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Assessment of the Impact of Diwali Festival on Ambient Air Quality of Udaipur - A Smart city in India

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ABSTRACT
Diwali festival the main festival of India is celebrated with great fun and frolic, however amidst the extravagance, then lies a harsh reality of its effect on the health of the city. Increase on concentration of basic pollutants warrants the cause of implementation of specific measures to be taken during the festival. Criteria pollutants SPM, RSPM, SO_2 , NO_2 and metals measured are found to have either crossed or on the edge of crossing the limits, necessitating the immediate installation of a continuous monitoring and control mechanism. While fire crackers and transport related emissions are the major sources of air contamination, increasing construction activities also contribute to particulate matter. The exponential rise in volume of vehicles, haphazard traffic flow pattern, differing driving cycle pattern and human interceptions deserve due attention. It is concluded that Udaipur city is a strong case for continuous monitoring of ambient air quality due to alarming and increasing level of pollutants specially for particulates. Exposures to airborne metals are known to cause physiological responses in organisms and wide-ranging health effects in humans. Hence determination of metals in particulate matter is important from a toxicological perspective. In the current study heavy metals associated with respirable (RSPM) and non respirable (NRSPM) fractions of suspended particulate matter were estimated in air samples from four stations in Udaipur, India, during November-2015 on the occasion of Diwali. The present study was conducted in order to understand the impact of crackers and related fireworks usage during diwali festival (Festival of lights) in the ambient air quality status including the metal concentrations of Udaipur city during November-2015. This was assessed by evaluating the air quality status by measuring the concentrations of various air pollutants such as Sulphur Dioxide, Nitrogen Dioxide, Suspended Particulate Matter (SPM) and Respirable Suspended Particulate matter (RSPM) and metals associated with particulate matter since usage of crackers is found to be the major activity during this particular festival and such firework related activity releases various gaseous and particulate air pollutants and toxic metals in a greater extent. Hence, in the present study, SO2, NO2, SPM, RSPM and metals were estimated at selected sites during the on diwali, Pre-Diwali and Post Diwali period. As a whole, it is understand that though the concentration of SO2, NO2, SPM, RSPM and metals were found to be at a higher rate at pre and post diwali period, these specified parameters had recorded significantly higher levels of these concentrations on the day of diwali. On the day of Diwali, the levels of SO2, NO2, SPM, RSPM and metals concentrations in residential area have been recorded and the concentrations have also recorded higher range when compared with National Ambient Air Quality Standards (NAAQS). From the present study it is elucidated that the usage of fireworks and bursting crackers were found to be the major factors for such elevated levels of pollutants in the atmosphere during the Diwali festival.

KEY WORDS: Air Pollution, Particulate Matter, Metals and Ambient Air Quality

INTRODUCTION

Diwali is the festival of lights and is celebrated with great enthusiasm all over India every year during October/November. Firing crackers is an integral activity of the celebrations during Diwali. Fireworks emit trace gases and particulates including metals into the atmosphere, which generate dense clouds of smoke, concentration of which depends on the composition of sparklers and crackers. Generally crackers contain potassium nitrate, charcoal, sulphur, potassium and trace elements, which severely affects environment as well as human health [1].

Several studies have been made all over the world based on the effect of firework activities on the air pollutants like particulate matter and its components and trace gases during various festivals. Firework activities on New Year's Eve on Oahu were responsible for an increase in TSPM (Total suspended particulate matters) by an average of 300% at 14 locations and by about 700% at one location [2]. The effect of firework activities on fine aerosol particle during New Year's Eve in Mainz, Germany [3]. High loading of some heavy metals due to firework activities during the celebration of win of FIFA world Cup in the year of 2006 over Italy [4]. The high loading of heavy metals during "Las Fallas", a 6-

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day celebration famous for its firework displays in Spain [5]. Similarly, higher level of air pollutants like SO2, NOx, PM2.5, PM10 in the ambient air of Beijing (China) and estimated five times higher levels for primary and secondary components of aerosols during fireworks of lantern days than on normal days [6].

In Indian context, studies have also been reported on the air quality deterioration for the crackers activities during Diwali festival but they are few. The fireworks lead to short term variation in air quality and observed 2 to 3 times increase in PM10 and TSPM concentrations in Hisar city (India) during Diwali festival [7]. Similarly, the high level of different trace elements in ambient air of Hyderabad was reported, which was due to fireworks during Diwali festival [8]. It is reported that the significant increase in PM2.5 concentration in Lucknow city due to firework activities during Diwali festival [9]. The effect of firework activities during Diwali on surface Ozone has also been reported in Delhi [10, 11]

Another detailed study during lantern day festival in Beijing on the air quality status revealed that extensive usage of fireworks reported 57.0, 25.0 and 183% increase in SO2, NO2 and PM10 levels when compared to the previous day. Besides these higher concentrations in the air, there is a strong relationship between higher concentration of SO2 and several health effects like cardiovascular diseases [12, 13]. Keeping all the literature reviewed, the present study was planned in order to monitor air quality status by evaluating selected parameters such as SPM (Suspended particulate matter), RSPM (Respirable suspended particulate matter), Sulphur Dioxide (SO2), Nitrogen Oxide (NO2) in and around the residential area in Udaipur city, Rajasthan during the festival of lights in November 15.

Health effects of particulate matters and their components are well documented. A consensus has been reached regarding adverse health impact of PM10 [14, 15]. In India, 30 to 40% increased cases of wheezing, respiratory diseases, exacerbation of the bronchial asthma and bronchitis patients of all age and sex groups, irrespective of a family history of asthma or not, are reported during the Diwali festival [16]. The study reported that inhalation of smoke from fireworks causes cough, fever, and dyspnoea and leads to acute eosinophilic pneumonia (AEP) [17]. Besides particulate matter, there is a strong relationship between higher concentration of SO2 and several health effects like cardiovascular diseases [12, 13], respiratory health effects such as asthma and bronchitis [18] reproductive and developmental effects such as increased risk of preterm birth [19]. Short-term but high emissions of trace elements from fireworks can induce severe health effects like neurological and haematological effects on the exposed population for Pb, carcinogenic effects in humans through inhalation and chronic lung diseases for Cd and Ni, carcinogenic effect on the bronchial tree for Cr, neurotoxic impairments for Mn, respiratory irritance for Cu etc..

Udaipur-The city of Lakes, situated in the south part of India world's tourist destination. With rapid pace of industrialization and urbanization, high vehicular density plying on insufficient road space and dumping of municipal/industrial solid waste disposal, air quality over this region is severely affected resulting heavy PM loading in Udaipur. Huge amount of crackers and sparklers are burnt mainly on the day of festival (Diwali day) and also on the day before (pre-Diwali day) and after (post-Diwali day) Diwali. There is no published data regarding the effect of firework activities on aerosol and its several components during Diwali festival over Udaipur. However a study was made on the air pollution during Diwali festival over a city Udaipur [20]. Particulate matter & gaseous concentrations, we also have investigated metal concentration in ambient air which have not been reported in any studies made earlier in Udaipur during Diwali to the best of our knowledge. This study is thus the first-time study made over Udaipur during Diwali festival in order to find out the effect of firework activities on SO2, Nox, SPM & PM10 and Metals. To do this, a sampling program was conducted during November 5, 11 and 14, 2015 over three residential, commercial and industrial locations in Udaipur. Thus this study is an attempt to assess the additional burden on air quality due to Diwali festival over Udaipur, where air pollution is already an acute problem through-out the year.

STUDY AREA AND PREVAILING METEOROLOGY

Udaipur is located at 24.525049°N 73.677116°E The city covers an area of 37 km2 and lies at an altitude of 598.00 m (1,962 ft) above sea level. It is located in the southern region of Rajasthan, near the Gujarat border. Udaipur with its lakes lies on the south slope of the Aravalli Range in Rajasthan. The Northern part

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of the district consists generally of elevated plateaus, while the eastern part has vast stretches of fertile plains. The southern part is covered with rocks, Hills and dense Forest. According to the 2011 census, the total urban population was 608,426 and the population density was 262/km2. As per the data, the male population of the city was 315,485 and the female population was 292,941 in 2011.

The study was carried out at three residential, commercial and industrial locations in Udaipur (Fig. 1). The first site (MIA) is situated in Mewar Industrial Area at Madri and the second site Suraj Pole (SP), heart of the city and Amba Mata Sceheme Colony (AMC) is residential area of the city. All side from the busy roads where the densities of all types of vehicles (light, medium and heavy) plying on these roads are quite high.

Udaipur city has particularly a tropical climate. The three main seasons, summer, monsoon and winter respectively, dominate the city of Udaipur. Being located in the desert lands of Rajasthan, the climate and weather of Udaipur is moderately hot. The summer season runs from mid-March to June and touches temperature ranging from 23 °C (73 °F) to 44 °C (111 °F) in the months of March to June. Monsoons arrive in the month of July heralded by dust and thunderstorms. With lush greenery and enchanting lakes, the sporadic rainfalls enhance the beauty of the city, making it one of the top monsoon destinations of the country. The winter season prevails from the month of October till the month of March. Humidity, which prevails during monsoons, diminishes at the arrival of winters. The city observes pleasant sunny days and enjoyable cool nights with the temperature ranging from 5 °C (41 °F) to 30 °C (86 °F). Sampling was done at the terrace of the buildings at these three side which are 10-15 meter from the ground level. The samplers were mounted on a platform at a height of 1.5 m from the roof level.

MATERIALS & METHODOLOGY

The study was conducted in a residential, commercial and industrial areas of the city during both day and night time. In order to understand the effect of crackers, four major air pollutants i.e., SPM, RSPM, SO2, NO2 and some heavy metals were estimated in the selected location for 8 hrs continuous ambient air quality monitoring. In the present study, ambient air quality was monitored using Respirable Dust Sampler (Envirotech-APM 460 NL) for suspended particulate matter and for gaseous pollutants.

The concentration of sulphur dioxide in the ambient air was analyzed by modified [21] pararosaniline method. While, NO2 concentration in the ambient air was monitored by sodium Arsenite method [22]. Some selected heavy metals associated with PM10 were analysed by using the Atomic Absorption Spectrophotometer (SPECTRA 558) by following the standard method as per CPCB guideline for measurement of Ambient Air Pollutants, Volume-I, 2011 [23].

RESULTS AND DISCUSSION

The major pollutants responsible for various health effects were collected on diwali day and were compared with pre-diwali and post-diwali days and all the concentrations were compared with the prescribed limits as given by NAAQS and a detailed discussion on the same is given below.

Sulphur Dioxide (SO2)

The present study reveals that the SO2 level at different sites were found low in comparison to other pollutants (Fig. 1-3). Sulphur-di-oxide is known to be toxic because of its nature of slowly getting absorbed in fine particles and are transported into the lung [24] and damages the tracheal nasal system [25]. In the present study, the concentration of SO2 on pre-diwali, diwali and post Diwali were estimated in the atmosphere is to be 7.5, 10.6, 8.4 µg/m3 respectively in residential area while it was reported as 9.1, 12.4, 9.6 µg/m3 respectively, in commercial area and in industrial area it was measured as 9.6, 11.5, 10.2 µg/m3, respectively. During Diwali day, the SO2 concentration has increased up in the residential area and after Diwali, there was a slight decrease in the concentration of the same was observed whereas comparatively lowest concentration was recorded on Pre-Diwali day. Overall the collected data on SO2 concentrations observed during the three day period showed that that the residential location has registered lower level of SO2 as prescribed by NAAQS which is 80 µg/m3. In a study conducted earlier, where data on short-term health response to SO2 exposure on asthmatic patients was done and the researchers found that exposure of SO2 for 10 minutes period exposure at concentration > 1.32 mg/m3 and ventilation 30 dm3/ min can cause short

term asthma problems in a significant manner than those usually get exposed without SO2 exposure [26].

Nitrogen Dioxide (NO2)

Similar to SO2, most of the health effects exerted by NO2 have impact in lungs which includes deep lung irritation, altered biochemical and histological phenomenon which was exhibited in laboratory animals [27]. In the present study as shown in Figure 2, the concentration of NO2 on Pre Diwali, Diwali and Post-Diwali day has been registered at elevated levels of 28.2, 41.5, 30.2 µg/m3 respectively in residential area, in commercial area 26.4, 43.9, 36.5 µg/m3 respectively, 34.8, 51.5, 40.2 respectively in industrial area when compared with the NAAQ standards prescribed. Whereas, pre-diwali day has recorded a quite lower value of 28.2µg/m3 when compared to the other two days and also as per NAAQS prescribed concentration. In a study, high concentration of NO2 of 46 µg/m3 were registered in commercial area respectively during diwali festival in Udaipur City of Rajasthan at the residential site whereas 44.5 µg/m3 of NO2 was recorded in the commercial location of the same town [28].

SPM and RSPM

Higher concentration of Particulate matter in air has more possibility of the particles to reach into the lungs and such particles caused severe health effects when entered into lungs since such particles carry mixture of pollutants present in the atmosphere derived from various sources including crackers and fireworks especially during diwali festival. Particles with diameter less than 10µm only can be respired to reach to the lungs and finer fractions less than 2.5µm such as fine particulate matter (FPM) can penetrate the lungs to alveolar level and can cause severe respiratory problems [29] including chronic respiratory and cardio vascular diseases, damage lung tissue and contribute to cancer [30-40]. Figure 3 shows that the SPM levels in all the three days were found to be in a higher concentration of 210,412, 248 µg/m3 respectively in residential area, in commercial area 302, 584, 524 µg/m3 respectively, 545, 734, 687 during Pre-diwali, Diwali and post-diwali days. Though the pre-diwali day recorded slightly higher concentration, diwali and post-diwali days registered higher when compared to the standard levels prescribed by NAAQS which is 500 µg/m3. Similarly, the trend of Respirable suspended particulate matter (RSPM) were observed where in the concentration increased up to 3 folds in the studied location where in diwali day recorded concentration of 94, 208, 110 µg/m3 respectively in residential area, in commercial area 106, 264, 230 µg/m3 respectively, 274, 330, 304 in industrial area respectively during Pre-diwali, Diwali and post-diwali days among the three days and as per the comparison made with NAAQS which is 100 µg/m3 [41].

Heavy metals in ambient air

Nine major heavy metals including Fe, Zn, Pb, Mn, Cu, Cd, Cr, Ni and Co in ambient air at different sites of Udaipur city were studied (Fig. 1-3). The design of the study was framed in such a way that the effect of diwali festival on ambient air of the city can be assessed. It was observed that before the festival of Diwali, at the residential site of Ambamata area, the contamination of heavy metals in the air was in order of Mn & Cu > Fe > Zn > Pb > Cd while during the festival, the level of these heavy metals at Surajpole, which is a commercial area, were in order of Mn > Fe > Zn > Cu > Pb. It was interesting to know that in both residential and commercial area, the concentrations of Cr, Ni and Co were found in BDL (Below Detection Limit).As for as the Mewar industrial area is concerned, the highest level of heavy metals before diwali festival found in the ambient air was Pb followed by Zn, Mn & Fe, Cu, Cd, Cr & Ni. The concentrations of Co were also found below BDL value.

The assessment of selected heavy metals in the ambient air during diwali festival in the city was also carried out. The residential area was highly contaminated with some of heavy metals. It is probably due to overuse of crackers. The ambient air of AMC residential area was highly contaminated with Fe followed by Pb, Cu, Zn, Mn and Cd, respectively. Almost similar pattern of different heavy metals observed in commercial area (SP). It was important to note that industrial area (MIA) was highly contaminated with different heavy metals and the order of contamination was Zn > Cu > Pb > Mn > Fe > Cd & Cr > Ni > Co. It was interesting to report that Co was only observed in MIA during entire study. At most of the sites Co was found below the detection level. The results of the present study is supported by the study in which the emissions and accumulation of metals in the atmosphere due to

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crackers and sparkles during diwali festival in India [42].

Similarly, the study was carried out to assess heavy metal contamination in the ambient air of the city after the festival. The study reveals that most of the metals were found lower in concentration as compared to their level during the festival. It may be probably settling down due to gravitational force of the earth. Some heavy metals like Fe, Pb, Mn and Zinc were in significant in MIA during the post festival period. It may be due to stake emissions and other industrial activities. The results of the present study are in analogous to some earlier findings [43-44]. It is suggested that the monitoring of such pollutants must be carried out on regular basis. The quantitative results of SPM, RSPM, SO2, NOx and heavy metals indicated that urban area is polluted due to the accumulation of these pollutants which were found to be significantly higher. Proper implementation of the Air (Prevention and Control of Pollution) Act 1981 is the need of the time to control and mitigate the effects of these pollutants.

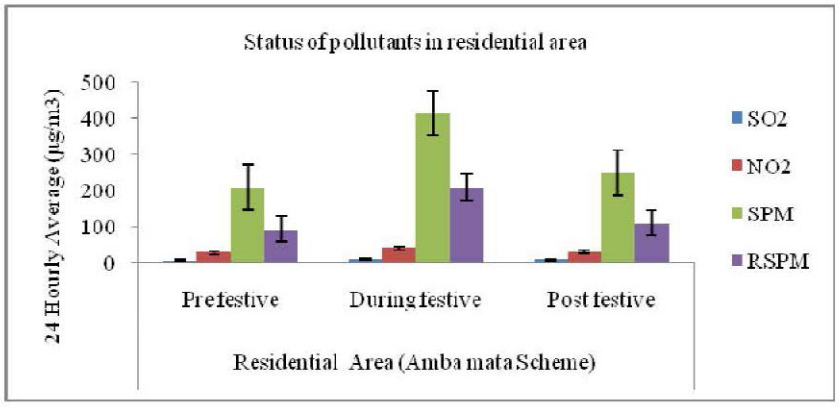

Fig. 1: Status of pollutants in residential area of Amba mata scheme

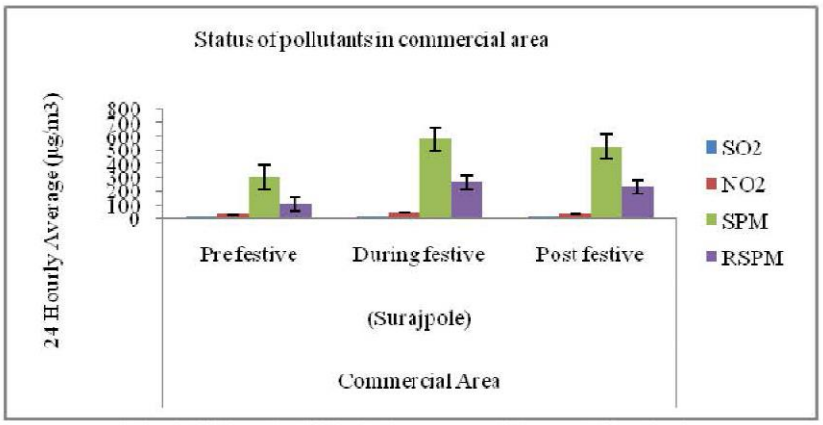

Fig. 2: Status of pollutants in commercial area of Surajpole

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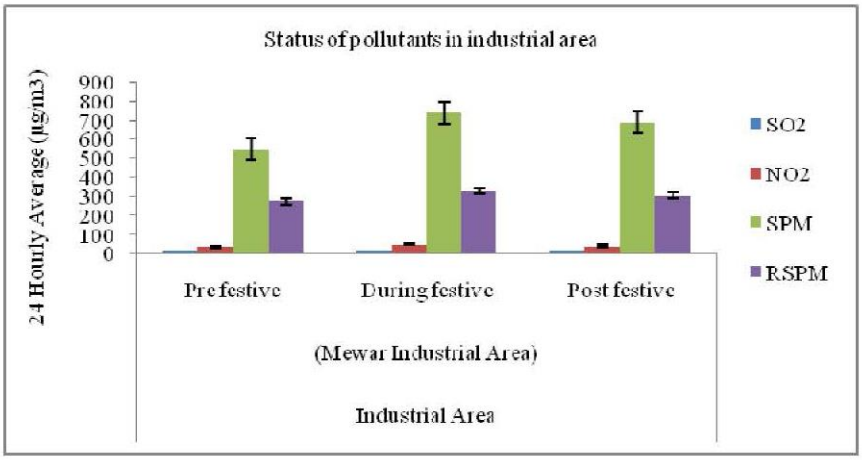

Fig. 3: Status of pollutants in Mewar industrial area

Table- 1: Concentration of heavy metals (µg/m3) in the ambient air of Udaipur before Diwali festival

Area	Fe	Zn	Pb	Mn	Cu	Cd	Cr	Ni	Co	STDEV
Ambamata	0.2	0.18	0.1	0.4	0.4	0.05	BDL	BDL	BDL	0.161383
Surajpole	0.4	0.29	0.18	0.5	0.24	0.05	BDL	BDL	BDL	0.187224
Mewar Industrial area	0.8	0.84	0.85	0.8	0.26	0.24	0.12	0.12	BDL	0.363586

Table- 2: Concentration of heavy metals (µg/m3) in the ambient air of Udaipur during Diwali festival

Area	Fe	Zn	Pb	Mn	Cu	Cd	Cr	Ni	Co	STDEV
Ambamata	0.8	0.36	0.42	0.1	0.4	0.05	BDL	BDL	BDL	0.277128
Surajpole	0.6	0.46	0.4	0.1	0.44	0.06	BDL	BDL	BDL	0.241684
Mewar Industrial area	0.24	1.84	0.8	0.4	0.84	0.3	0.3	0.14	0.05	0.555903

Table- 3: Concentration of heavy metals (µg/m3) in the ambient air of Udaipur after Diwali festival

Area	Fe	Zn	Pb	Mn	Cu	Cd	Cr	Ni	Co	STDEV
Ambamata	0.2	0.18	0.1	0.4	0.4	0.05	BDL	BDL	BDL	0.161383
Surajpole	0.4	0.29	0.18	0.5	0.24	0.05	BDL	BDL	BDL	0.187224
Mewar Industrial area	0.8	0.84	0.85	0.8	0.26	0.24	0.12	0.12	BDL	0.363586

CONCLUSION

To conclude, the present study provided basic information of how the usage of crackers and fireworks has impacted on the air quality of Udaipur city in terms of RSPM, SPM, SO2 and NO2, the four major parameters of air quality. Among the three days studied, most of the days recorded a slightly higher concentration of the pollutants except SO2, whereas other pollutants were in a higher range as per the permissible limit of National ambient air quality standards (NAAQS). This study is important because release of such particulate matter and gaseous pollutants from crackers poses deleterious effects on human health especially during such festivals where huge amount of fireworks are being used.

The above study for metals indicates that the concentration of Lead increased to 400% during the Diwali festival in residential area and nearby 250% in commercial area. Although the average concentration may be within limit, the current peak exposure level may uncomfortably increase causing respiratory problem instantly. The concentration of Zinc increased 200% in residential area and 150% in commercial areas. The concentration of Lead also decreased to the pre Diwali level after the festival which indicates that the same was specifically due to firing of crackers. The concentration of iron also increased 400% times in residential areas during the festival/ the concentration of Lead can be speculated to be for greater in the interior residential areas which are congested and having no plantation and children can develop neurological and behavioural disorder on its inhalation and ingestion. The healthy adult can develop kidney disease and blood pressure problem especially on congested areas which the pollutants do not easily dissipate or get absorbed. Moreover along with the increased RSPM the increased Lead concentration level can trigger problems like annoyance, hypertension and stress especially in interior residential areas where ambient air monitoring cannot be performed due to space constraints. Hence this study can be summarized as indicative only and throws light on the tips of ice berg.

The Ambamata residential area where this study was performed is a developed posh colony of Udaipur and is specious without any congestion roads and high rise buildings surrounding it and also with adequate trees for absorbing the pollutants. Even then the Lead levels increase to 400% which throws light on the anticipated increase in the areas having narrow lanes, high rise buildings, high density population and negligible plantation especially in the interior and where such conditions can persist for a fairly long time.

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