Research Article

Association between changes in air quality and hospital admissions during the holi festival

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Abstract
In this paper we observe the association between changes in air quality and number of hospital admission during "holi—the festival of colours". Proposed research performed during holi festival, where playing colour are very common practice. Fine particle and its ion concentration were analyzed by air monitoring and ion chromatography. Reported concentration profile of fine particle were 25–40 μg m^{-3}, 54–171 μg m^{-3}, and 35–70 μg m^{-3}, for $PM_{2.5}$ and while for PM_{10}, 53–251 μg m^{-3}, 92–291 μg m^{-3}, and 58–277 μg m^{-3}, respectively, which are more than the permissible limit. The major anions (Sulphate, Nitrate, and Chloride) and cations (Sodium, Potassium, and Magnesium) were obtained on fine particle with higher permissible limit. $PM_{2.5}$ were 67 μg m^{-3}, which was 1.11 times and ~ 2 times higher than Indian and WHO standards, moreover, probably first time reported during holi festival. Very limited study is available on association between fine particle ($PM_{2.5}$) available in air quality and number of hospital admission. The pollution generated due to holi festival and hospital admission related data were collected in four different locations and nine hospitals near by the selected study area, respectively. Empirical relationships have been developed between particle concentration due to colour festival and hospital admission.

Keywords Fine particle · Holi festival · Colors · Eye irritation

1 Introduction

The earth's atmosphere and ambient air quality is significantly influenced by fine particles [9, 10]. Epidemiology studies have found the association between air particle concentrations and mortality along with other health risks, both daily and over time [31]. Recently, a growing number of studies in toxicology, and epidemiology have shown that increased fine particle concentrations are associated with health effects like respiratory diseases, eye irritation, skin diseases, increased system inflammation, oxidative stress, increased blood pressure, and allergic illness related problems [7, 8, 31, 32]. National Ambient Air Quality Standards (NAAQS) are implemented based on evidence from epidemiology and toxicology studies [5]. For example, United States Environmental Protection Agency (USEPA) developed NAAQS in 1997 and revised in the years of 2006, 2012, and 2013, to protect public health and environment and its variations being adopted in other countries [28].

Air quality in South Asian countries especially in India varies extensively over time and across different states or areas. According to the recent studies [9, 10] on air quality in India, air pollution has increased overtime, resulting in deteriorating air quality and has been attributed to different anthropogenic activities across the areas. Gautam et al. [7, 8] reported that many Indian cities have been identified as amongst the most polluted in Asian countries, after Bangladesh, and China. Air pollution not only affects human health but also has impact on buildings and materials (i.e., Taj Mahal, Red Fort etc) [22].

Air pollution has both short and long term effects on health. Air pollution has adverse effects on eye,

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cardiovascular, respiratory and neurological system and affects individuals of all age groups [11]. Certain population groups (i.e., very young children and elderly) or populations with pre-existing health issues may be more sensitive to air pollutants than others. The indirect health costs related to the harmful effects of air pollution may be significant.

India is a country of festivals and among them holi is an important festival. Moreover, now holi is celebrated across many countries over the world [3]. Holi is celebrated between the late winter (February) and summer season (i.e., March–April). Bonfires are often it on the nights before and during the festival day can have significant impact on the ambient air quality. Concerns regarding degradation of air quality and possible subsequent effects on human health related to use of bonfire during festivals and celebrations has been highlighted [3]. Colours and bonfires are closely linked to elevated levels of pollutants, including particulate matter (PM), SO_2, NO_x, K, and ozone, amongst others [3, 10]. Gupta et al. [14] reported that colors used during holi create high concentrations of ambient PM with a chemical composition that differs from normal atmospheric conditions and may be harmful to human health. Previous studies (Table 1) indicated degradation of air quality by holi-related use of colours and bonfires and subsequent impacts on human health.

Few studies are available on use of colors and its association with health effects such as skin diseases and respiratory problems; moreover they also have reported the changes in concentration of PM during festival activities like playing with colors [3, 12, 14]. Despite growing evidence of adverse air quality and possible health effects related to the use of colors and bonfires, hardly studies have measured $PM_{2.5}$, its constituents during holi.

Few studies have reported air pollution exposure using chemical analysis [8–11, 13, 25]. Generally, chemical analysis is used to assess the chemical variation in concentrations at workplaces and to compare concentrations with regulatory standards or guidelines to improve the air quality [25]. Bossmann et al. [3] reported that chemical based air quality analysis is superior to digital data set in predicting the accurate exposure to PM concentrations. The aim of is the present study was to assess the change in air quality during the holi festival period and changes in the number of hospital admission due to emergency medical conditions such as eye irritation, skin diseases and respiratory problems.

2 Materials and methods

2.1 Study area and research design

The study was carried out at four selected locations (i.e., Marwadi University campus, Satya Sai road, Pushkardham, and Raiya Circle) and nine hospitals (i.e., PDU civil hospital, RMC public health center, Railway government hospital, Milestone hospital, Jalaram hospital, Vatsaly hospital, Giriraj hospital, Krishna hospital and Salus hospital) in Rajkot district (22.3039°N and 70.7833°E) of Gujarat, a state in West India (Fig. 1). The study area is selected on the following criteria: (1) the selected locations covered all types of hospitals available in Rajkot city; (2) there are no industrial areas within 5 km radius to minimize the impact of industrial pollution; and (3) local people uses different type of colors for playing holi in huge number.

2.2 Sampling procedure and data collection

In the year 2018, holi was celebrated on 1st March. Measurements including mass and ions concentration of PM ($PM_{2.5}$ and PM_{10}) were performed for 5 days, beginning

Table 1 Summary of relevant past concentration of PM due to colours and bonfires during Holi based studies

Study area	PM types	Key observations	Authors (year)
Germany	PM_{10}	Recorded that colours can contain up to 80% of PM10 particles	Bossmann et al. 3]
India	PM	Reported different types of cutaneous manifestations especially due to colours using in holi festival	Ghosh et al. [12]
India	PM	Chemical analysis of pollutant emitted due to colours during holi	Chauhan et al. [4]
India	PM	Chemical injury due to incremental concentration of particles during holi festival	Dada et al. [6]
India	PM	Occular hazards from the different colors are identified during holi festival	Velpandian et al. [29]
India	PM	Significant amount of emission in an around the month end reported higher in concentration due to celebrating "Holika Dhahan" using waste wood is burn at holi festival	Venkataraman et al. [30]
India	PM	Particle pollution and its contribution to regional climate during holi festival. Moreover, reported higher level of aerosol optical depth, water vapor, and lower down-welling short-wave radiative flux during the festival period (pre holi, holi and post holi days)	Simha et al. [27]
India	PM	Variation in changing the optical properties of aerosol during holi festival, as generally extensive burning of biomass reported in same festival days	Kumar et al. [17]

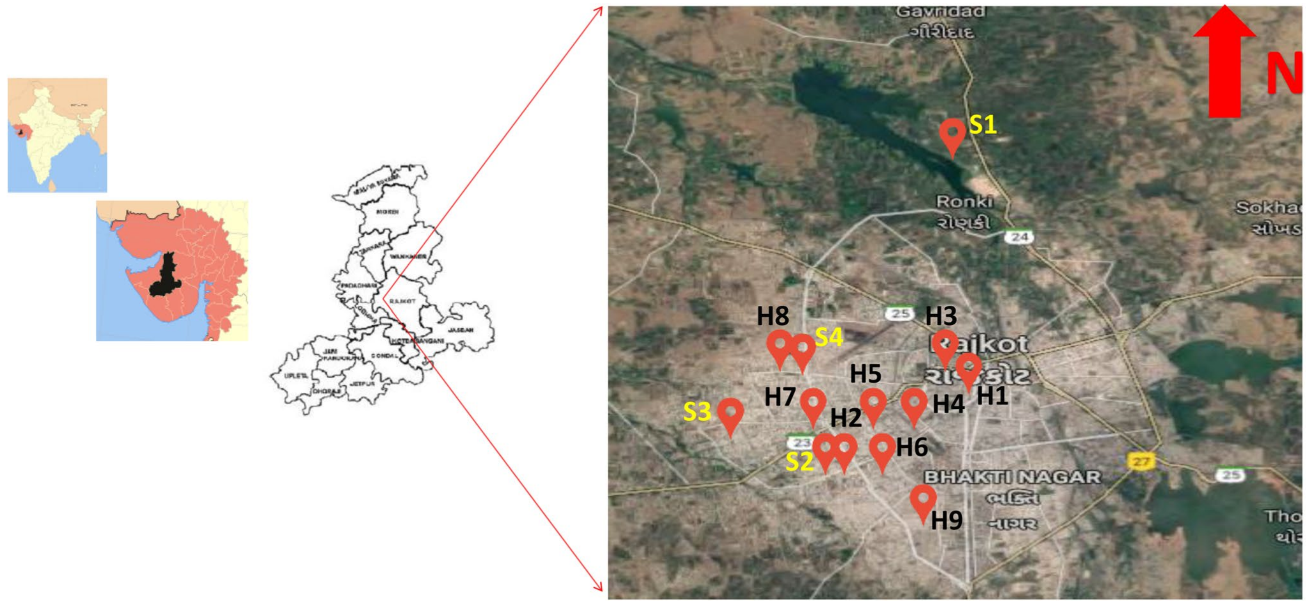

Fig. 1 Study area of interest in Rajkot city of Gujarat

27th February 2018 and ending 3rd March 2018. Bonfire activities were observed to begin in the evening (around 18:00) and to continue until approximately 21:00. The study was divided into two experiments periods; experiment 1—to measure the incremental concentration of PM ($PM_{2.5}$ and PM_{10}) generated from different type of colors during holi festival, experiment 2—to collect the hospital admission data from different hospitals in Rajkot city.

Digital data of air pollutants (PM_{10}, and $PM_{2.5}$) concentrations were also measured in the evening time period (18:00–21:30) when most of people come together around bonfires for holi celebration. Sampling thus started at 18:00–21:30 in the evenings and continued for 3 h and 30 min. Digital data of air pollutants were monitored using the AirVeda air quality monitor (AirVeda Technologies, India), which is calibrated by BAM (Beta Attenuation Monitor). It uses high quality laser sensors to measure $PM_{2.5}$ and PM_{10}. Each sensor is individually calibrated against BAM (Beta Attenuation Monitor—used by govt). An independent study showed correlation greater than 90% with BAM.

To measure PM, we utilized 4 fine particulate matter samplers running at a flow rate of 16.67 L per minute for 24 h sampling [14]. Flows were checked pre- and post-filter exchange using a Mesa DryCal Defender 530 (Mesa Labs, Butler, NJ, USA). $PM_{2.5}$ was collected on pre-weighed 47 mm Quartz Filter paper. Filters were pre- and post-weighed at Environmental laboratory at Marwadi University after being conditioned for 48 h 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 0.1 μg m^{-3}. Ion Chromatography (IC IN6-1809a-022018 model, make Metrohm India Ltd.) used to determine the chemical composition (cation and anion column) of collected air samples during festival. On other hand, in experiment 2, nine hospitals were selected to collect hospital admission data including facing problems in eyes, skin and respiratory issues during defined study periods.

3 Results and discussion

3.1 Time series of PM

The leading point of this section is to reveal the fine particle concentration profile in selected study locations. Detail descriptive analysis of particle concentration of pre holi, holi and post holi are shown in Fig. 2a, b and Table 2.

Concentration of pre holi, holi and post holi varied in the 25–40 μg m^{-3}, 54–171 μg m^{-3}, and 35–70 μg m^{-3}, for $PM_{2.5}$ and while for PM_{10}, 53–251 μg m^{-3}, 92–291 μg m^{-3}, and 58–277 μg m^{-3}, respectively (Fig. 2a, b). Mean ± SD of pre holi, holi and post holi varied from 34 ± 4 μg m^{-3}, 88 ± 16 μg m^{-3}, and 43 ± 6 μg m^{-3}, for $PM_{2.5}$ and while for PM_{10}, 87 ± 20 μg m^{-3}, 176 ± 19 μg m^{-3}, and 86 ± 21 μg m^{-3}, respectively. The reported data indicates that $PM_{2.5}$ and PM_{10} concentrations during holi festival are 7 times and 3 times and 2–2 times higher than pre holi and post holi days, respectively.

In current study, the observed range of $PM_{2.5}$ and PM_{10} concentrations during holi is 117 μg m^{-3}, 199 μg m^{-3}, which is 2 times and 5 times for $PM_{2.5}$ and 2 times and

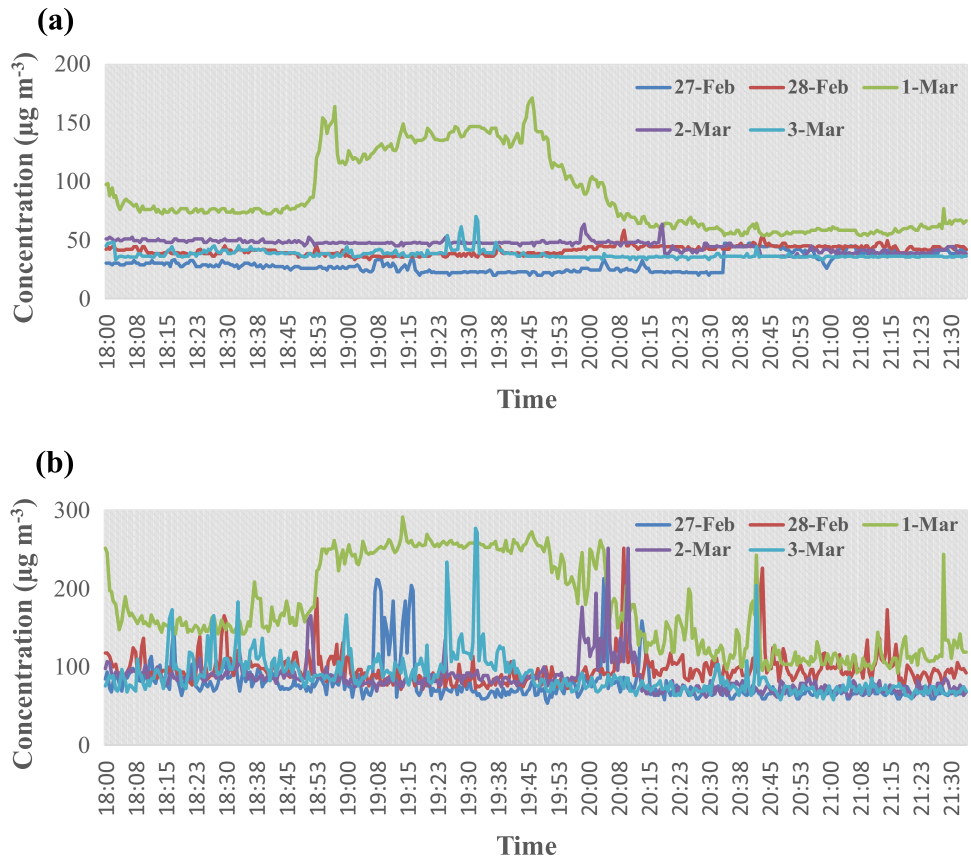

Fig. 2 **a** Fine particle concentration, **b** corse particle concentrationin pre holi, holi and post holi days

Table 2 Descriptive statistics of PM during pre holi, holi and post holi festival

Particle size	Events	Min	Max	Average ± SD ($\mu g\ m^{-3}$)
$PM_{2.5}$	Pre-holi	25	40	34 ± 4
	Holi	54	171	88 ± 16
	Post-holi	35	70	43 ± 6
PM_{10}	Pre-holi	53	251	87 ± 20
	Holi	92	291	176 ± 19
	Post-holi	58	277	86 ± 21

~ 4 times for PM_{10} higher than 24 h average concentration of particles in national ambient air quality standards [20]; 60 $\mu g\ m^{-3}$, and 100 $\mu g\ m^{-3}$ for $PM_{2.5}$ and PM_{10}, respectively), India and World Health Organization (WHO; 25 $\mu g\ m^{-3}$, and 50 $\mu g\ m^{-3}$ for $PM_{2.5}$ and PM_{10}, respectively), respectively. However, the observed results are quite equivalent with reported previous study based on fine particle concentration due to holi festival [3, 6]. Incremental concentration of particle observed during holi festival indicates that holi festival activities (i.e., using and playing colors) generate coarser particle than fine particles, similarly observation has made by previous research work [3].

3.2 Mass concentration of PM

Figure 3 have showed that the particle concentration in the urban atmosphere has increased in the result of playing/using different types of colour in holi festival. The presented work in this section is to show that mass concentration of particle concentration in four selected locations in Rajkot city during pre holi, holi and post holi days (Fig. 3). The 24 h average concentrations of $PM_{2.5}$ in the selected locations during pre holi (39 $\mu g\ m^{-3}$), holi (67 $\mu g\ m^{-3}$) and post holi (34 $\mu g\ m^{-3}$) festival are depicted in Fig. 3. For $PM_{2.5}$, the average concentrations were observed higher during holi as compare to normal day of measurement. The observed results indicated that fine particle concentration during holi is approximately two times higher than pre and post holi. Figure 3 shows the higher concentration of $PM_{2.5}$ during the 24 h of holi, which could be due to the increased use of different types of colors and bonfire activity to celebrate for the festival. On a normal day, the higher concentration of $PM_{2.5}$ could be attributed to the maximum movement/transportation of people associated with festival, observed near the sampling location. The average concentration of $PM_{2.5}$ during pre and post holi were observed to be almost same.

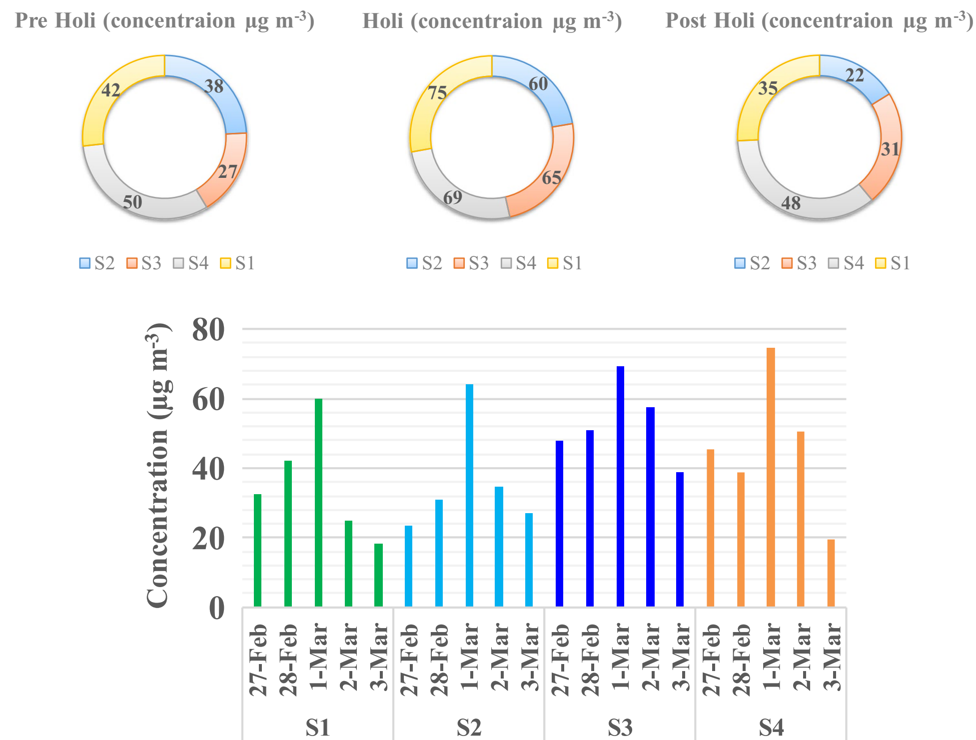

Fig. 3 Fine particle concentration in selected study sites during pre holi, holi and post holi days: S1 = Marwadi university campus; S2 = Satya sai road; S3 = Pushkardham; and S4 = Raiya circle

These increases potentially indicate the impact of bonfire and colors on ambient air quality on the day and night of holi, as evidenced by increased concentrations of $PM_{2.5}$. Recently, Gautam et al. [10] reported the incremental concentration and personal exposure to $PM_{2.5}$ from bonfire activities; however, $PM_{2.5}$ related study during holi festival is now probably first time reported.

3.3 Hospital admission

Number of hospital admissions and particle concentration is depicted in Fig. 4. The reported PM concentrations are the range of 34–88 µg m^{-3} and 86–176 µg m^{-3} for $PM_{2.5}$ and PM_{10}, respectively. The informed results (Fig. 4) reveal variability of PM concentration between pre-holi, holi and post holi; the PM_{10} concentrations were observed approximately 3 times higher than $PM_{2.5}$. Furthermore, the PM concentrations monitored during day of festival were approximately 2 times higher than concentration reported in normal day of monitoring. Results of these monitoring was approximately ~ 2 times higher than Indian standards [20] and 3 and 4 times higher than WHO air quality standards for the $PM_{2.5}$ and PM_{10}, respectively. The observations are very much comparable with previous study [3], they had reported that coarse particle (PM_{10}) found higher in concentration during color of festival—"Holi".

In Fig. 4, it can be seen that the number of hospital admission to respiratory related problems, are reported ~ 2 and 1.3 times higher in festival day (holi) than normal day like pre holi and post holi, respectively, while 1.2 and 1.3 times higher number of hospital admission for eye infection reported in same holi day than pre holi and post holi,

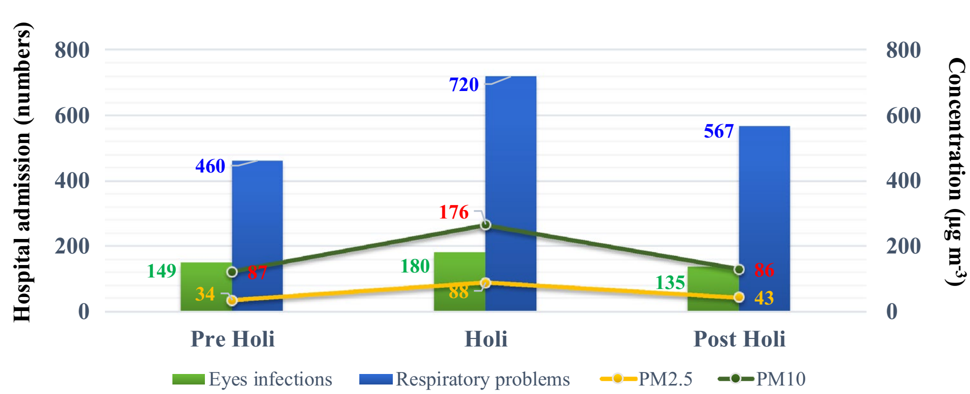

Fig. 4 Hospital admission and its comparison with PM concentration

respectively. Becker et al. [1] made a survey on the "color of festival—Holi" in Germany, and they observed that the respiratory affected people are ~4 times higher than the number of person having problem with eyes infection due to festival. Furthermore, the outcomes of the presented study also having similar results where respiratory problems are reported significantly higher than eyes infections.

3.4 Possible effect of ions concentrations on human health

Figure 5 have demonstrated that reported ions concentrations of PM have much higher than the permissible limits. Moreover, ions present in particle are more important to assess the impact on human health. Exposure to ions which are toxic in nature may lead to numerous health diseases to those who are involved in holi festival related activities as mentioned in Table 3. It is clearly noticed that reported ions are higher in concentration than their permissible limits. These results may affect not only on exposed individual person but also on its living and surrounding environment [22]. The quality of soil may also effect from the ions of PM generated during color festival, having the tendency to settle down onto soil due to gravity phenomenon. The deposited ions onto soli, generally accumulate into plants and may ascribe to bio accumulation. Gupta et al. [14] suggested that human who have direct inhalation of dust during holi celebration carries PM including different type of ions may significantly affect the eyes, respiratory function and causing of lung cancer and chronic obstructive pulmonary disease. On the other side, Government of India (Health Ministry of India; Report—2017) have introduced strategic plan to eradicate diseases (i.e., HIV, malaria and tuberculosis) by 2025. The outcomes of report give serious concern and good platform to the scientists who are associated with research study to improve the quality of life in the developing countries. Furthermore, this presented study shall help to make baseline to monitor the health issues and help to eradicate the health diseases. Hence, there is serious concern to change the quality of color (dust) is being used during festival of color.

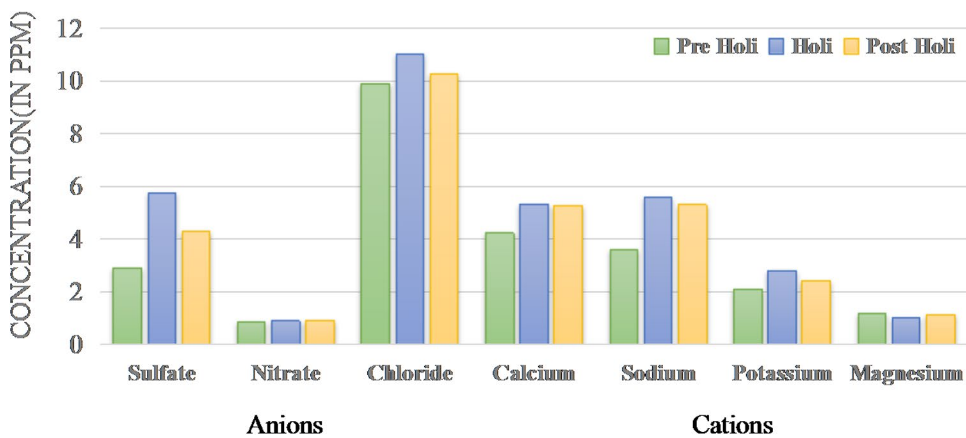

Fig. 5 Ionic concentration profile of particles

Table 3 Ions of $PM_{2.5}$ exposure and its possible health impacts

Ions	Diseases	References
Anions	No significant effects on lung functioning. severity of bronchospam decreased by a factor of 3–0.2	Palti et al. [23] and Kirkham et al. [16]
Cations	Showed mild to moderate wheezing and dyspnea. Severity of bronchospam increased by a factor of 0–2. Have significant effects on lung functioning, resulting in breathing difficulties, allergy	Palti et al. [23], Zylberberg and Loveless [33] and Lipin et al. [19]
Sulphate	Affect lung function, worsen asthma attacks	Reiss et al. [24] and Schlesinger [26]
Nitrate	Decreases in blood pressure, increased heart rate, reduced ability of the blood to carry oxygen to tissues, headaches	Lipfert et al. [18] and Reiss et al. [24]
Calcium	Vomiting, increased thirst or urination, hypercalcemia	Han et al. [15]
Potassium	Hyperkalemia, changes in heart rhythm, poor kidney function	Pachauri et al. [22]
Magnesium	Irritate the eyes and nose	Bell [2]
Chloride	Hypertension, sweating, hypochloremia	Oh et al. [21]
Sodium	Severe sweating or fever; vomiting and diarrhea	Han et al. [15]

3.5 Empirical relationship between incremental particle concentration and hospital admission

Incremental concentration of fine particle increases number of hospital admission in terms of eyes problems and respiratory diseases. The developed empirical equation shows a good relationship ($R^2 = 0.68$ for respiratory diseases, and $R^2 = 0.60$ for eye problems) between particle concentration and hospital admission.

$C = 42.26x^{0.263}$ and $C = 42.13x^{0.261}$ for representing relationship between particle concentration and respiration problems, and particle concentration and eye problems, respectively. Where C, number of hospital admissions; x, particle concentration.

Increased number of hospital admission related to respiratory diseases than eye problems have been reflected through high exponential decay constant in mentioned equations. Similar observations have already reported in previous study showing respiratory problems due to colors using in holi festival [3, 14].

4 Limitations

This study has a number of limitations. First, the number of sampling days was relatively small, especially pre-holi. More sampling before and after holi may have enabled more rigorous statistical analysis and more conclusive results. Second, the reported information about hospital admission may have been impacted by sources other than holi colors, including increased bonfire and cooking with biomass due to the festivities. The observed limitations may give more directions to scientist who are working on exposure to PM especially during festival days. We were unable in the current study to measure these activities; our findings from elemental analysis are, however, consistent with recent study showing elevated anions and cations resulting from use of bonfire [9, 10].

5 Summary and conclusions

Many researchers [17, 27, 30] have been updated the similar kinds of work of presented study on air pollution especially in holi festival based on incremental concentration of particles, chemical properties, contribution to atmosphere due to bonfire activities etc., however probably first measurement was reported based on impact of PM especially fine particle ($PM_{2.5}$) and its association with number of hospital admissions, which was missing in literature. In India, 68% of total population still belongs to remote / rural area, therefore assessment of association between changes in air quality and hospital admission performed in western region of India. The incremental concentration of coarse and fine particles has been observed especially in dense population area in India. Observed results indicated that exposure to PM_{10} is ~ 2 times higher than $PM_{2.5}$ on human health, similarly it is supported that number of hospital admission related of upper respiratory issues belongs more to PM_{10} than $PM_{2.5}$. Predictor equations have been developed to understand the impact of specific size of particle on increasing the number of hospital admission via different types of disease. $PM_{2.5}$ was 67 μg m^{-3}, which was ~ 2 times higher than national and international standards, moreover, probably first time reported during holi festival. The potential for exposure to the reported pollutants at elevated concentrations during holi can increase the potential for acute health effects, suggesting need for guidance in developing countries on ways to ensure that the most vulnerable populations are able to avoid additional exposure or rapidly seek treatment if needed. 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:

1. Try to use toxic chemical free colours on flat open ground away from house or society to enhance proper pollutant dispersion.
2. Ensuring that emergency medical treatment is available for vulnerable populations on festival and pre-festival days, which also see different colour use.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interests.

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