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Variation of particle number and mass concentration and associated mass deposition during Diwali festival

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ABSTRACT

Diwali is one of the main festivals in India when firecrackers bursting lead to short term increase in particulate matter (PM) concentration in atmosphere. In this study, real time observations of size segregated particles number and mass concentration have been made during Diwali campaign in November 2015 at Kanpur. Results show that particle concentrations were highest during Post Diwali night as compared to Diwali night. This is attributable to build up of pollutants concentration from local and upwind region during Post Diwali. The $PM_{2.5}$ mass concentration during Post Diwali was higher by a factor of 1.8 (day) and 1.3 (night) as compared to Pre Diwali. The average particle number concentration in ultrafine size (0.01 to 0.2 μm) and cumulative particle size (0.01 to 1 μm) during Post Diwali was higher by a factor of 6.8 and 3.7, respectively as compared to Pre Diwali nighttime. Size segregated PM data set for Pre Diwali, Diwali and Post Diwali periods were assessed for their deposition in human lung utilizing a computational model viz. MPPD (Multiple Path Particle Dosimetry). Results from lung deposition modeling have been systematically discussed. One of the major highlights of this study relates to penetration and significant deposition of fine particles in the pulmonary region during the study period in IGP. Our study, first of its own kind over Indian region, shows clearly the implications of air pollution on human health.

1. Introduction

Particulate matter (PM) has been linked previously to both short and long term adverse health impacts. The momentous rise in short term PM exposure (from few hours to a few days) has been concomitant to rise in hospital visits and admissions predominantly due to respiratory problems, eye irritants and skin diseases (Kaushik et al., 2006; Nag et al., 2005), oxidative stress and asthma attack (Holgate et al., 2003), cardiovascular morbidity and mortality (Raaschou-Nielsen et al., 2016; Rice et al., 2013). Studies have shown that escalation in $PM_{2.5}$ mass concentration (MC) by 10 μg/m^3 led to escalation in chances of acute coronary symptom by 4.5% (Pope et al., 2006) and congestive heart catastrophe elevate by 1.3% (Dominici et al., 2006). Monitoring at various places in densely populated Indo-Gangetic Plain (IGP), have shown the exceedance of PM national ambient air quality standard (NAAQS) of 100 μg/m^3 and 60 μg/m^3 for 24 h average PM_{10} and $PM_{2.5}$ mass concentration (MC). This gets even worse during the winter and post-monsoon season which include episodic event of fire cracking during Diwali festival and frequent biomass burning spread over the post-monsoon and winter season.

Diwali is one of the main festivals in India which is celebrated in the month of October or November (Nov). This festival is

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celebrated by lighting candles and bursting fire crackers mainly during evening time. The bursting of firecrackers leads to significant loading of gaseous pollutants (like nitrogen oxide, sulphur dioxide, ozone) and PM (Attri et al., 2001). This leads to short term degradation of ambient air quality which eventually affect adversely both visibility and human health (Hirai et al., 2000; Lin et al., 2016). This also changes the particle number and mass concentration size distribution characteristics of PM in the ambient air. Vecchi et al. (2008) reported the excessive increase of particle number concentration (PNC) with particles ranging between 0.5 and 1 μm during pyrotechnic display at Milan, Italy. Many studies over the Indian region have reported the significant rise in PM concentration during Diwali night and Post Diwali period (Karar and Gupta, 2007; Nasir and Brahmaiah, 2015; Ravindra et al., 2003). Nasir and Brahmaiah (2015) reported as much as 30 times increase in PM_{10} MC as compared to normal days.

Different particle sizes including ultrafine, fine and coarse are important characteristic of the emission sources (Rajeev et al., 2016; Rajput et al., 2016).Furthermore, numerous studies have revealed that ultrafine and fine size particles cause adverse health impacts as they get deposited in the deeper sections of our lungs, they are present in relatively higher number concentration, have large surface area so act as carrier for toxic species like PAHs and ultimately their residence time in human respiratory tracts is much longer (Gupta et al., 2004; Ham et al., 2010). Thus, particle size distribution of PM is very important for complete understanding and assessment of their deposition within human respiratory tracts. However, in most of the previous regional studies reported, these adverse assessment were primarily based on $PM_{2.5}$ and PM_{10}. In other words, the impact of ultrafine and fine particle size distribution and subsequent quantification of their deposition in human respiratory regions is hitherto unknown in the literature. One of the major objectives of the present study is to assess particulate matter size distribution and to quantify the deposition of PM mass in different regions of human respiratory system on and near to Diwali period at Kanpur in northern India.

2. Methodology

2.1. Sampling site

The measurements were carried out at roof-top of CESE (Centre for Environmental Sciences and Engineering) building, Indian Institute of Technology Kanpur, India (26.30°N, 80.14°E; 142 m above mean sea level) (Fig. 1) (Chakraborty et al., 2017; Rajput et al., 2018). Sampling was carried out near continuously for about 7 days starting from 8th Nov 2015, 10 am to 15th Nov 2015, 8 am. The main festival of Diwali was on 11th Nov. However, in the next consecutive days till 14th Nov intermittent fire cracking activities were still active during early morning and evening time. Therefore, we have considered 9– 10th Nov as Pre Diwali period, 11th Nov as Diwali period and 12–14th Nov as Post Diwali period and represented systematically throughout this paper. It should be noted that during the months of post-monsoon and winter, the Kanpur city receives air-masses predominantly from North-west direction

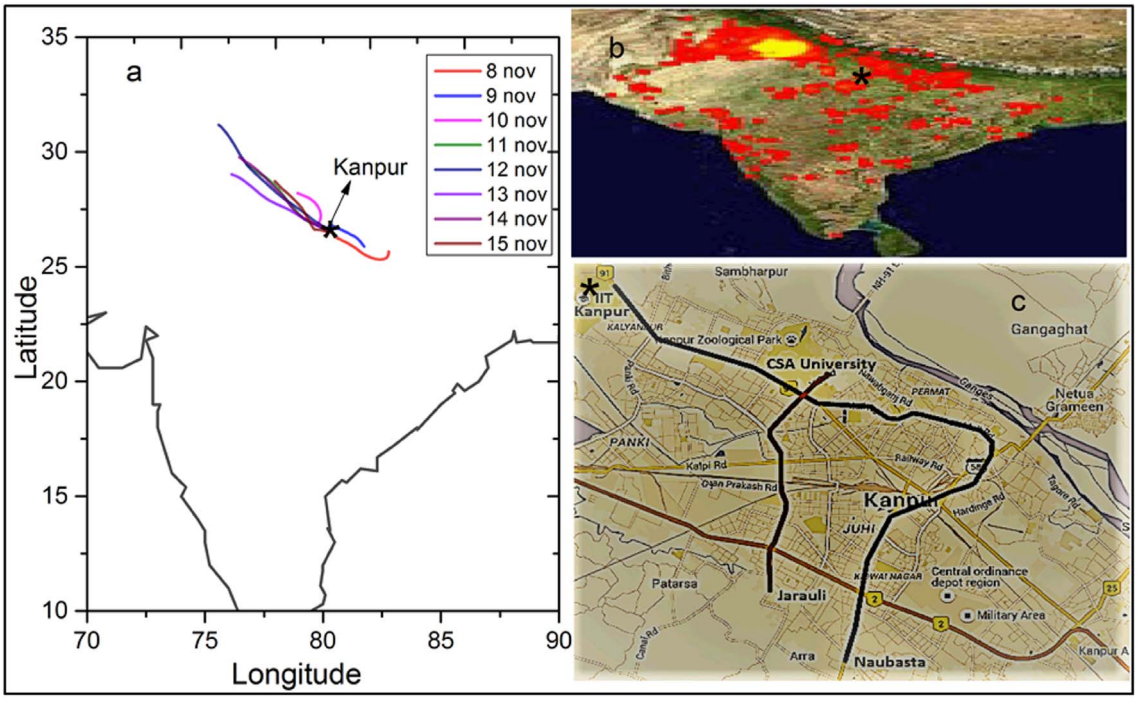

Fig. 1. (a) Air-mass backtrajectories at sampling site (IIT Kanpur, star mark) h at height of 500 m above mean sea level, for all sampling days. (b) The fire map data showing locations of the fires detected by MODIS on board the Terra and Aqua satellites during Diwali period. The yellow colour shows more intensity of fire compared to red (https://lance.modaps.eosdis.nasa.gov/cgi-bin/imagery/firemaps.cgi). (c) The spatial distribution of Kanpur showing main road and built areas. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)