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Effects of air pollution on meteorological parameters during Deepawali festival over an Indian urban metropolis

Upal Saha [a, b], Shamitaksha Talukdar [b], Soumyajyoti Jana [b], Animesh Maitra [a, b, *]

[a] Institute of Radio Physics and Electronics, University of Calcutta, 92 Acharya Prafulla Chandra Road, Kolkata 700009, West Bengal, India
[b] S.K. Mitra Centre for Research in Space Environment, Institute of Radio Physics and Electronics, University of Calcutta, 92 Acharya Prafulla Chandra Road, Kolkata 700009, West Bengal, India

HIGHLIGHTS

- Both long-term and short-term study reveals an increase in pollutant concentration.
- PM10 has been found to be the most dominant air pollutants during this Deepawali.
- Boundary layer is affected by retained change in lapse rate and low relative humidity.
- Windrose diagram also validated the cause of severe urban Deepawali pollution.
- Increased pollution is a serious concern on the changing pattern of environment.

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ABSTRACT

Atmospheric pollutants (NO_2, SO_2, PM10, BC, CO, surface O_3), emitted during fireworks display, have significant effects on meteorological parameters like air temperature, relative humidity, lapse rate and visibility in air over Kolkata (22°65′ N, 88°45′ E), a metropolitan city near the land–ocean boundary, on the eve of Deepawali festival when extensive fireworks are burnt. Long-term trend (2005–2013), indicates that the yearly average concentrations of both primary and secondary air pollutants have increased, exceeding the National Ambient Air Quality Standard (NAAQS) limit, on the respective Deepawali days. Short-term study (2012–2013) during the festival shows that the average pollutant concentrations have increased too compared to normal days. This study also reveals the immediate effects of the increased air pollutants on the boundary layer meteorology. PM10 has been found to be the most dominant atmospheric pollutants during this period. As a result of an increase in atmospheric heat content with elevated surface air temperature, a significant increase in the environmental lapse rate bears a signature of the influence of pollutants on the boundary layer temperature profile. A change in the diurnal pattern of relative humidity as well as in the vertical temperature profile is due to the change of the lapse rate during the festival days. Thus, the atmospheric pollutants during this festival over the urban region have significant effect on the boundary layer meteorology with bearings on environmental hazards.

1. Introduction

In recent times, short-term air quality degradation episodes are drawing increased attention of the scientific community as they considerably affect human health through long-term adverse effects (Pope et al., 2002; Pope and Dockery, 2006; Nastos et al., 2010; Singh et al., 2010; Samoli et al., 2011; Bapna et al., 2013; Bhuyan et al., 2014). Burning of fireworks during festivals are significant contributors to air pollution in India, which are of increasing concern in terms of health hazards and effects on environment. Fireworks during celebrations like Deepawali in India, Lass Fallas in Spain, Lantern festival in Beijing, New year celebration belong to same category and have been reported to be significant sources of anthropogenic aerosols all over the world (Mandal et al., 1997; Drewnick et al., 2006; Vecchi et al., 2008; Wang et al., 2007; Nishanth et al., 2012; Vyas and Saraswat, 2012; Cheng et al., 2014). Deepawali festival experiences the most extensive burning of fireworks in India causing a major concern for environmental

* Corresponding author. Institute of Radio Physics and Electronics, University of Calcutta, 92 Acharya Prafulla Chandra Road, Kolkata 700009, West Bengal, India.
E-mail addresses: animesh.maitra@gmail.com, am.rpe@caluniv.ac.in (A. Maitra).

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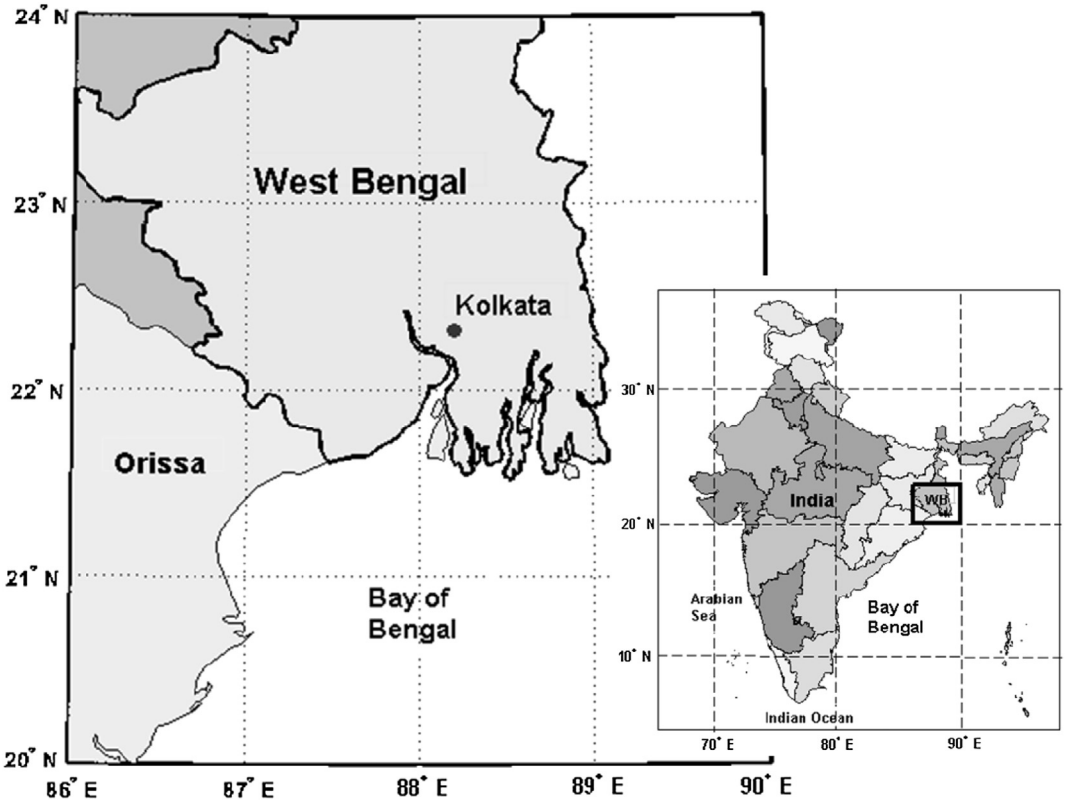

Fig. 1. Political map of India, the zoomed portion in a square box is shown outside the map presenting the geographical location of Kolkata showing the area of interest (black circle) for the present atmospheric pollution study (after: Saha et al., 2014).

and atmospheric pollutants such as, sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matters (PM10) and several metals like aluminium, manganese and cadmium, etc., are released in significant quantity associated with serious health hazards (Ravindra et al., 2003; Kulshrestha et al., 2004; Wang et al., 2007; Pachauri et al., 2013). The atmospheric pollutants not only causes health hazards (Burkart et al., 2013; Roberts, 2013; Tao et al., 2014) but also displays its effects on meteorological parameters, such as, aerosol optical depth, mixed depth, air temperature, relative humidity and lapse rate before, during and after the day of festival. Attri et al. (2001) reported display of fireworks could produce ozone (O_3), a strong and harmful oxidizing agent, at the ground level without the participation of NO_x. Babu and Moorthy (2001) reported a three-fold increase in atmospheric black carbon (BC) in Thiruvananthapuram, India during Deepawali. In Hisar, India a study about the short term variation in air quality during Deepawali reported 2–10 times increase in concentrations of PM10, TSP (total suspended particulates), NO_2 and SO_2 over a typical winter day (Ravindra et al., 2003). Barman et al. (2008, 2009) reported the remarkable increase in PM2.5 concentration in Lucknow city due to firework activities during Deepawali festival. Effect of firework activities during this festival on surface ozone has also been reported in Delhi (Ganguly, 2009; Attri et al., 2001).

Kolkata, situated in the eastern part of India, is located near the world's largest delta of Ganges in Bay of Bengal. The ambient air quality over this region is severely affected due to the industrialization and urbanization with very high population density. The daily vehicular emissions results in the increase of atmospheric pollution with heavy particulate-loading (Chatterjee et al., 2013). However, Kolkata also receives pollutants from the coastal regions as well as oceanic sprays. Deepawali festival is also celebrated in Kolkata along with rest of India with great enthusiasm. Huge amount of crackers and sparklers are burnt mainly on the day of festival (Deepawali day) and also on the day before and the day after. A very few researchers have studied and published data regarding the effect of firework activities on aerosol and its several components during Deepawali festival over Kolkata and its adjoining areas (Thakur et al., 2010; Chatterjee et al., 2013). The purpose of this present study is to find out the short-term effects of the primary pollutants (NO_2, SO_2 and PM10) and secondary pollutants (BC, CO and surface O_3) on the meteorological parameters, such as, air temperature, relative humidity, environmental lapse rate and visibility in air, during the Deepawali festival over Kolkata for the years 2012–2013. The long term variation of atmospheric pollutant concentrations are also studied during the period 2005–2013.

Table 1
Dates of the present study during Deepawali festival.

Time of study	2012	2013
Pre-Deepawali	12th November	2nd November
Deepawali	13th November	3rd November
Post-Deepawali	14th November	4th November

Table 2
National Ambient Air Quality Standards (NAAQS), by CPCB, India.

Atmospheric pollutant	National Ambient Air Quality Standards
Nitrogen Dioxide (NO_2)	80 μg/m^3 (24 h)
Sulphur Dioxide (SO_2)	80 μg/m^3 (24 h)
Particulate Matter (PM10)	100 μg/m^3 (24 h)
Carbon Monoxide (CO)	2 mg/m^3 (8 h)
Surface Ozone (O_3)	100 μg/m^3 (8 h)