.82′′ E longitude. It has a hot and extremely dry climate influenced by the Desert to the west, central hot plains to the south and hilly region to the northeast, having population of about 2398165 inhabitants [14].

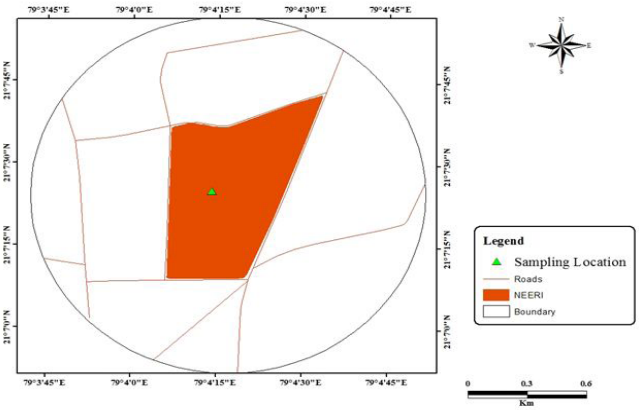


Figure1: Sampling Station of the study area.

Methodology

Particulate Matter (PM), gases and surface meteorological parameters are collected at every one-hour interval during the entire operation that includes before diwali, diwali and after diwali period. The air quality monitoring data is generated from "Continuous Ambient Air Quality Monitoring Station" (CAAQMS) at "National Environmental Engineering Research Institute" (NEERI), Nagpur, India, to study the trends of concentration of Particulate Matter (PM) and gases air pollutants during diwali festival. The ambient air quality monitoring network involves measurement of various number of air pollutants. A variety of methods exist to measure particulate matter as well as gaseous pollutants in the air. The analyzers was automatic programmable for the measurement of ppm, mg/m3and µg/m3 units. RSPM analyzer (MP101M, Environment S.A., France) was used to determine PM_{10} and $PM_{2.5}$ concentration at this site. Its principle is radioactive tracing, consists of a particle collector and a radioactive detector. The sensor is set up on the decoration of the filter with collection efficiency around 99%. To measure the SO_2 concentration at the site, an on-line SO_2 analyzer (AF22M-LCD, Environment S.A., France) was used. The analyzer is equipped with a low-pressure zinc vapour lamp which emits ultraviolet radiation at certain wavelength (λ = 213.9 nm) and measures the concentration of SO_2 based on fluorescent in ultraviolet technique. Nitrogen monoxide and nitrogen dioxide are analyzed by Chemiluminescent oxides of nitrogen analyzer (AC32M, Environment S.A., France) are designed to monitor low concentration of NOx in ambient air. The analyzer work on chemiluminescent based principles, which corresponds to an oxidation of NO molecules of ozone molecules. The return to a fundamental electronic state of the excited NO_2, molecules are made by luminous radiation in a 600-1200 nm spectrum. The $O_3$42M (Environment S.A., France) is a continuous ozone analyzer, which is based on the principle of ozone detection of absorption in ultraviolet light. The ozone absorption spectrum is extended to a wavelength of 253.7 nm. The CO12M is a continuous carbon monoxide monitor specific to low carbon monoxide concentrations in ambient air under atmospheric conditions. Carbon monoxide analyzer is operates on the principle of infrared absorption. Infrared absorption phenomenon is known as Beer Lambert law. According to beer lambert law the attenuation of light to the properties of the material through which the light is traveling [15-16].

Meteorological Study

Automatic weather station provides meteorological data, e.g. wind speed, pressure, humidity, temperature, wind direction and rainfall with the help of weather link software. It gives data updates every 2.5 seconds. The meteorological parameters like temperature (°C), relative humidity (%), and wind speed (m/s) over NEERI, Nagpur during the study period have been shown in (Table 1 and 2) for pre-diwali, diwali and post-diwali days in 2014 and 2015. For this period, minimum and maximum surface temperature, relative humidity vary from 25.0 to 26.0°C, 27 to 28.3°C, and 46% to 63%, respectively. The wind direction was mostly calm and stable during the intensive observation period. When wind speed below 1km/h are recorded as calm condition. The wind rose diagrams are shown in (Figure 2) for pre diwali, diwali and post diwali day for the year 2014 and 2015. Conditions of wind, its direction and speed were analyzed by wind rose diagrams, which is an effective graphical tool for such kind of observation. It is divided in a number of spokes, which represent the frequency of winds blowing from a particular direction.

Day	Year	Particulate Pollutants (µg/m3) Daily avg.		Gaseous Pollutants (µg/m3) Daily avg.				Meteorological Parameter		
	2014	PM_{10}	$PM_{2.5}$	CO (mg/m3)	SO_2	O_3	NO_2	Temp. (°C)	Relative Humidity (%)	Wind speed(m/s)
Before Diwali	10/20/2014	94.12	43.21	0.62	5.82	58.65	16.59	27.14	65.52	1.96
	10/21/2014	85.60	52.37	0.76	3.76	45.22	22.95	27.09	66.02	1.40
	10/22/2014	119.44	74.15	0.96	4.96	46.37	28.41	26.41	61.36	1.52
Diwali	10/23/2014	154.79	103.26	0.78	10.51	52.33	24.82	26.05	51.75	1.23
After Diwali	10/24/2014	319.58	295.65	0.71	9.68	34.57	19.90	25.16	58.05	2.07
	10/25/2014	83.50	55.30	0.68	3.28	30.82	16.88	23.53	72.39	1.16
	10/26/2014	76.28	46.80	0.72	2.40	29.41	18.52	21.95	75.41	1.18

Table 1: Ambient concentration of particulate and gaseous pollutants compare with meteorological parameter in the Nagpur recorded Before-Diwali, Diwali and After-Diwali 2014.

Day	Year	Particulate Pollutants (µg/m3)		Gaseous Pollutants (µg/m3) Daily avg.				Meteorological Parameter		
	2015	PM_{10}	$PM_{2.5}$	CO (mg/m3)	SO_2	O_3	NO_2	Temp. (°C)	Relative Humidity (%)	Wind speed(m/s)
Before Diwali	11/8/2015	103.23	46.88	0.81	3.01	92.81	22.16	26.9	57.48	1.88
	11/9/2015	117.90	54.39	1.39	3.29	90.88	30.94	26.8	58.52	1.67
	11/10/2015	134.88	66.19	2.03	10.33	87.04	29.76	27.0	56.74	1.7
Diwali	11/11/2015	177.27	97.82	1.02	7.73	92.40	24.85	26.7	56.52	1.64
After Diwali	11/12/2015	301.33	202.15	0.82	6.56	95.52	22.10	26.8	55.63	1.57
	11/13/2015	138.90	91.69	0.83	17.06	93.12	26.29	26.6	55.11	1.70
	11/14/2015	96.86	77.34	1.00	3.83	100.00	25.06	26.3	55.41	1.53

Table 2: Ambient concentration of particulate and gaseous pollutants compare with meteorological parameter in the Nagpur recorded Before-Diwali, Diwali and After-Diwali 2015.

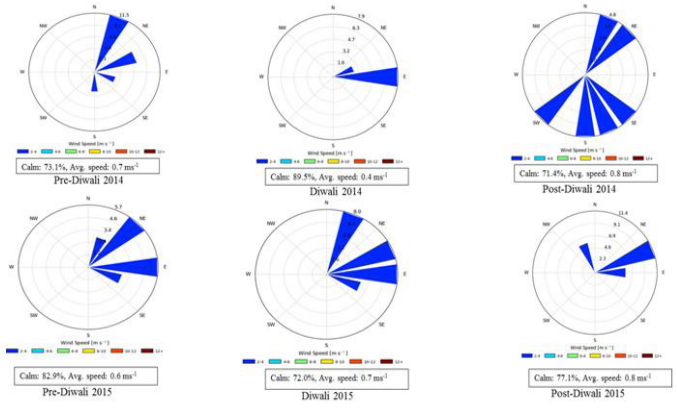


Figure2: Wind rose of the study period.

Results and Discussion

The concentration of particulate matter (PM_{10} and $PM_{2.5}$) concentration was thoroughly studied and compared with meteorological parameters such as relative humidity, wind speed and temperature as well as with gaseous pollutants SO_2, NOx and O_3, during 2014 and 2015 in pre-diwali, diwali, and post-diwali days at NEERI, Nagpur city. Diurnal variation of PM_{10} and $PM_{2.5}$ concentrations has been illustrated in (Figure 3). In the year 2014, the minimum and maximum concentration of PM_{10} was recorded in the range of 57.78 - 222.47 µg m-3 during pre-diwali, whereas on diwali day, the concentration was in the range of 63.66 - 900.0 µg m-3. While on post-diwali, the concentration was in the range of 31.78 - 131.3 µg m^{-3}. $PM_{2.5}$ concentration recorded in the year 2014 during pre- diwali was 17.91 - 121.76 µg m-3, diwali day range was 40.53 - 950 µg m^{-3} while on post- diwali day, concentration was found to be 25.10 - 93.95 µg m-3. During pre-diwali, diwali and post- diwali in year 2015, the concentration of PM_{10} is noted minimum and maximum range of 59.67 - 272.85, 80.64 - 974.49 µg m_{-3} and 45.56 - 425.64 µg m^{-3} while $PM_{2.5}$ is recorded for 17.98 - 144.44 µg m^{-3}, 31.53 - 536.77 µg m^{-3} and 34.87 - 315.56 µg m^{-3}. The results show that the average $PM_{2.5}$ concentration was around 295.64 µg m^{-3} on diwali days in 2014 and decreased in 2015 which is 202.01 µg m^{-3} as shown in (Figure 5). Similar results are also observed for PM_{10} for both year 2014 and 2015 which is 319.58 - 301.20 µg m^{-3} depicted in (Figure 4). In these studies,

the Pearson correlation is used between meteorological parameters and concentration of pollutants shown in (Table 3). It is shown that temperature; humidity and wind speed can preferably explain the relationship between the concentration of particulate matter and meteorological factors. In 2014 and 2015, it can be seen that the concentration of PM_{10} was found slightly positive correlation between temperature (R^2 = 0.095 and R^2 = 0.204), while $PM_{2.5}$ was slightly positive (R^2 = 0.014) in 2014 and slightly negative (R^2 = -0.049) in 2015. This is shown in (Table 3) and the relationship display in (Figure 6). The concentration of PM_{10} and $PM_{2.5}$ is decreased when the temperature decreases. Therefore, the magnitude of the temperature is directly proportional to the concentration of PM_{10} and $PM_{2.5}$ in both years during diwali festival. (Figure 7) shows that the comparison between PM_{10} and $PM_{2.5}$ with relative humidity at 2014-15. In the (Figure 7), the relative comparison in PM_{10} and $PM_{2.5}$ with relative humidity for both years is presented. In 2014, relative humidity found a moderate negative correlation (R^2 = -0.605) with PM_{10} while in 2015 less negative correlation (R^2 =-0.331). Whereas $PM_{2.5}$ found a moderate negative correlation (R^2 = -0.517 and R^2 = -0.535) for both years. Hence, relative humidity has an inversely relation between PM_{10} and $PM_{2.5}$.

Wind speed and concentrations of PM_{10}, shows a moderate positive correlation (R^2= 0.627) during 2014 but in 2015 a negative one (R^2 = -0.393). While $PM_{2.5}$ shows moderate positive correlation (R^2= 0.595) in 2014 and moderate negative correlation (R^2 = -0.539) in 2015 (Table 3). Wind speed strongly influenced concentrations of $PM_{2.5}$ than concentrations of PM_{10}. This relationship is depicted in (Figure 8).

Parameters	PM_{10}		PM2.5	
	2014	2015	2014	2015
Temp. (°C)	R^2= **0.095**	R^2= **0.204**	R^2= **0.014**	R^2= **-0.049**
	(+ve) Correlation	(+ve) Correlation	(+ve) Correlation	(-ve)Correlation
Relative Humidity (%)	**R^2 = -0.605** Moderate (-ve) Correlation	**R^2= -0.331** (-ve) Correlation	**R^2= -0.517** Moderate (-ve) Correlation	**R^2= -0.535** Moderate (-ve) Correlation
wind speed(m/s)	**R^2 = 0.627** Moderate (-ve) Correlation	**R^2= -0.393** (-ve) Correlation	**R^2 = 0.595** Moderate (-ve) Correlation	**R^2 = -0.539** Moderate (-ve) Correlation

Table 3: Correlation coficience of particulate matter during study peread.

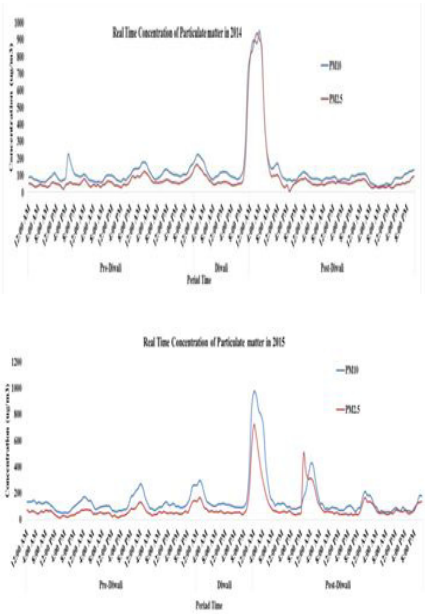


Figure 3: Real-time concentration of PM_{10} and $PM_{2.5}$ during 2014-15 study time in Nagpur.

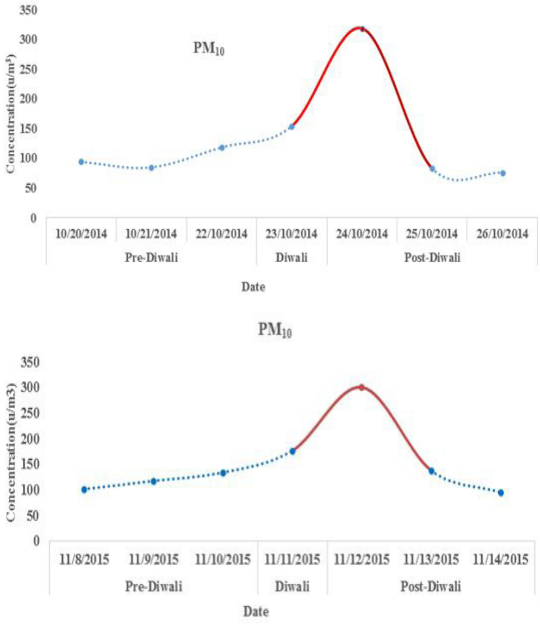


Figure 4: Daily avg. variation of PM10 in Nagpur (2014-15).

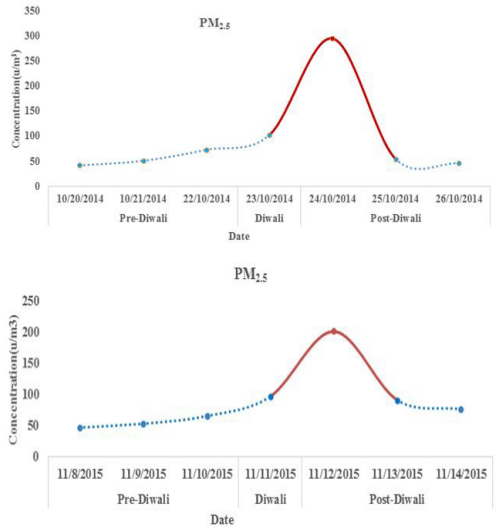


Figure 5: Daily avg. variation of PM 2.5 in Nagpur (2014-15).

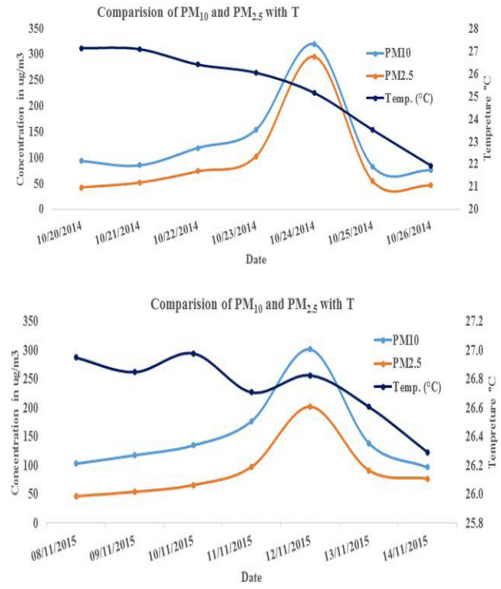
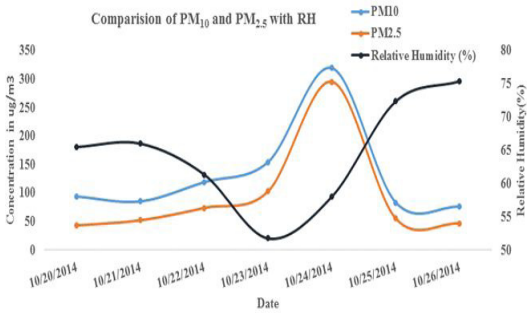


Figure 6: Comparison of PM10 and PM2.5 with Temperature in 2014-15.



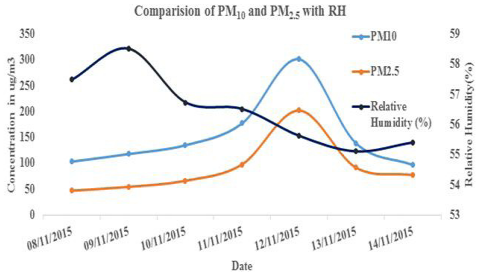


Figure 7: Comparison of PM10 and PM2.5 with Relative Humidity in 2014-15.

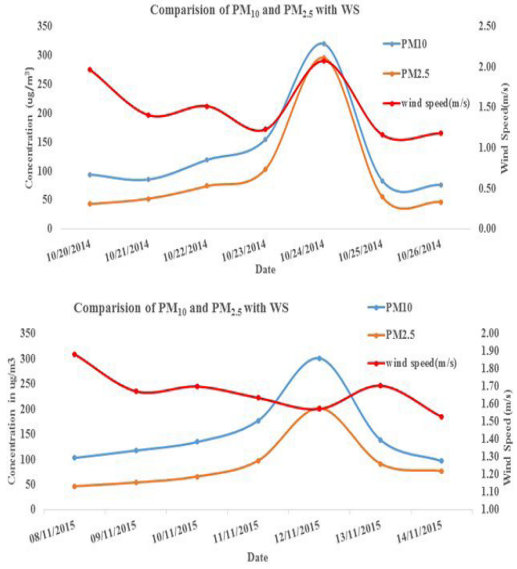
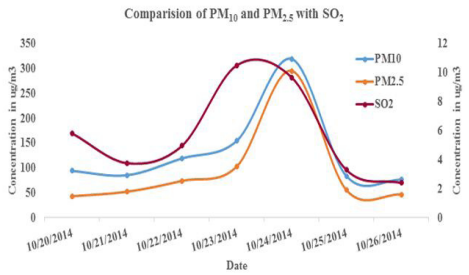


Figure 8: Comparison of PM_{10} and $PM_{2.5}$ with wind speed in 2014-15.

Daily average variation of SO_2, PM_{10} and $PM_{2.5}$ during the study period in 2014 and 2015 has presented in (Figure 9). SO_2 concentration has found decreased level for pre-diwali and after diwali but has increased on diwali in days both the years. The PM_{10} and $PM_{2.5}$ have correlated with SO_2, which depicted in (Figure 9). In 2014 the SO_2 avgerage concentration was found to be 4.96 µg m^{-3}, 10.51 µg m^{-3} and 9.68 µg m^{-3} during pre-diwali, diwali and post-diwali but in 2015, average concentration is 10.33 µg m^{-3}, 7.33 µg m^{-3} and 6.56 µg m^{-3}.



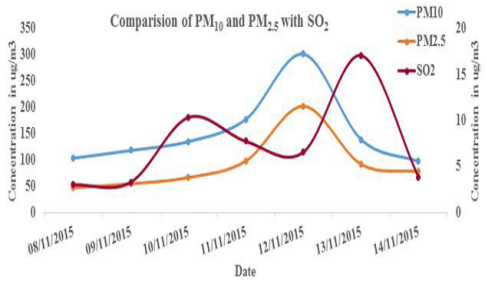


Figure 9: Comparison of PM_{10} and $PM_{2.5}$ with SO_2 in 2014-15.

Depicted in (Figure 10), the ozone concentration during diwali was found to be higher in 2015 compared to 2014 and also on pre-diwali and post-diwali. In 2015, the average concentration of O_3 is 92.40 µg m^{-3} whereas in 2014, concentration was 52.33 µg m^{-3}. Ozone is inversely correlated with NO_2, because ozone increases with the decrease in NO_2 concentration, presented in (Figure 10) for both the years. There is a slight increase in CO concentration during diwali time in the both years (Table-1and Table-2) and then decreases in both the year during the Pre diwali and post-diwali time.

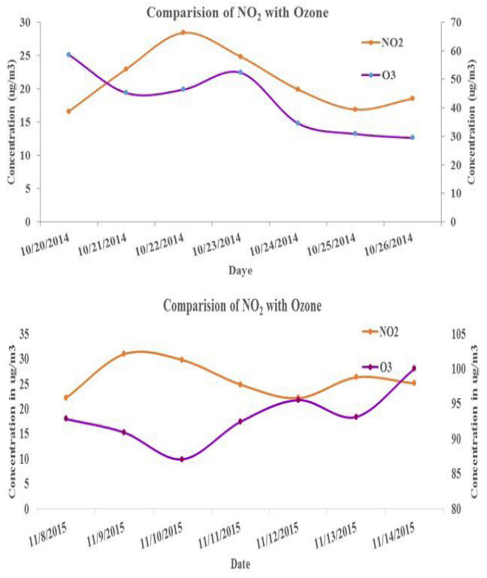


Figure10: Comparison of NO2 with Ozone in 2014-15.

Conclusion

To conclude, the present study provides basic information about how the usage of crackers and fireworks has impacted on the air quality of a NEERI, Nagpur in terms of PM_{10}, $PM_{2.5}$, SO_2, NO^2, and O_3 which are five major air pollutants deciding air quality. Among the seven days of study, most of the days recorded slightly higher concentration of the pollutants except O_3 in 2015, whereas other pollutants were in the higher range PM_{10}, $PM_{2.5}$, SO_2, NO_2, and CO (10, 9.5, 3.83, 3.27 and 4.1 time) in both years as per the permissible limit of National Ambient Air Quality Standards (NAAQS) in 24hr. This study is important because the release of such particulate matter and gaseous pollutants from crackers poses deleterious effects on human health, especially during such festivals where huge amount of fireworks are being consumed. Levels of Sulphur dioxide, which can lead to a spike in asthma, bronchitis and bronchiolitis, were also found to be very high in many areas.

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