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Short-Term Introduction of Air Pollutants from Fireworks During Diwali in Rural Palwal, Haryana, India: A Case Study

S Gautam^{1,2}, A Yadav², A Pillarisetti³, K Smith³ and N Arora²

1 Marwadi University, Rajkot, India

2 The INCLEN Trust International, Okhla Industrial Area, Phase-I, New Delhi, India

3 School of Public Health, University of California, Berkeley, Berkeley, United States

E-mail: sneha.gautam@marwadieducation.edu.in

Abstract. The contribution of firework-related air pollutants into the rural atmosphere was monitored by measuring ambient air concentrations of PM_{2.5}, CO, and metals over Mitrol–Aurangabad, Haryana, India, before, during, and after the 2015 Diwali celebration. PM_{2.5} concentrations were observed to be approximately 5 times and 12 times higher than Indian and WHO 24-h standards, respectively. CO concentrations on the day of Diwali were found to be nearly 7.5 times and nearly 1.5 times higher than Indian standards and WHO 8-h standards, respectively. Increased concentrations of SO₄, K, N₃, Al, and Na were observed. SO₄, K, N₃, Al, and Na were found between approximately 2 and 5 times higher on festival days than on a normal, non-festival day in November. Use of firecrackers during Diwali and surrounding celebrations thus contribute to decreased air quality and elevated levels of air pollutants associated with adverse health impacts. Optimization or controlled use of firecrackers during Diwali is suggested in rural areas.

1. Introduction

In recent years, there has been concern that degradation of air quality and subsequent effects on human health has increased due to use of fireworks during festivals and celebrations [1]. Fireworks are closely linked to elevated levels of pollutants, including particulate matter, SO₂, NO_x, K, and ozone, amongst others [2]. In India, a number of festivals are celebrated throughout the year; Diwali, the Festival of Light, is one of the most important. Diwali is celebrated between the pre-winter season (October) and the post-monsoon season (November). As the festival of light, firecrackers are often used on the days before and during the festival, resulting in deteriorated air quality. Pathak et al. [3] and Wang et al. [4] reported that fireworks used during Diwali create high mass concentrations of particulate matter (PM) with a chemical composition that varies from normal atmospheric conditions and can be harmful to human health.

Pathak et al. [3] quantified the amount of PM exposure by air mass back trajectory analysis using the NOAA–HYSPPLIT model in order to examine the existence of the transported aerosols which people in urban areas are exposed to over the short-term. PM emitted from firecrackers and its contribution to pollution in the urban atmosphere has also been measured [3], [5]. Further recent studies [3], [6] measured elevated local PM concentrations due to firecrackers during Diwali. Moreover, Hindustan Times [7] reported that the Delhi pollution Control Committee (DPCC)'s reported Air Quality Index (AQI), a combined measure of air pollution, peaks between 6 pm – 1am on Diwali. The AQI starts a downward trend after 2 am. Data from real-time monitoring stations operated by DPCC, Indian Institute of Tropical Meteorology (IITM), and Indian Meteorological Department (IMD) indicate that



concentrations of PM_{10} and $PM_{2.5}$ exceed the national standards during festival periods, sometimes by greater than 10 times.

While these early studies evaluate concentrations in urban area of India, there is no information about the air quality of rural areas during Diwali. According to the recent report of The World Bank [8], 68% of the Indian population is rural. Despite growing evidence of adverse air quality and health effects attributable to the use of fireworks, no literature could be found measuring PM, its constituents, or CO in rural areas of India during Diwali. In the present study, the particle concentrations, including metals and ion analysis, and CO levels were recorded to describe the short-term impact of firecrackers on concentration due to Diwali in the rural area of Palwal District, Haryana state, India.

2. Material and methods

2.1. Study area

INCLIN has established SOMAARTH: a Demographic Development and Environment Surveillance Site (DDESS) in Palwal district, Hayana covering 51 villages (Figure 1). The demographic surveillance site includes 51 villages (approximately 200,000 population) from three Blocks of Palwal (Hathin, Hodal and Palwal) and is circumscribed by three major roads – Mathura National Highway (NH2) that forms eastern boundary of surveillance site; Palwal–Hathin State Highway, forming the western boundary; and intersecting roads that form the southern boundary (Figure 1).

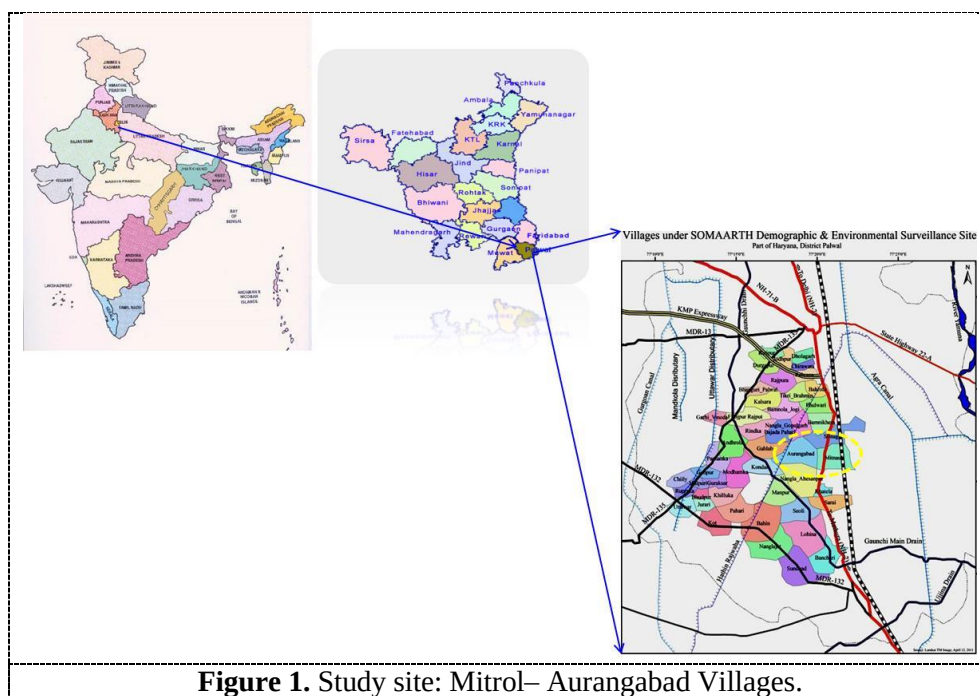


Figure 1. Study site: Mitrol– Aurangabad Villages.

2.2. Sampling protocol

In the year 2015, Diwali was celebrated on 11th November. Data were collected for 8 days, beginning 9th November 2015 and ending 16th November 2015. Firecracker activities were observed to begin in the evening (around 18:00) and continued until approximately 1:00. Sampling began nightly at 17:00. CO was measured for 24 hr, while PM was monitored in three 8 hr periods.

To measure $PM_{2.5}$, we utilized an URG-2000-30ED cyclone (URG Corporation, Chapel Hill, NC, USA) connected to an SKC PCXR8 pump (SKC Inc, Eighty-Four, PA, USA) running at a flow rate of 3 liters per minute. To ensure a stable power supply to the PCXR8, batteries were changed every 8 hours (daily at 6:00, 14:00, and 22:00). Flows were checked pre- and post- battery exchange using a Mesa DryCal Defender 530 (Mesa Labs, Butler, NJ, USA). $PM_{2.5}$ was collected on pre-weighed 47mm

PTFE filters. Filters were pre- and post-weighed at Kirk R. Smith's laboratory at University of California, Berkeley after being conditioned for 48 hours at 23-25 °C and a relative humidity of between 35 and 40%. Filters were weighed in triplicate on a Mettler-Toledo XP2U microbalance with a readability of 1 $\mu\text{g m}^{-3}$. To measure CO, we used a Lascar EL-CO-USB electrochemical monitor with a detectable range of 0 – 500 ppm. Batteries in the CO monitor were replaced every 48 hours.

2.3. Elemental, cation, and anion analysis

The sampled PTFE filters were analyzed for elements, anions, and cations by Desert Research Institute (Reno, NV, USA). Elemental analysis was performed by X-ray Fluorescence (XRF) using the PAN analytical Epsilon 5 XRF analyzer, which uses a side-window, dual-anode x-ray tube with Scandium and Tungsten anodes. Seven different condition sets are used during a single analysis run to enable detection of specific groups of elements. Anions and cations analysis was performed using the Dionex ICS 5000, a liquid chromatographic technique based on an ion exchange mechanism and suppressed conductivity detection for the separation and determination of cations and anions.

3. Results

3.1. CO concentration

Figure 2 depicts the CO concentration profile during the experiment. Mean CO concentrations (averaged over 8 hour periods) were higher during Diwali as compared to non-Diwali. The average concentration of CO varied from 0.62 – 15.4 mg m^{-3} (Figure 2). The 8-hour CO standard for residential areas in India is 2 mg m^{-3} . In the present study, CO concentration varied between 0.62 – 15.1 mg m^{-3} .

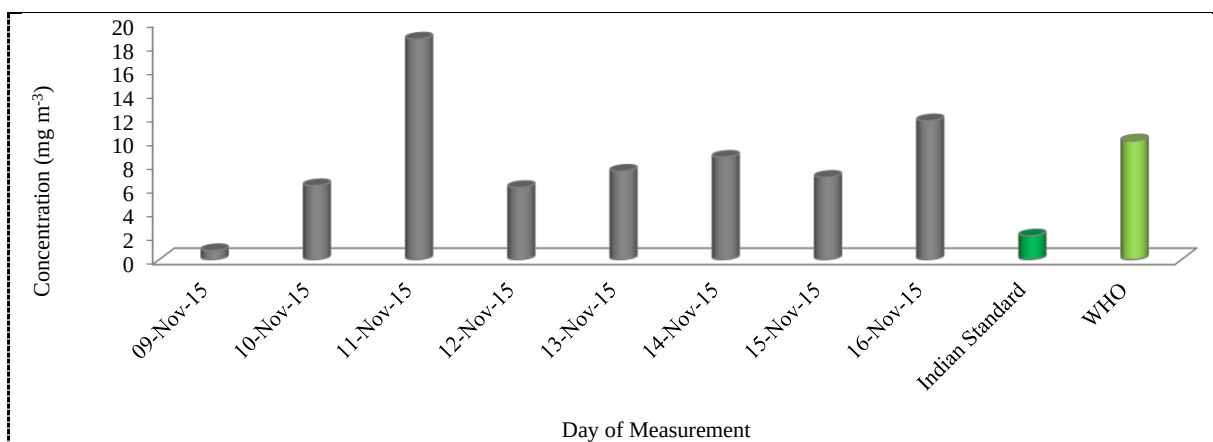


Figure 2. Average CO concentration profile with Indian standards and 8 hour WHO guideline at Mitrol – Aurangabad Village [9, 10].

3.2. PM concentration ($\text{PM}_{2.5}$)

The 24-hour average concentration of $\text{PM}_{2.5}$ during Diwali is depicted in Figure 3. The concentrations vary between 141 to 345 $\mu\text{g m}^{-3}$. The results indicate variability of fine particle concentration between the pre-Diwali (9th November) period, Diwali (11th November) itself, and the post-Diwali (12th November) period. Higher concentrations of $\text{PM}_{2.5}$ were recorded on 10th and 12th November, 2015. The 24-hour average concentration of $\text{PM}_{2.5}$ during pre-Diwali, Diwali, post-Diwali periods and a normal day are depicted in Figure 4.

The concentration of fine particle decrease as one moves further forward in time from Diwali. The festival day concentrations were 2.10 times, 1.31 times, and 1.34 times higher than a normal day, and the pre-Diwali and post-Diwali concentrations, respectively. The incremental difference in concentration from a normal day was 155 $\mu\text{g m}^{-3}$.

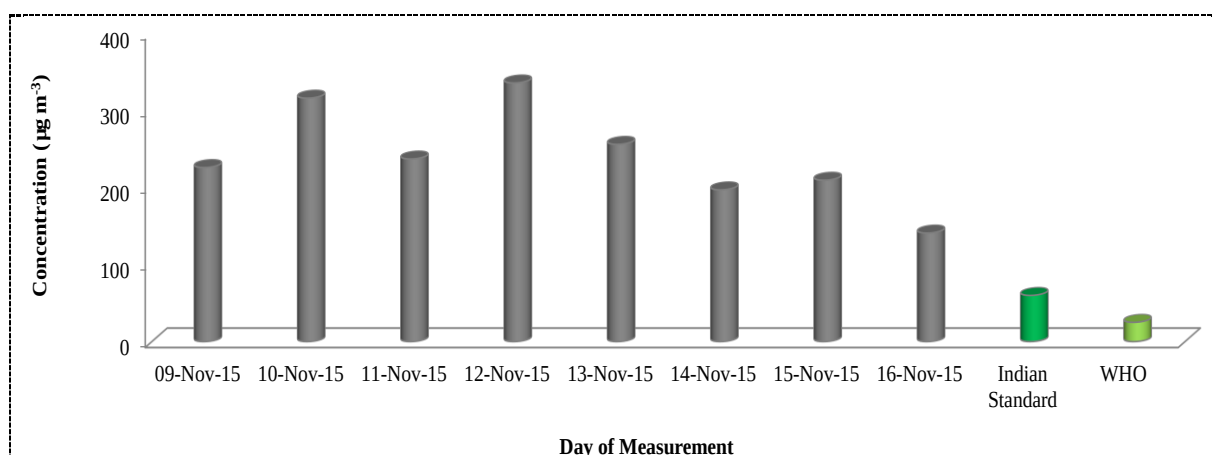


Figure 3. Daily average $PM_{2.5}$ concentration profile with Indian standards and WHO guidelines at Mitrol – Aurangabad Village [9], [11].

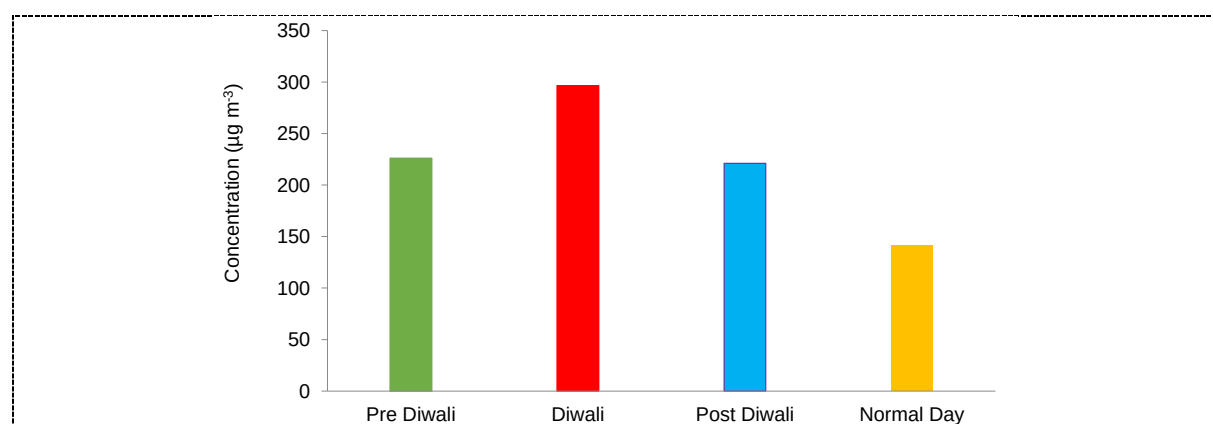


Figure 4. Variation of $PM_{2.5}$ concentrations on Pre- Diwali, Diwali, post-Diwali and Normal day at Mitrol – Aurangabad Village.

3.3. Variation of $PM_{2.5}$ and CO concentration at Mitrol – Aurangabad Village

The 24 hr and 8 hr average concentration of $PM_{2.5}$ and CO respectively in the study village during Diwali festival are depicted in Figure 5. For both $PM_{2.5}$ and CO, the average concentrations were observed higher during Diwali as compare to normal day of measurement. Figure 5 shows the higher concentration of CO during the night of Diwali, which could be due to the increased use of solid fuel to make sweets for the festival. On a normal day, the higher concentration of CO could be attributed to the maximum open pit fire observed near the sampling location. The higher concentration of $PM_{2.5}$ on the day following Diwali could be due to effect of “Goverdhan Puja,” a separate celebration. The average concentration of $PM_{2.5}$ and CO during pre and post Diwali were observed to be almost same as on a normal day (Figure 5). Mg, Zn, Fe, Mn, Cu, Sr, and Cd have low concentrations pre-Diwali, post-Diwali, and on a normal day, but were elevated during Diwali. Similarly, SO_4 , K, N_3 , Al, Na, NH_4 , and Ba have been shown to have higher concentrations during Diwali than on a normal day. These increases potentially indicate the impact of firecrackers on ambient air quality on the night of Diwali, as evidenced by increased concentrations of $PM_{2.5}$ and CO.

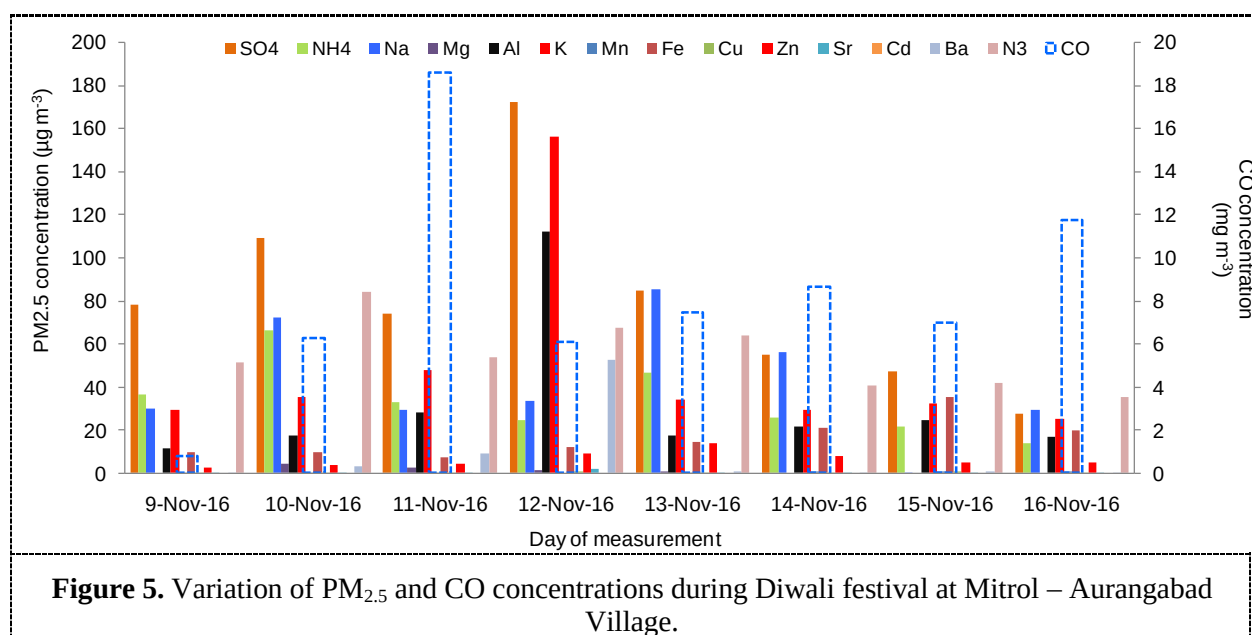


Figure 5. Variation of $PM_{2.5}$ and CO concentrations during Diwali festival at Mitrol – Aurangabad Village.

4. Discussion

The daily mean CO concentrations measured were as high as 7.5 times and 1.5 times the Indian National Ambient Air Quality Standards (NAQSQS, 2 mg m^{-3} for 8 hr, [9]) and WHO standards (7 mg m^{-3} for 8 hr, [11]), respectively. The observed results are, however, comparable with CO concentrations of $0.21 - 26.1 \text{ mg m}^{-3}$ [12] reported previously for rural area of developing country in a non-festival period.

The maximum average $PM_{2.5}$ concentration measured was 296 µg m^{-3} on Diwali, which were ~5 times higher than the Indian standard and ~12 times higher than the WHO 24-h standards [11]. The recorded concentrations during the festival were 1.32 times, 1.34 times and 2.1 times higher than the concentration of pre-Diwali, post-Diwali and normal day respectively. SO_4 , K, N_3 , Al, Na, NH_4 , and Ba were 1.52 times, 1.13 times, 1.51 times, 4.59 times, 2.74 times, 52.4 times, and 1.34 times higher than pre-Diwali concentration, 1.91 times, 1.33 times, 0.95 times, 2.47 times, 2.51 times, 35.9 times, 1.41 times higher than post-Diwali concentration, and 4.30 times, 3.03 times, 1.53 times, 3.11 times, 3.19 times, 86.6 times, and 1.93 times higher than normal day concentration. In our study setting, people generally celebrated “Choti Diwali” (“Small Diwali”) on the 10th November and “Goverdhan Puja” on the 12th November with firecrackers, potentially explaining elevated PM concentrations on those days relative to non-festival days and Diwali itself.

Our findings are comparable with $PM_{2.5}$ concentrations 2-3 times higher than normal concentrations [13], 5.74 times higher than normal concentrations [3], and 34.3 µg m^{-3} greater than normal concentrations [14] reported across different urban areas of India during the Diwali. Beyond Diwali, our study indicates elevated levels of $PM_{2.5}$ in rural areas even during non-festival days, warranting further investigation.

SO_4 and K show substantial elevations, presumably due to firework use on Diwali. $PM_{2.5}$ metals species concentration were recorded to follow a same trend at Mitrol – Aurangabad village during study period and which was, Diwali > post-Diwali > pre-Diwali > normal day. Our research indicates that an impact of Diwali firework uses on the next day (post-Diwali) concentrations.

5. Conclusion

We report on the first measurements of the impact of Diwali on air quality in rural India. 68% of the Indian population lives in rural areas; this percentage has been consistent for the past 4 years [8]. In India, all of the air quality monitoring stations is operated in urban areas; no such stations are being operated in rural areas. Our findings suggest non-trivial increases in $PM_{2.5}$ and CO concentrations, as

well as changes in the elemental composition of PM_{2.5}, during this festival. The potential for exposure to the reported pollutants at elevated concentrations during Diwali can increase the potential for acute health effects, suggesting need for guidance in rural areas on ways to ensure that the most vulnerable populations are able to avoid additional exposure or rapidly seek treatment if needed. Stagnant air typical of winter months in North India prevents dispersion of pollutants. We suggest new strategies to reduce the emission from firework-related activities. Possible measures to reduce the emissions of or increase the dispersion of pollutants from fireworks include the following:

- Use of some plastic cracker (without chemical material and fire) with sound.
- Try to use firecrackers on flat open ground away from house or society to enhance proper pollutant dispersion.
- Ensuring that emergency medical treatment is available for vulnerable populations on festival and pre-festival days, which also see firecracker use.

6. References

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