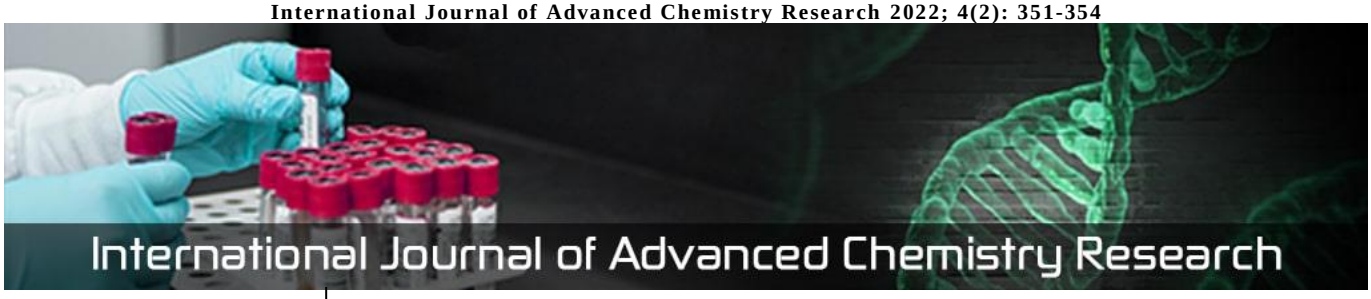

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Study of the impact of Diwali on the air quality of Dehradun

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Abstract
The study focused on analyzing the levels of air quality parameters across 2 areas of Dehradun – Clock Tower & Nehru Colony, both pre and post Diwali 2021.
The data analyzed showed higher concentrations across all parameters during the 5-day period around Diwali. While the concentrations of SO_x & NO_x were within National Ambient Air Quality Standards of the Central Pollution Control Board, PM_{10} & $PM_{2.5}$ concentrations exceeded the standards. It was also noted that the levels almost reached back to pre-Diwali levels within a week post-Diwali.
These could impact both plants and animals with devastating effects, causing severe respiratory problems.

Keywords: Ambient air, SPM, Diwali, air pollution, Dehradun

Introduction
Deepavali, also known as Diwali, is a traditional festival often referred to as the "festival of illuminations." This significant five-day celebration typically takes place between mid-October to mid-November and holds varying significance across India. For Hindus, Diwali is a momentous occasion, marked by the observance of traditional rituals within their homes.
The specific customs and traditions may vary across regions and communities, but some common elements characterize the celebration of Diwali throughout India. Lighting oil lamps (diyas) and candles is a central part of Diwali. The illumination signifies the victory of light over darkness and the triumph of good over evil. Fireworks and firecrackers also form a major part of Diwali celebrations. People burst fireworks to symbolize the victory of light and the dispelling of darkness, and it is this practice that has the potential to impact air quality especially in population centers. The colors, light, and sound of fireworks are all achieved using various metals (Table 1) which then impact the suspended particulate content of the air. Although the Supreme court of India banned the use of certain chemicals [1] to minimize the usage of the most hazardous compounds, a lot of small, unregulated manufacturers might still be using these chemicals.
Chatterjee *et al*., [2] investigated air quality in Kolkata during Deepavali in November 2010. Their findings indicate that the concentration of PM10 was nearly five times higher on Deepavali night compared to regular days due to the extensive use of firecrackers during that period. Similarly, air pollutant concentrations during Diwali were observed over Howrah [3].
Dhananjayan *et al*., [4] conducted a study on the air quality during the Diwali festival in Bhuj. The research focused on estimating SO2, NO2, SPM, and RSPM levels from selected residential sites during Diwali, as well as in the pre- and post-Diwali periods. The study concluded that all the estimated pollutants (SO2, NO2, SPM, and RSPM) exhibited higher concentrations during Diwali compared to the periods before and after the festival.
Given this context, the current study aims to evaluate the potential risk of air pollution in Dehradun, India, by analysis of air quality parameters measured for a 15-day period pre, during and post-Diwali.

Study Area
Dehradun, situated in the picturesque Doon Valley in Uttarakhand in North India, has been grappling with air pollution concerns that warrant serious attention from environmental researchers.

Rapid urbanization, vehicular emissions, industrial activities, and unchecked construction have collectively contributed to a discernible decline in air quality over recent years.

Studies conducted on Dehradun's air quality have revealed elevated levels of particulate matter (PM10 and PM2.5), nitrogen dioxide (NO2), and sulfur dioxide (SO2). The region's topography, with its surrounding hills, can exacerbate pollution concerns by trapping pollutants and hindering proper dispersion.

Materials and Methodology

The criteria used to assess air quality consist of two main categories of air pollutants: Total Suspended Particulate Matter (TSPM) or Suspended Particulate Matter (SPM), and gaseous pollutants.

Sampling

High-volume air sampling is conducted using a specialized air sampler suitable for monitoring air quality both in a workspace environment and in the ambient air outdoors. Particulate matter is measured by directing air at a high flow rate of 0.9 to 1.4 cubic meters per minute through a high-efficiency filter media that captures the particles. The standard AC electrical blower from Rally Wolf tools, with a free flow of 1.4 to 1.8 cubic meters per minute, is typically employed to generate the required suction pressure.

Particulates

Once the sampled air volume is known over a period, the gravimetric determination of collected particulates is established by measuring the increase in the weight of the filter paper due to sampling. Gaseous pollutants are absorbed using a suitable absorbing reagent and analyzed spectrophotometrically [5].

NOx

For the determination of nitrogen dioxide in the atmosphere (Jacob and Hochheiser's method), 10 ml of the sampled absorbing medium are placed in a 50 ml volumetric flask. One ml of H2O2 solution, 10 ml sulfanilamide solution, and 1.4 ml NEDA solution are added to the volumetric flask. A control absorbing medium with these chemicals is used for comparison. The volumetric flask is shaken and left to stand for 20 minutes to allow color development. Transmittance is measured at 540 mm [6].

SOx

To determine sulfur dioxide in the atmosphere (Weast and Geake method), 10 ml of the sampled absorbent sodium tetrachloromercurate solution is placed in a volumetric flask. Subsequently, 1 ml of sulphamic acid, 2 ml of formaldehyde solution, and 5 ml of roaniline are added one by one. The solution is gently shaken, and after 30 minutes, transmittance is determined at 550 mm using a spectrophotometer. In the control (blank), the sampled absorbing medium is replaced. The concentration of SO2 is determined by incorporating the transmittance (%) value into the calibrated standard curve [7-10].

Air Quality Index (AQI)

Air Quality Index (AQI) is a common measure of air pollution used globally. It can be calculated using the following equation:

$$AQI = \frac{1}{4}\left[\frac{PM2.5}{sPM2.5} + \frac{PM10}{sPM10} + \frac{SOx}{sSOx} + \frac{NOx}{sNOx}\right] x100$$

Where, PM2.5, PM10, SOx & NOx are the measured values of these parameters and sPM2.5, sPM10, sSOx & sNOx are the ambient air quality standards.

Results and Discussion

The concentration of key parameters (in µg/m^3 of sampled air) across the 2 sites, and their variation across the different time periods are compared with ambient air quality standards in Tables 2-7.

Table 1: Minerals Used in Fireworks [11]

Color	Chemical
Red	Strontium
Orange	Strontium, Sodium
Yellow	Sodium
Green	Barium, Nickel
Blue	Copper
Purple	Strontium, Copper
Greys & White	Titanium, Zirconium, Magnesium

Table 2: Concentration of SOx (µg/m^3)

Dates	Clock Tower	Nehru Colony	Standard [12]
17.10.21	16.78	14.5	80
18.10.21	18.6	16.4	
19.10.21	17.22	15.2	
20.10.21	15.2	14.2	
21.10.21	21.26	18.62	
22.10.21	24.34	20.87	
23.10.21	23.64	22.45	
24.10.21	26.84	24.62	
25.10.21	24.62	20.46	
26.10.21	27.48	23.62	
27.10.21	24.6	18.42	
28.10.21	21.64	16.48	
29.10.21	23.4	19.1	
30.10.21	18.4	16.4	
31.10.21	17.22	17.84	

Table 3: Concentration of NOx (µg/m^3)

Dates	Clock Tower	Nehru Colony	Standard [12]
17.10.21	23.46	16.2	80
18.10.21	23.68	20.6	
19.10.21	25.64	22.66	
20.10.21	23.24	23.65	
21.10.21	32.68	29.3	
22.10.21	37.54	32.64	
23.10.21	35.6	35.62	
24.10.21	39.48	37.48	
25.10.21	33.6	31.48	
26.10.21	36.74	33.48	
27.10.21	32.4	28.46	
28.10.21	27.58	25.62	
29.10.21	31.62	27.6	
30.10.21	26.52	24.62	
31.10.21	24.4	25.68	

Table 4: PM10 (µg/m^3)

Dates	Clock Tower	Nehru Colony	Standard [12]
17.10.21	122.3	102.5	100
18.10.21	126.32	106.4	
19.10.21	128.68	110.3	
20.10.21	121.64	108.64	
21.10.21	138.62	126.3	
22.10.21	142.8	134.2	
23.10.21	148.64	142.65	
24.10.21	232.42	250.64	
25.10.21	210.3	195.74	
26.10.21	224.65	208.62	
27.10.21	184.62	178.62	
28.10.21	167.42	154.65	
29.10.21	155.26	146.24	
30.10.21	142.3	132.48	
31.10.21	130.64	126.42	

Table 5: PM2.5 (µg/m^3)

Dates	Clock Tower	Nehru Colony	Standard [12]
17.10.21	58.95	50.62	60
18.10.21	60.22	52.62	
19.10.21	62.84	55.64	
20.10.21	57.62	53.65	
21.10.21	66.48	62.42	
22.10.21	69.42	66.56	
23.10.21	71.62	69.78	
24.10.21	105.5	102.52	
25.10.21	90.5	86.48	
26.10.21	93.46	90.26	
27.10.21	78.62	72.24	
28.10.21	72.23	66.48	
29.10.21	68.94	63.65	
30.10.21	63.42	59.5	
31.10.21	60.16	57.86	

Table 6: AQI

Dates	Clock Tower	Nehru Colony
17.10.21	115	102
18.10.21	118	104
19.10.21	119	107
20.10.21	114	106
21.10.21	126	118
22.10.21	131	123
23.10.21	139	133
24.10.21	252	242
25.10.21	202	188
26.10.21	212	201
27.10.21	162	152
28.10.21	145	136
29.10.21	137	131
30.10.21	128	122
31.10.21	119	117

Table 7: AQI Standards

Range	Category	Implications
0-50	Good	Minimal Impact
50-100	Satisfactory	Minor breathing discomfort to sensitive people
100-200	Moderate	Breathing discomfort to the people with lungs, asthma and heart diseases
200-300	Poor	Breathing discomfort to most people on prolonged exposure
300-400	Very Poor	Affects healthy people and seriously impacts those with existing diseases
400+	Severe	Respiratory illness on prolonged exposure

The study revealed that both SOx and NOx values during the Diwali period increased to almost twice their value before Diwali. The values did subsequently fall post-Diwali but did not return to their pre-Diwali levels during the current study's 5-day period. The overall pollution levels of Dehradun being comparatively lower in terms of industrial air pollutants, these values still remained within the daily prescribed limits as per Ambient Air Quality Standards and are therefore not as alarming.

The particulates, on the other hand, increased 2-2.5x their normal values and exceeded the ambient air quality standards. These values also did not return back to their pre-Diwali levels but their decrease was more rapid compared to SOx and NOx levels.

The AQI measures paint an even more grim picture. The overall categorization of Dehradun even during pre-Diwali period is in the moderate range. On the days 3-5, this falls to poor across both the regions under the study.

Relatively speaking, the clock tower area, which falls in the central business and commercial district of the city, recorded worse measurements across all the parameters. This was anyways expected due to the higher vehicular traffic as well as population density in the area.

Elevated levels of PM10 and PM2.5 pose severe environmental and health risks. These fine particulate matter fractions contribute to respiratory diseases, cardiovascular problems, and overall compromised air quality. Mitigating their impact is imperative for safeguarding public health and fostering a sustainable environment.

Moving forward, research endeavors should focus on determining the chemical components linked to different size fractions of particulate matter (PM). This approach will enhance our comprehension of the carcinogenic properties inherent in these particles. Additionally, it is crucial to conduct epidemiological studies aimed at identifying the distinct health effects associated with fireworks.

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