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The air pollution during Diwali festival by the burning of fireworks in Jamshedpur city, India

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ABSTRACT

Short-term measurements of PM_{10}, trace gases (SO_2, NO_2, and O_3) and heavy metals during Diwali festival were studied in a moderately polluted site in the city of Jamshedpur (India). In this study, Diwali day event recorded extremely high 12-h PM_{10} levels (500.5 μgm^{-3}, which is > 5 times to the WHO standard) and massive loadings of ozone (53.33 μgm^{-3}), SO_2(8.6 μgm^{-3}) and NO_2 (73.32 μgm^{-3}), On Diwali day, all the measured values for PM_{10}, SO_2, NO_2 and O_3 were found to be higher than prescribed limit of National Ambient Air Quality Standard (NAAQS) (PM_{10} = 60 $\mu g/m^3$). The first time study about any firework episode was carried in this region. The concentrations of Fe, Zn, Pb, Mn, Cu, Cd, Be and Ni were higher by the 2.2,1.5,2.8,1.6,2.2,1.2,5.9 and 3.3, times respectively, on Diwali as compared to normal days values. The metal concentrations on Diwali day were found to be significantly different from a normal day (except Zn & Cd). In Diwali day the Diurnal variation of PM_{10}, SO_2, and NO_2 was found to be significantly higher than daytime concentrations for a normal day (control). It was estimated that firework aerosol contributed 21–27% to ambient PM_{10} on Diwali. Inter correlation among the trace gases, PM_{10} and metals are clearly indicates the fireworks emissions extremely fluctuates in air quality. These results indicate that fireworks episode during Diwali festival affected the ambient air quality adversely due to emission and accumulation of PM_{10}, SO_2, NO_2, O_3, and trace metals.

1. Introduction

Diwali, or Deepawali, is a festival of “rows of light”, which is celebrated every year during October/November in India. Celebrating with the brightness and sparklers brings happiness, delight and festivity. Firecrackers are associated with worldwide festivities such as New Year's Eve celebrations (Bach et al., 1975), The Las Fallas in Spain (Moreno et al., 2007), The Lantern Festival in China, Bonfire Night in UK, Tihar in Nepal, Day of Ashura in Morocco, Sky fest in Ireland, Bastille day in France and Diwali in India (Babu and Moorthy, 2001; Ravindra et al., 2003; Kulshrestha et al., 2004; Ambade and Ghosh, 2013) and also with many other communities of the world (Drewnick et al., 2006; Vecchi et al., 2008; Nishanth et al., 2012; Cheng et al., 2014).

Firecrackers consist of, chemical such as potassium nitrate (KNO_3), potassium chlorate ($KClO_3$), arsenic (Ar), sulphur (S), manganese (Mn), sodium oxalate ($Na_2C_2O_4$), aluminium (Al), iron dust powder ($Fe_2O_3.H_2O$), potassium perchlorate ($KClO_4$), strontium nitrate ($Sr(NO_3)_2$), barium nitrate ($Ba(NO_3)$) and charcoal.(Barman et al., 2008; Ravindra et al., 2003; Kulshrestha et al., 2004). A laboratory study revealed that highly toxic contaminants like polychlorinated dioxins and furans are produced during the display of fireworks like “blue lightning rockets” and “fountains” (Wehner et al., 2000; Barman et al., 2008; Vecchi et al., 2008; Camilleri and Vella, 2010; Drewnick et al., 2006; Godri et al., 2010; Croteau et al., 2010). Burning of firecrackers release pollutants, like sulphur

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dioxide (SO_2, 10%,), potassium nitrate (75%), charcoal (15%), (Kulshrestha et al., 2004; Drewnick et al., 2006), carbon dioxide (CO_2), carbon monoxide (CO), suspended particles (including particles below 10 μm in diameter, i.e. PM_{10}) and several metals like aluminium, manganese and cadmium, etc., which accompanying with serious health risks (Burkart et al., 2013; Roberts, 2013; Tao et al., 2014; Sarkar et al., 2010).

In the Indian context, studies have also been reported on the air quality degradation for the firework activities during Diwali festival but studies are few. In Thiruvananthapuram, India a study about the effect of firework display during Deepawali on the mass concentration of atmospheric black carbon reveals over 3 times increase compared to normal days (Babu and Moorthy, 2001). Ravindra et al., 2003 has observed that there is 2 to 3 times increased in PM_{10} and TSPM concentrations in Hisar city (India) that leads to short-term variation in air quality during Diwali festival. Bursting crackers is turning to a competition and a status indicator. It is estimated that the annual U.S. carbon dioxide emissions from fireworks are 60,340 tons or the same emissions from 12,000 cars on the road for a year.

According to Attri et al. (2001) reported that the use of fireworks could produce ozone which is a strong and harmful oxidizing agent, at the ground level without the participation of NO_X. A different pattern of formation of O_3 during night-time on the basis of emission spectra derived from UV visible spectrophotometer has been suggested by Nishanth et al., (2012).

$$O_2 (\lambda < 240\ nm) \rightarrow O^{\cdot} + {}^{\cdot}O$$

$$O^{\cdot} + O_2 + M \rightarrow O_3 + M$$

$$NO_2 \rightarrow NO^{\cdot} + O^{\cdot}$$

$$O^{\cdot} + O_2 + M \rightarrow O_3 + M$$

$$NO^{\cdot} + O_3 \rightarrow NO_2 + O_2$$

$$NO^{\cdot} + HO_2 \rightarrow NO_2 + {}^{\cdot}OH$$

$$NO^{\cdot} + RO_2 \rightarrow NO_2 + RO^{\cdot}$$

Alkanes (RH) are formed in the gaseous phase during the burning of firecrackers which may react with the OH radical in the presence of O_2 to form alkyl peroxy (RO_2) radicals.

$${}^{\cdot}OH + RH \rightarrow H_2O + {}^{\cdot}R$$

$$R^{\cdot} + O_2 \rightarrow RO_2$$

$$RO_2 + NO_3 \rightarrow RO^{\cdot} + NO_2 + O_2$$

Thus the peroxy radicals efficiently convert nitrous oxide (NO) into nitrogen dioxide (NO_2) regenerating OH. The NO_2 which is formed is photolyzed in the presence of the blaze of firecrackers to generate O_3. This scheme proposed for night-time production O_3 by fireworks (Finlayson-Pitts and Pitts, 1997).

The particulate matter during cracker bursting has been a major concern for its short-term and long-term health effects. Despite the necessity of some of the metals in all living organisms, certain metals cause various toxic effects if accumulated in animal tissues (Yasutake and Hirayama, 1997) and One of the interesting source of the metals in the atmosphere in India are Diwali, one of the biggest festivals of India. A consensus has been reached regarding the adverse health impact of PM_{10} (Peters et al., 2001; Nastos et al., 2010; Bapna et al., 2013; Bhuyan et al., 2014). In India, during the Diwali festival there has been increased of 30 to 40% cases regarding respiratory diseases, wheezing, and exacerbation of bronchial asthma and bronchitis patients of all age and sex groups (Clark, 1997). It has been observed that inhalation of smoke from fireworks during Diwali causes a cough, fever, and dyspnoea and leads to acute eosinophilic pneumonia (AEP) (Hirai et al., 2000). Besides particulate matter, there is a strong relationship between higher concentration of SO_2 and several health effects like cardiovascular diseases (Cheng et al., 2014; Dockery et al., 2005), respiratory health effects such as asthma and bronchitis, reproductive and developmental effects such as increased risk of preterm birth (Liu et al., 2003). Along with the air quality, noise quality is also affected by the fireworks activity during Diwali festival. Noise is an unwanted and unpleasant sound, which acts as an environmental pollutant in the atmosphere which creates interference in communication and created health problems.

Firecrackers during Diwali emit a large amount of PM and poisonous gases in the air. They degrade the air quality which causes air pollution in the society leading to serious health hazards and disturbance in the ecosystem. The present aim of this study is to monitoring interpreting and assessing the concentrations of PM_{10}, trace gases (SO_2, NO_2, and O_3) and heavy metals during Diwali festival found at the Jamshedpur sites.

1.1. Area description and sampling site

The impact of firecrackers on the air quality over Jamshedpur in Jharkhand was carried out at National Institute of technology (NIT) Campus (22.8 N, 86.4 E), situated 7 km north from Jamshedpur town. The sampling site (Down Hostel) is situated near to NIT down boy's hostel. The Sampling site is close to state highway Jamshedpur kandra road, Godowns of Food Corporation of India, hotels, bakeries and Adityapur railway station also exist in the vicinity of the sampling area. Jamshedpur is a major industrial center of East India. It houses companies like Tata Steel, Tata Motors, Tata Power etc. It is home to one of the largest industrial zones of India