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Air Quality deterioration by Firecracker during Diwali Festival in Jamshedpur, India

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ABSTRACT

During Diwali festival public used to burn firecrackers to express their happiness and joy. Fireworks in large amounts exaggerate the level of air pollutants and cause significant short-term air quality degradation. In this study pilot experiment were analyzed for PM_{10}, $PM_{2.5}$ and inorganic (sulfate, ammonium, nitrate, potassium, chloride, sodium, calcium and magnesium) chemical components. Initial results show that throughout day and night times for pre Diwali (before Diwali), Diwali day and post Diwali (after Diwali). On Diwali schedule the short term PM_{10} concentration was between 430 µg m^{-3} *(before Diwali) to 883 µg* m^{-3} *(Diwali day), which is about fourteen times higher than the Indian Ambient Air Quality (NAAQ) Standard which is 60 µg* m^{-3} *and $PM_{2.5}$ Concentration was between 183 µg* m^{-3} *(before Diwali) to 263 µg* m^{-3} *(Diwali). The $PM_{2.5}$ values are more than six times higher than the NAAQ Standard value which is 40 µg* m^{-3}.

Keywords: PM_{10}, $PM_{2.5}$, Diwali, Ions, Firecrackers, NAAQS.

INTRODUCTION

Diwali is one of the biggest festival in India and different colorful varieties of fireworks are always associated with this festival. On this auspicious day, people light up diyas and candles all around their house. The festival Diwali is never complete without bursting of fireworks. The burning of fireworks is enormous source of gaseous pollutants such as ozone, sulphur dioxide, and nitrogen oxides [1,2] as well as of suspended particles. The aerosol particles released by fireworks are usually composed of metals (e.g. potassium, magnesium, strontium, barium, and copper), elemental carbon and secondary compounds like nitrate and organic substances [3-6].The subject of exposure to preeminent particle concentrations throughout celebrations with fireworks has insinuations in many countries of the world (e.g. during Diwali Festival in India, New Year's celebration world-wide, Las Fallas in Spain, Lantern Festival in Beijing etc.). During Diwali festival in India, Ba, K, Al and Sr went up to 1091, 25, 18 and 15 times higher [3], black carbon increased by a factor of over 3 [7], and SO_2, NO_2, PM_{10}, TSP increased 2–10 times higher [2].During fireworks on Lantern Day in China, PM_{10} showed an increase of up to 183% over the previous days while $PM_{2.5}$ and PM_{10} were more than 6 and 4 times higher than the normal day. During firework incident in Milan, Italy PM_{10} mass and chief contributors were elemental and organic carbons as metals such as Mg, K, Sr, Ba and Cu etc.,[8].Firecrackers are commonly used during celebrations because of their sound, sparkle and sudden burst of colors, expressing the festive mood. They are used during Tihar in Nepal, Hari Raya in Malaysia, Day of Ashura in Morocco, Guy Fawkes Night or bonfire night in the United Kingdom, Independence Day and Halloween in the USA, Bastille Day in France, Spanish Fallas and New Year's Day in Guatemala, Chinese New Year by the Chinese and many other festivals all over the world.

Nevertheless in India Diwali festival is considered as a short term sources but is adverse effect due to burning of oil lamps, crackers and fireworks [9]. There is many studies have been carried out to explain the effect of burning of fireworks in many urban cities. The short period average of PM_{10}, $PM_{2.5}$ and PM_1 concentration during Diwali festival and observed upsurge of particulate matters related with Diwali celebration in megacity Delhi [10]. Raising concentrations of various air pollutants such as O_3, NO_2, NO and PM_{10} were measured throughout the Diwali fireworks. amazingly, the organic analysis of the Particulate Matter (PM) samples collected on Diwali exposed the emanation of a diversity of hazardous organic compounds during the fireworks shows**.** The burning of fireworks consists mainly of fine toxic dusts and chemicals that easily enter the lungs and responsible for severe health impact.

The objective of the present study was set to monitor air quality parameters such as PM_{10}, $PM_{2.5}$, Mg^{2+}, $K^{+,}$ SO_4^{2-} , $NH_4^{+,}$ NO_2^- , NO_3^- , Ca^{2+}, Cl^- and Na^+ on and around the day of Diwali in the year 2012. The results are compared with typical winter day concentration levels for the chosen parameters and with the ambient air quality standards. The probable health impact for observed short-term degradation in air quality.

MATERIALS AND METHODS

Study Area: Jamshedpur is the home to one of the largest industrial zones of India . The Adityapur which houses more than 1,200 small and medium scale industries. The population is 1,337,131; the Jamshedpur urban agglomeration (JUA), which includes the adjoining areas, The JUA is the third largest city in Eastern India after Kolkata and Patna. Jamshedpur (fig. 1) is situated in the southern end of the state of Jharkhand and is bordered by the states of Orissa and West Bengal. The average elevation of the city is 135 m while the range is from 129 m to 151 m. Total geographical area of Jamshedpur is 149.23 km square. Jamshedpur is primarily located in a hilly region and is surrounded by the Dalma Hills running from west to east and covered with dense forests. The other smaller hill ranges near the city are Ukam Hill and the Jadugoda-musabani hill range. The city is also a part of the larger Chota Nagpur Plateau region. The region is formed of the sedimentary, metamorphic and igneous rocks belonging to the Dharwarian period. The study was carried out the residential Up Hostel; Jamshedpur (fig. 1) the sampler was operated on the terrace of a double-storied building at a height of ~20 m from the ground level. The samplers were mounted on a wooden platform at a height of 2 m from the roof level. The site was surrounded by open fields with a lot of vegetation in the immediate vicinity.

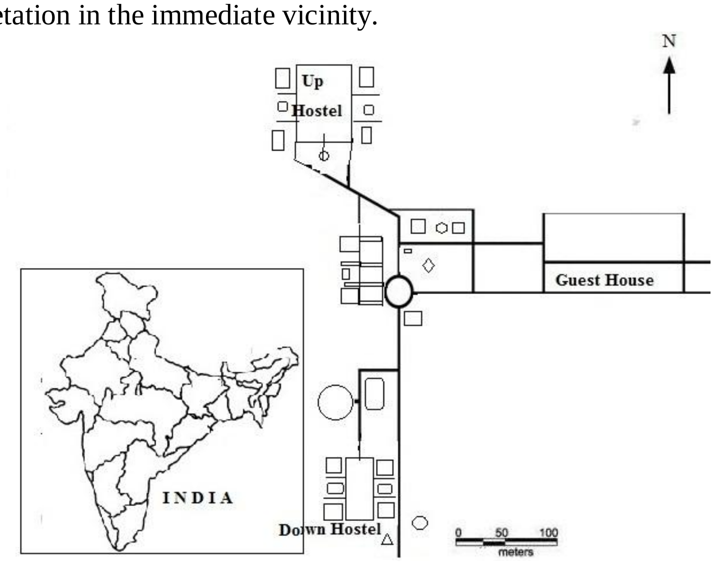

Fig.1 Location map showing the sampling area.

Sample Collection : The ambient air sampling was carried out by using an PM_{10} and $PM_{2.5}$ samples were collected by using Envirotech (New Delhi, India) APM-460 and APM-550 high volume sampler respectively, having a minimal particle size cutoff with diameter of 10 mm and 2.5 mm respectively. set up operating at an ambient air flow rate of l $m^3 min^{-1}$ (CPCB-2000; 2006) for 11 h from 6.00 AM to 5.00 PM in the before and after and same festival days. The filtration media for each PM_{10} were 47mm Whatman quartz microfiber filters (QM/A) and $PM_{2.5}$ collected by Teflon micro fiber filter paper (2µm PTFE) of size 46.2mm. The filters were cleaned by heating at 800 ^{0}C for 3 h before being used. All the filters are pre-conditioned at 25°C and 60% relative humidity before sampling and post-conditioned after sampling at same condition, each day the one samples were always kept as a blank. The blank filters were kept at same condition as the actual samples. After the sampling filters were immediately transferred to a sealed plastic container and kept in refrigerator till further analysis. Subsequently the collection of aerosol samples, filters were again conditioned at 20±5^{0}C temperature and a relative humidity of 40±5 % for ~24 h and then weighed three times using an electronic microbalance (Sartorius Micro MC210P). All weight measurements were repeated thrice to ensure reliability, and average was taken to make the consistency in reading.

Sampling schedule and wind diagram: The samples were collected for 11 h in day and night during Before Diwali, Diwali and After Diwali days, the systematic plan for sampling schedule are described in table.1 and fig.2 presenting the wind velocity data; which indicates meteorology to give a short and irritable view of wind speed and direction are typically distributed at a particular location of Jamshedpur.

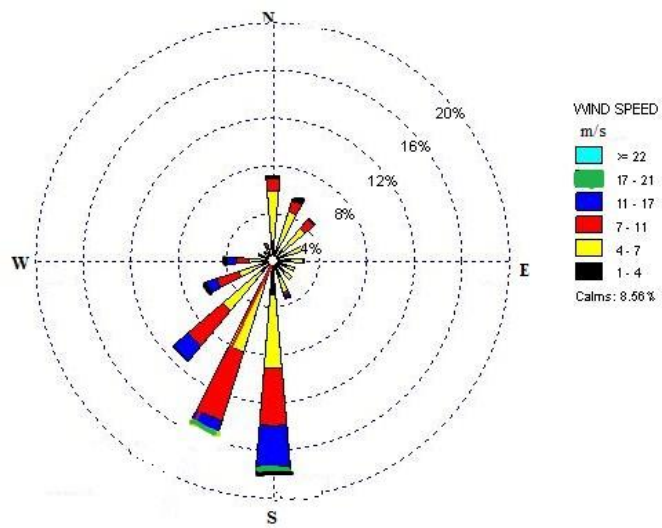

Fig. 2 Wind rose diagram of Jamshedpur during the Diwali schedule period (wind speed in m/s)

Table: 1 Sampling Schedule during firework displays in Jamshedpur

Sample Set	Sampling date	Sampling time	Duration (hrs)
Before Diwali	12-11-2012	6.00 AM-5.00 PM	11
	12-11-2012	6.00PM- 5.00 AM	11
Diwali	13-11-2012	6.00 AM-5.00 PM	11
	13-11-2012	6.00PM- 5.00 AM	11
After Diwali	14-11-2012	6.00 AM-5.00 PM	11
	14-11-2012	6.00PM- 5.00 AM	11

Aerosol composition analyses: Composition analysis of the exposed filters was done by the following way-

Each exposed filter is cut into half portion and then one half portions is cut into several small fragments and kept in a digestion vessel which was a conical flask of 100 ml capacity. Then 20 ml of conc. nitric acid (65%, analytical grade) was poured into the digestion vessel and it is then placed over a hot plate and kept for around 2h at 180°C until the most of the nitric acid is evaporated but not completely dried the vessel. The residual is then filtered through 22 µm Teflon filter and diluted to 100 ml for elemental analysis.

The PM_{10} and $PM_{2.5}$ collected on the filter paper was estimated following the guidelines of United states EPA [11].

For the analysis of the soluble ions (Cl^-, NO_3^-, $SO_4{}^{2-}$, Na^+, K^+, NH_4^+, Ca^{2+}, Mg^{2+}) one aliquot was extracted 20 min ultrasonically in 3 ml ultra-pure water. All field blanks and a laboratory blank were treated in the same way as the samples. The determination of the ions was performed with anion (Dionex AS12A, electrochemical suppression, sodium carbonate/bicarbonate eluent, eluent flow 1.5 ml min^{-1}) and cation (Dionex CS12A, electrochemical suppression, methansulfonic acid eluent, eluent flow 1ml min^{-1}) chromatography using standard procedures.

RESULTS AND DISCUSSION

Per day and night average values of PM_{10} and $PM_{2.5}$ mass concentrations based on their observations in the Jamshedpur region during 12 November to 14 November, 2012 are presented in Fig. 2. The short term PM_{10} concentration range was between 430 μg m^{-3} (Before Diwali) to 883 μg m^{-3} (Diwali). According to National Ambient Air Quality (NAAQ) Standards [12] using Beta attenuation system for continuous monitoring of $PM_{2.5}$ and PM_{10} are set to 60 μg m^{-3} and 100 μg m^{-3} for 24-hour average respectively. (http://cpcb.nic.in). The PM_{10} is about fourteen times higher than the standard and $PM_{2.5}$ concentration was between 183 μg m^{-3} (before Diwali) to 263 μg m^{-3} (Diwali). The $PM_{2.5}$ values are more than six times higher than the standard value. Fig. 3 shows the average concentration of PM_{10} and $PM_{2.5}$ during day time and night time. During Diwali night PM_{10} was highest. Similar type of research result was found by[2,3,13].

Like short-term degradation in air quality of episodic nature has been observed in several studies at different urban locations of India carried out during Diwali by Central and State Pollution Control Boards in recent years[14].

During Diwali day the Fireworks began at early morning 9.00 AM and finished close to midnight and maximum fireworks observed during evening 5.00 PM to 11.00 PM. As Diwali is the festival of light and celebrated during nighttime, the unfavorable meteorological conditions (lower wind speed, lower boundary layer height etc.) for the dispersion of pollutants during night-time helps them to be accumulated near the earth surface till next day day-time.

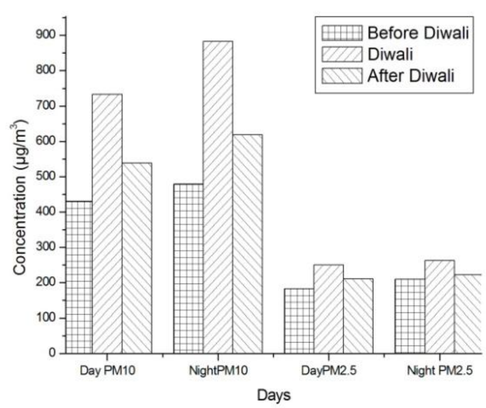

Fig. 3 Average concentration of PM_{10} and $PM_{2.5}$ during day time and night time

The average concentration of anions and cations of PM_{10} and $PM_{2.5}$ during day time and night time trials was given in fig. 4 to 7. In which Day events, in Fig. 4 shows the average concentration of Days PM_{10} with anions and cations during Diwali the concentration of magnesium and potassium were highest. In Fig. 5 displays average concentration of Days $PM_{2.5}$ with anions and cations during day Diwali potassium and magnesium were maximum. But in night events, in Fig. 6 focus the average concentration of Night PM_{10} with anions and cations during day Diwali it was found that magnesium and potassium are main component. In figure Fig. 7 the average concentration of Night $PM_{2.5}$ with anions and cations during day Diwali, here we have also seen the same type of result means magnesium and potassium was highest amid all the anions and cations.

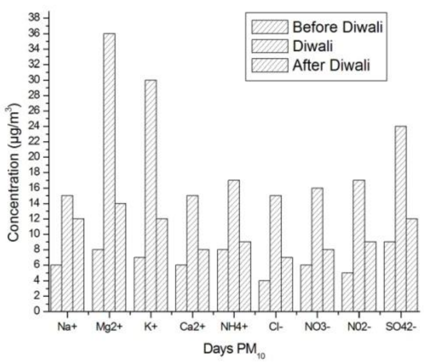

Fig. 4 Average concentration of Days PM_{10} with anions and cations during Diwali

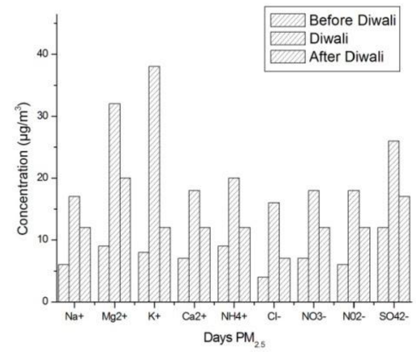

Fig. 5 Average concentration of Days $PM_{2.5}$ with anions and cations during day Diwali

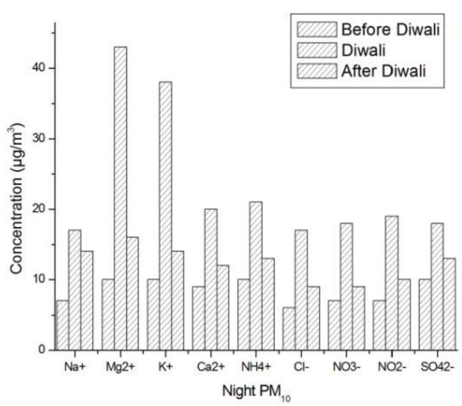

Fig. 6 Average concentration of Night PM_{10} with anions and cations during day Diwali

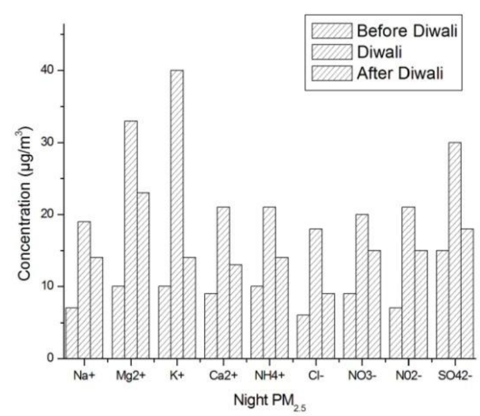

Fig. 7 Average concentration of Night $PM_{2.5}$ with anions and cations during day Diwali

Among the anionic components in Days PM_{10}, Days $PM_{2.5}$ and Night $PM_{2.5}$ were showed similar results were sulfate followed by nitrite and nitrate was the major and chloride was minor component but in night PM_{10} are nitrite followed by sulfate and nitrate and chloride was minor component. Whereas in cationic component, in Days PM_{10} and Night PM_{10} shows Magnesium followed by potassium and ammonium and was major and calcium and sodium were minor components. But in both Days $PM_{2.5}$ and Night $PM_{2.5}$ was shows Potassium followed by magnesium and ammonium were major and minor was calcium and sodium. The total ionic concentration in Days PM_{10} and Days $PM_{2.5}$ were followed by order $Mg^{2+} > K^+ > SO_4^{2-} > NH_4^+ > NO_2^- > NO_3^- > Ca^{2+} > Cl^- > Na^+$ but in Night PM_{10} is followed the following order $Mg^{2+} > K^+ > NH_4^+ > Ca^{2+} > NO_2^- > SO_4^{2-} > NO_3^- > Cl^- > Na^+$ and in Night $PM_{2.5}$ shows $K^+ > Mg^{2+} > SO_4^{2-} > NH_4^+ > NO_2^- > NO_3^- > Ca^{2+} > Cl^- > Na^+$. Very strong correlation was observed amongst all these ions indicating their sources are same means by burning of fireworks. Figure shows the major concentration like Mg^{2+}, K^{+}, SO_4^{2-} and NH_4^{+} are higher than other ions and which may be predicted that during fireworks powder preparation these ions are added. The addition of strontium, magnesium, barium, potassium and copper as firework tracers has been also reported by [8].The atmospheric emission of fireworks has a specific color significances like Na and K are used as metal oxidizers, Mg (white, silver), Cu (blue), Al (white, silver), Ba (white as carbonates and nitrates, green as chlorates), Sr (red), Na (yellow) and Ti (silver) are color and sparkle emitters, S is used as propellant, Zn is used to generate smoke effects, chloride, nitrate and sulfate are components of metal salts fabricating colors, potassium nitrate, sulfur and potassium chlorate or perchlorate are component of the black powder, the combustible material.

It has been roughly estimate that about half of the PM mass increase recorded during Diwali was due to element, magnesium and sulfate directly produced by fireworks explosion. It is also reasonable that a remarkable increase of elemental carbon (non–metallic fuels used in fireworks contain charcoal) and organic matter (burning illumination are widely used during the festival) occur during Diwali.

Throughout the study period inorganic species were found enriched more in $PM_{2.5}$ than PM_{10} it was due to burning of fireworks as strong source in emission of inorganic species in ambient air during this Diwali festival.

Similar air quality studies have been carried out during Diwali in by [2, 13].These studies have reported similar patterns of deterioration of short-term air quality. The present and similar studies, in both studies focus on consistently indicate acute short term increase of particulate matter in Diwali. For elementary studies Inter-correlations of the monitored pollutants for this investigate are calculated and the correlation matrix (for Pearson correlation coefficient) is presented in Table 2 and 3. The findings seem to suggest that the temporal variations of particulate levels are correlated in all Diwali studies. The similarities among the studies tend to establish the fact that acute increase of particulates in Diwali is not just a remote area but also in the urban side.

Table 2 Correlation matrix of Diwali PM_{10} aerosol

	Na^+	Mg^{2+}	K^+	Ca^{2+}	NH_4^+	Cl^-	NO_3^-	NO_2^-	SO_4^{2-}
Na^+	1.00	0.91	0.89	0.92	0.83	0.89	0.84	0.90	0.97
Mg^{2+}		1.00	0.83	0.90	0.81	0.93	0.78	0.87	0.86
K^+			1.00	0.94	0.79	0.97	0.96	0.86	0.74
Ca^{2+}				1.00	0.92	0.82	0.93	0.86	0.87
NH_4^+					1.00	0.81	0.85	0.95	0.85
Cl^-						1.00	0.78	0.92	0.97
NO_3^-							1.00	0.87	0.86
NO_2^-								1.00	0.96
SO_4^{2-}									1.00

Table 3 Correlation matrix of Diwali $PM_{2.5}$ aerosol

	Na^+	Mg^{2+}	K^+	Ca^{2+}	NH_4^+	Cl^-	NO_3^-	NO_2^-	SO_4^{2-}
Na^+	1.00	0.87	0.90	0.95	0.94	0.91	0.96	0.95	0.95
Mg^{2+}		1.00	0.97	0.92	0.85	0.93	0.91	0.93	0.93
K^+			1.00	0.86	0.91	0.91	0.85	0.84	0.89
Ca^{2+}				1.00	0.88	0.87	0.82	0.83	0.94
NH_4^+					1.00	0.89	0.93	0.89	0.93
Cl^-						1.00	0.94	0.93	0.86
NO_3^-							1.00	0.91	0.91
NO_2^-								1.00	0.89
SO_4^{2-}									1.00

APPLICATIONS

These studies are useful to know the Air Quality during Diwali days due to firecrackers and its Health effects.

CONCLUSIONS

The study shows deterioration in aerosol parameters concentrations associated with the Diwali festival when fire activities and anthropogenic activities are at a high peak. Experiment focuses on the burning of crackers and sparkles on the occasion of Diwali is a strong source of PM_{10}, $PM_{2.5}$, and ions in ambient air and are emitted in very high quantity, as high as seven to fourteen times, as compared to before and after-Diwali festival days. The short-term exposure of these contaminants and the high increase in their concentrations during Diwali festival can increase the likelihood of acute health effects. The same result may be expected in other cities in India as this festival is celebrated all over the country during fireworks celebration.

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