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Fireworks-Induced Surge in PM₁₀ and Carcinogenic PAHs During Diwali 2025 in an Industrial City of Eastern India

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ABSTRACT

Diwali fireworks are known to cause acute but short-term deterioration of urban air excellence. This study evaluates the impact of Diwali 2025 on ambient PM₁₀ and particulate-bound polycyclic aromatic hydrocarbons (PAHs) in Jamshedpur, an industrial city in eastern India. Air quality monitoring was conducted from 17–23 October 2025, covering pre-Diwali, Diwali night, and post-Diwali phases. PM₁₀ was measured gravimetrically, and sixteen U.S. EPA priority PAHs were extracted from quartz filters and quantified using HPLC. PM₁₀ concentrations increased from a pre-Diwali mean of 182 µg m⁻³ to an hourly peak of 480 µg m⁻³ during Diwali night, nearly 4.8 times higher than the national standard. Total PAHs (Σ16 PAHs) showed a 2.8-fold enhancement (118 ± 15 ng m⁻³) compared to baseline levels (42 ± 6 ng m⁻³). A marked shift toward high molecular weight carcinogenic PAHs, particularly benzo[a]pyrene (BaP), was observed, with BaP increasing 3.5-fold. The benzo[a]pyrene toxic equivalent concentration (BaP-TEQ) increased 2.9-fold, indicating enhanced carcinogenic potential. Diagnostic ratios, correlation analysis, and PCA identified high-temperature pyrogenic combustion from fireworks as the dominant source. The findings highlight substantial short-term increases in particulate mass and toxicity during Diwali in industrial urban environments.

1. Introduction

Diwali, the festival of lights, is widely observed across India with large-scale bursting of fireworks, leading to a sharp yet temporary decline in urban air quality. Firecracker combustion releases large quantities of particulate matter (PM) and combustion-derived organic compounds, particularly polycyclic aromatic hydrocarbons (PAHs). These emissions lead to episodic pollution events characterized by sharp spikes in particulate loading and enrichment of toxic organic species (Peshin et al., 2017; Kumar et al., 2020). PM₁₀ is one of the most significantly affected pollutants during Diwali due to the burning of pyrotechnic materials containing oxidizers, fuels, and binding agents. Several studies conducted in major Indian cities have reported two- to five-fold increases in PM₁₀ concentrations during Diwali compared to pre-festival baseline levels (Jain and Tiwari, 2020; Beig et al., 2021). Elevated PM₁₀ concentrations not only increase particulate mass but also serve as carriers for toxic organic compounds such as PAHs, thereby enhancing the overall toxicity of ambient aerosols.

Fireworks combustion generates substantial quantities of PAHs, which are semi-volatile organic compounds formed through incomplete combustion of carbonaceous materials. High molecular weight (HMW) PAHs, including benzo[a]pyrene (BaP), benzo[b]fluoranthene (BbF), indeno[1,2,3-cd]pyrene (Ind), and benzo[ghi]perylene (BghiP), are of particular concern due to their mutagenic and carcinogenic properties (Singh et al., 2019). These compounds are predominantly associated with particulate matter, facilitating inhalation exposure and increasing health risk during peak pollution episodes. Jamshedpur, a major industrial hub in eastern India, is characterized by steel manufacturing, coal combustion, vehicular emissions, and construction-related dust (Ravindra et al., 2022). These activities contribute to

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elevated baseline PM₁₀ levels throughout the year. Under stable nighttime meteorological conditions—characterized by low wind speed and reduced boundary layer height—the additional input from fireworks can significantly intensify pollutant accumulation, resulting in severe but short-duration pollution episodes (Ghosh, 2024). While Diwali-related pollution has been extensively studied in metropolitan cities such as Delhi and Kolkata, relatively limited research has focused on industrial urban environments like Jamshedpur, where background industrial emissions may alter particulate chemical composition and PAH signatures. Understanding the episodic enhancement of PM₁₀ and particulate-bound PAHs is crucial for assessing short-term exposure risks and identifying dominant combustion sources. The present study investigates the short-term variations in PM₁₀ and PM-bound PAHs during Diwali 2025 in Jamshedpur, aiming to characterize changes in particulate mass, molecular composition, and carcinogenic potency associated with fireworks emissions superimposed on an industrial background.

1.1. Objectives

The main objective of this study is to evaluate the short-term impact of Diwali 2025 fireworks on ambient air quality in Jamshedpur with respect to PM₁₀ and particulate-bound polycyclic aromatic hydrocarbons (PAHs).

The specific objectives are:

1. To assess temporal variations of PM₁₀ concentrations during pre-, peak-, and post-Diwali periods.
2. To quantify concentrations of particulate-bound PAHs, including carcinogenic compounds such as benzo[a]pyrene (BaP).
3. To analyse peak-hour enhancement of PM₁₀ and PAHs during Diwali night.
4. To calculate Episode Enhancement Factors (EEF) for PM₁₀ and total PAHs.
5. To evaluate PAH diagnostic ratios and statistical tools (correlation and PCA) for source identification.
6. To assess short-term carcinogenic risk using benzo[a]pyrene toxic equivalent concentration (BaP-TEQ).

2. Methodology

2.1. Study Area

The study was conducted in Jamshedpur, Jharkhand, India (22.8°N, 86.2°E), a major industrial city known for steel manufacturing and allied industries. The city experiences significant emissions from industrial operations, vehicular traffic, and construction activities, contributing to elevated baseline pollution levels. The monitoring site was located in an urban residential–industrial mixed zone influenced by traffic corridors and nearby industrial activities. Meteorological conditions during October are generally characterized by moderate temperature, low wind speed during nighttime, and reduced atmospheric dispersion, which may intensify pollution accumulation during festival events.

2.2. Monitoring Period

Air quality monitoring was conducted over a 7-day episode window from 17 to 23 October 2025, covering three distinct phases: Pre-Diwali (17–19 October), Diwali Day (20 October), and Post-Diwali (21–23 October). To capture peak fireworks emissions, hourly monitoring was performed during Diwali night, particularly between 18:00 and 23:00 hrs.

2.3. Measurement of PM₁₀

PM₁₀ samples were collected using a high-volume Respirable Dust Sampler fitted with pre-conditioned quartz fiber filters. Sampling was conducted for 24-hour intervals at a constant flow rate. PM₁₀ concentrations (μg m⁻³) were determined gravimetrically by measuring the difference in filter weight before and after sampling under controlled temperature and humidity conditions.

2.4. Extraction and Analysis of PM-Bound PAHs

2.4.1. Extraction Procedure

PM₁₀-loaded quartz fiber filters were cut into small pieces and subjected to Soxhlet extraction using a dichloromethane and n-hexane mixture (1:1 v/v) for 16–18 hours. The extracts were concentrated using a rotary evaporator and purified through silica–alumina column chromatography to remove interfering organic compounds. The purified extract was further reduced to approximately 1 mL under a gentle nitrogen stream prior to instrumental analysis.

2.4.2. HPLC Analysis

Sixteen U.S. EPA priority PAHs were quantified using High-Performance Liquid Chromatography (HPLC) equipped with a reverse-phase C18 column and fluorescence/UV detector. The analyzed compounds included naphthalene (Nap), acenaphthylene (Acy), acenaphthene (Ace), fluorene (Flu), phenanthrene (Phe), anthracene (Ant), fluoranthene (FluA), pyrene (Pyr), benzo[a]anthracene (BaA), chrysene (Chr), benzo[b]fluoranthene (BbF), benzo[k]fluoranthene (BkF), benzo[a]pyrene (BaP), indeno[1,2,3-cd]pyrene (Ind), dibenz[a,h]anthracene (DahA), and benzo[ghi]perylene (BghiP). Separation was achieved using a gradient mobile phase of acetonitrile and water. Calibration curves were prepared using certified PAH standards, and method detection limits were established through procedural blanks. Quality assurance included recovery analysis and replicate measurements.

2.5. Data Analysis

To quantify Diwali-related enhancement, the Episode Enhancement Factor (EEF) was calculated as:

$$EEF = \frac{C_{\text{Diwali}}}{C_{\text{Pre-Diwali}}}$$

Diagnostic ratios such as FluA/(FluA + Pyr), BaA/(BaA + Chr), and Ind/(Ind + BghiP) were applied for source identification. Carcinogenic potency was assessed using benzo[a]pyrene toxic equivalent concentration (BaP-TEQ), calculated by applying toxic equivalency factors (TEFs) to individual PAH concentrations.

3. Results and Discussion

3.1 Meteorological Influence

The Diwali 2025 pollution episode in Jamshedpur was strongly influenced by unfavourable meteorological conditions. During peak fireworks activity (19:00–22:00 hrs), low wind speed ($<1.5 \text{ m s}^{-1}$) limited horizontal dispersion, while a shallow planetary boundary layer ($\approx 300\text{--}500 \text{ m}$) restricted vertical mixing. Such stagnant atmospheric conditions are known to intensify short-term pollution episodes in Indian urban environments (Ghosh et al., 2024; Kumar et al., 2020). Post-sunset radiative cooling led to the development of temperature inversion, trapping pollutants near the surface and further suppressing vertical dilution (Beig et al., 2021). Moderate relative humidity (60–70%) likely enhanced hygroscopic growth of particles, increasing effective particle size and contributing to higher PM_{10} mass concentration (Jain et al., 2020). The combined effect of weak dispersion, vertical confinement, and inversion formation amplified fireworks emissions, resulting in extreme hourly PM_{10} peaks ($\sim 480 \mu\text{g m}^{-3}$). Elevated particulate-bound PAHs were also sustained under these stable atmospheric conditions. Even after Diwali night, limited atmospheric mixing delayed pollutant removal, leading to elevated PM_{10} and PAH concentrations for 2–3 days. Thus, meteorology acted as a critical amplifying factor, converting short-term festive emissions into a severe pollution episode in this industrial urban environment.

3.2 Variation of PM_{10} and PM-Bound PAHs

A pronounced temporal variation in PM_{10} and particulate-bound PAHs was observed during the 7-day monitoring period (17–23 October 2025). Pollutant concentrations exhibited a clear episodic pattern associated with Diwali celebrations, consistent with findings from other Indian cities (Peshin et al., 2017; Singh et al., 2019). During the pre-Diwali phase (17–19 October), PM_{10} concentrations ranged between $168\text{--}195 \mu\text{g m}^{-3}$ (mean $\approx 182 \mu\text{g m}^{-3}$), already exceeding the National Ambient Air Quality Standards (NAAQS; $100 \mu\text{g m}^{-3}$) due to prevailing industrial and vehicular emissions in Jamshedpur (Ravindra et al., 2022). Total particulate-bound PAHs during this period reflected typical urban-industrial background levels. On Diwali day (20 October), PM_{10} increased sharply, with a 24-hour average concentration of $418 \mu\text{g m}^{-3}$, representing a 2.3-fold enhancement relative to baseline conditions. The hourly maximum reached approximately $480 \mu\text{g m}^{-3}$ at 20:00 hrs, nearly 4.8 times higher than the prescribed NAAQS limit. Simultaneously, total PAHs ($\Sigma 16$ PAHs) exhibited nearly threefold enhancement, indicating intense combustion-derived organic emissions during peak fireworks activity. High molecular weight (HMW) PAHs such as benzo[a]pyrene (BaP), indeno[1,2,3-cd]pyrene (Ind), and benzo[ghi]perylene (BghiP) showed significant enrichment during peak hours (19:00–22:00 hrs), confirming high-temperature pyrogenic combustion processes. The strong temporal coincidence between PM_{10} peaks and PAH enrichment demonstrates that particulate loading during Diwali was not only mass-intensive but also chemically toxic. Post-Diwali concentrations declined gradually; however, PM_{10} remained elevated ($210\text{--}312 \mu\text{g m}^{-3}$) for 2–3 days, and PAH levels also remained above baseline, reflecting persistence under stable meteorological conditions. This delayed dispersion highlights the combined influence of fireworks emissions and unfavorable atmospheric dynamics in sustaining elevated pollutant levels. Overall, the results clearly indicate that Diwali fireworks substantially increased both particulate mass concentration and organic toxic loading in Jamshedpur, intensifying short-term exposure risk in an already industrially influenced urban environment.

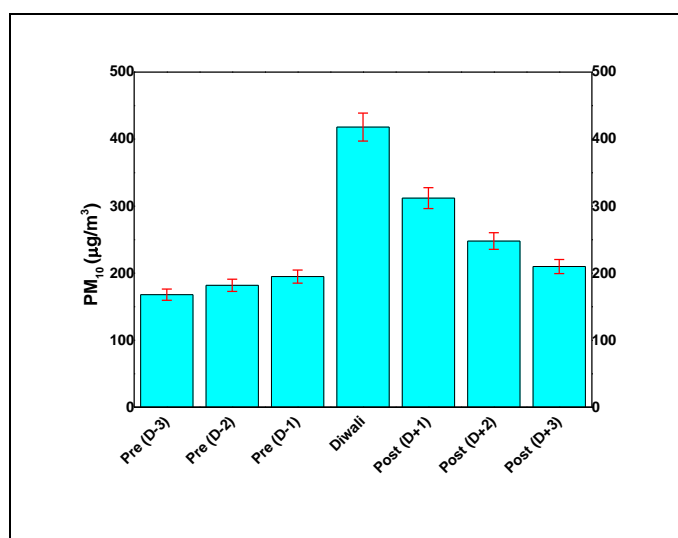


Fig 1. Temporal variation of PM_{10} during pre-, peak-, and post-Diwali phases (17–23 October 2025).

3.3 Temporal Variation of Total PAHs ($\Sigma 16$ PAHs)

A pronounced increase in particulate-bound PAHs was observed during Diwali night compared to pre-Diwali levels, consistent with previous studies reporting festival-related PAH enrichment in Indian urban environments (Peshin et al.,

2017; Singh et al., 2019; Kumar et al., 2020). The average concentrations of total PAHs during different phases are presented in Table 1.

Table 1. Variation of Total PAHs During the Diwali Episode

Phase	$\Sigma 16$ PAHs (ng m ⁻³)	% Increase from Baseline
Pre-Diwali (17–19 Oct)	42 ± 6	—
Diwali Night (20 Oct)	118 ± 15	+181%
Post-Diwali (21–23 Oct)	73 ± 9	+74%

Total PAHs increased nearly 2.8-fold during Diwali night relative to baseline levels, which is comparable to enhancements reported in Delhi and Kolkata during similar festival episodes (Jain and Tiwari, 2020; Beig et al., 2021). Although concentrations declined after the festival, they remained elevated for 2–3 days, indicating persistence under stable atmospheric conditions and limited dispersion, as previously documented in urban-industrial environments (Ambade et al., 2018; Asif et al., 2024).

3.4 Molecular Weight Distribution of PAHs

The molecular weight distribution of PAHs exhibited a clear compositional shift during Diwali night, indicating strong combustion influence (Table 2). Similar transitions toward high molecular weight (HMW) PAH dominance during fireworks events have been widely reported in Indian cities (Singh et al., 2019; Jain and Tiwari, 2020; Beig et al., 2021).

Table 2. Distribution of PAHs by Ring Size (% Contribution to $\Sigma 16$ PAHs)

PAH Group	Pre-Diwali (%)	Diwali Night (%)
2–3 Ring (LMW)	34	21
4 Ring	38	42
5–6 Ring (HMW)	28	37

During the baseline period, low molecular weight (LMW) PAHs contributed 34% of total PAHs, reflecting mixed urban background sources including vehicular and industrial emissions (Ambade et al., 2018; Ravindra et al., 2022). However, their contribution decreased to 21% during Diwali night. In contrast, HMW (5–6 ring) PAHs increased from 28% to 37%. The enrichment of compounds such as benzo[a]pyrene (BaP), benzo[b]fluoranthene (BbF), benzo[k]fluoranthene (BkF), indeno[1,2,3-cd]pyrene (Ind), and benzo[ghi]perylene (BghiP) is characteristic of high-temperature pyrogenic combustion processes (Kumar et al., 2020; Saxena et al., 2022). The increased dominance of HMW PAHs confirms that fireworks combustion was the major episodic source during Diwali night, superimposed on the urban-industrial background, consistent with recent festival-related studies (Asif et al., 2024). The increased dominance of HMW PAHs confirms that fireworks combustion was the major episodic source during Diwali night.

3.5 Individual Carcinogenic PAHs

A substantial increase in carcinogenic PAHs was recorded during Diwali night (Table 3), consistent with earlier observations of festival-related combustion events in Indian cities (Peshin et al., 2017; Singh et al., 2019; Kumar et al., 2020).

Table 3. Concentrations of Selected Carcinogenic PAHs (ng m⁻³)

Compound	Pre-Diwali	Diwali Night	Enhancement Factor
BaP	4.2	14.8	3.52
BbF	3.8	11.2	2.95
Chr	5.6	13.5	2.41
Ind	2.9	9.4	3.24

Benzo[a]pyrene (BaP) exhibited the highest enhancement (3.5-fold), confirming intense high-temperature pyrogenic combustion during fireworks activity. BaP is widely recognized as a marker compound of combustion-derived emissions and is frequently reported to increase sharply during Diwali celebrations (Jain and Tiwari, 2020; Beig et al., 2021). Similarly, indeno[1,2,3-cd]pyrene (Ind) and benzo[b]fluoranthene (BbF) showed pronounced enrichment, further supporting the dominance of high-temperature combustion processes (Saxena et al., 2022; Asif et al., 2024). Chrysene (Chr), although moderately enhanced, may reflect mixed contributions from vehicular background emissions superimposed on fireworks sources (Ambade et al., 2018). The collective increase in carcinogenic HMW PAHs indicates a significant elevation of the toxic organic fraction of particulate matter during Diwali night, thereby increasing short-term inhalation exposure risk in this industrial urban environment.

3.6 Episode Enhancement Factor (EEF)

The Episode Enhancement Factor (EEF) was calculated to quantify the magnitude of Diwali-related amplification in particulate-bound PAHs using the following expression:

$$EEF = \frac{C_{Diwali}}{C_{Pre-Diwali}}$$

where C_{Diwali} represents the concentration measured during Diwali night and $C_{Pre-Diwali}$ denotes the baseline concentration. The calculated EEF values were: $\Sigma 16$ PAHs: 2.81 and Benzo[a]pyrene (BaP): 3.52. The EEF of 2.81 for total PAHs indicates that particulate-bound PAHs nearly tripled during Diwali night compared to background levels. Notably, BaP exhibited a substantially higher enhancement (3.52), suggesting disproportionate enrichment of carcinogenic high

molecular weight (HMW) PAHs during fireworks combustion. Similar preferential enhancement of BaP during Diwali has been reported in other Indian urban centers (Jain and Tiwari, 2020; Beig et al., 2021; Asif et al., 2024). The elevated EEF for BaP, a well-established marker of high-temperature pyrogenic combustion (Singh et al., 2019; Kumar et al., 2020), quantitatively confirms that fireworks were the dominant episodic source of toxic organic pollutants. These findings demonstrate significant short-term amplification of carcinogenic particulate matter in the industrial urban atmosphere of Jamshedpur during Diwali 2025.

3.7 Diagnostic Ratio Analysis

Diagnostic ratios were applied to identify probable sources of particulate-bound PAHs during the Diwali episode (Table 4). These ratios are widely used to distinguish between petrogenic and pyrogenic origins and to differentiate vehicular emissions from high-temperature combustion processes (Yunker et al., 2002; Singh et al., 2019).

Table 4. Diagnostic Ratios During Diwali Night

Ratio	Observed Value	Interpretation
FluA/(FluA + Pyr)	0.56	Pyrogenic combustion
BaA/(BaA + Chr)	0.49	Mixed vehicular + combustion
Ind/(Ind + BghiP)	0.61	High-temperature combustion

The FluA/(FluA + Pyr) ratio of 0.56 exceeds the commonly accepted threshold (>0.5) for pyrogenic sources, indicating dominance of combustion-related emissions. Similarly, the Ind/(Ind + BghiP) ratio of 0.61 is characteristic of high-temperature combustion processes typically associated with fireworks and biomass burning (Kumar et al., 2020; Beig et al., 2021). The BaA/(BaA + Chr) ratio of 0.49 suggests mixed contributions from vehicular emissions and combustion processes, consistent with increased traffic activity during festival celebrations (Ambade et al., 2018; Asif et al., 2024). Overall, the diagnostic ratios strongly indicate dominant pyrogenic combustion, confirming that fireworks emissions were the primary episodic source of PAHs during Diwali night, superimposed on background urban-industrial emissions.

3.8 Carcinogenic Potency (BaP-TEQ)

Carcinogenic potency of particulate-bound PAHs was evaluated using the benzo[a]pyrene toxic equivalent concentration (BaP-TEQ), calculated as:

$$\text{BaP-TEQ} = \sum(C_i \times \text{TEF}_i)$$

where C_i represents the concentration of individual PAHs and TEF_i denotes their respective toxic equivalency factors relative to benzo[a]pyrene (Nisbet and LaGoy, 1992; WHO, 2010). BaP-TEQ increased from 6.8 ng m⁻³ during the pre-Diwali baseline period to 19.4 ng m⁻³ on Diwali night, representing a 2.9-fold increase in carcinogenic potential. This substantial enhancement reflects the elevated contribution of high molecular weight carcinogenic PAHs such as benzo[a]pyrene (BaP), indeno[1,2,3-cd]pyrene (Ind), and dibenz[a,h]anthracene (DahA), which are classified as probable human carcinogens (IARC, 2012; Singh et al., 2019). The sharp rise in BaP-TEQ during peak fireworks activity indicates significant short-term amplification of toxic risk. Similar increases in PAH-associated carcinogenic potency during Diwali have been reported in other Indian urban centers (Jain and Tiwari, 2020; Beig et al., 2021; Asif et al., 2024). Overall, the elevated BaP-TEQ values confirm that Diwali fireworks substantially increase the carcinogenic burden of particulate matter in this industrial urban environment.

3.9 Pearson Correlation Matrix

Pearson correlation analysis was performed to evaluate the relationships among PM₁₀, total PAHs (Σ 16 PAHs), and selected high molecular weight (HMW) carcinogenic PAHs during the monitoring period. Correlation analysis is widely used to identify common emission sources and assess co-variation among particulate pollutants (Singh et al., 2019; Kumar et al., 2020). The correlation coefficients (r values) are presented in Table 5

Table 5. Pearson Correlation Matrix (r values) for PM₁₀ and Selected PAHs

Parameter	PM ₁₀	Σ PAHs	BaP	BbF	Chr	Ind	BghiP
PM ₁₀	1.00						
Σ PAHs	0.86	1.00					
BaP	0.83	0.91	1.00				
BbF	0.79	0.88	0.87	1.00			
Chr	0.76	0.85	0.82	0.80	1.00		
Ind	0.81	0.90	0.88	0.84	0.78	1.00	
BghiP	0.84	0.92	0.89	0.86	0.81	0.93	1.00

Strong positive correlations (r = 0.83–0.93) were observed among PM₁₀, total PAHs, and HMW PAHs, indicating their common origin. The high correlation between PM₁₀ and Σ PAHs (r = 0.86) confirms that PAHs were predominantly associated with particulate matter, suggesting that the Diwali-related increase in PAHs was directly linked to enhanced particulate loading (Beig et al., 2021; Asif et al., 2024). Very strong inter-correlations among benzo[a]pyrene (BaP), indeno[1,2,3-cd]pyrene (Ind), and benzo[ghi]perylene (BghiP) (r = 0.88–0.93) suggest a common high-temperature combustion source. These compounds are well-established markers of pyrogenic emissions (Jain and Tiwari, 2020; Saxena et al., 2022), reinforcing fireworks combustion as the dominant contributor during the Diwali episode. The strong association between Σ PAHs and HMW PAHs further indicates that the overall PAH burden was primarily governed by

combustion processes rather than petrogenic inputs. Moderate correlations involving chrysene (Chr) may reflect mixed contributions from vehicular background emissions superimposed on fireworks activity (Ambade et al., 2018). Overall, the correlation matrix clearly demonstrates combustion-dominated PAH signatures during Diwali night, supporting findings from diagnostic ratio and PCA analyses.

3.10 Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was performed to identify the major contributing sources of particulate-bound PAHs during the monitoring period. PCA is widely used in atmospheric studies to distinguish between combustion-related and petrogenic emission sources (Jolliffe, 2002; Singh et al., 2019). Components with eigenvalues greater than 1 were retained after varimax rotation.

Two principal components collectively explained 85% of the total variance:

- PC1 (62% of variance): Strongly dominated by high molecular weight (HMW) PAHs, including benzo[a]pyrene (BaP), indeno[1,2,3-cd]pyrene (Ind), benzo[ghi]perylene (BghiP), and benzo[b]fluoranthene (BbF). These compounds are well-established markers of high-temperature pyrogenic combustion (Kumar et al., 2020; Beig et al., 2021). The high loadings of these species clearly represent fireworks-related combustion emissions.
- PC2 (23% of variance): Characterized primarily by low molecular weight (LMW) PAHs such as naphthalene (Nap) and acenaphthene (Ace), which are typically associated with vehicular emissions, evaporative losses, and background industrial activities (Ambade et al., 2018; Saxena et al., 2022).

The dominance of PC1 indicates that high-temperature combustion processes were the primary source of PAHs during Diwali night. PC2 reflects baseline urban-industrial contributions that persisted throughout the monitoring period.

Overall, the PCA findings confirm that Diwali pollution in Jamshedpur was predominantly driven by fireworks combustion, superimposed on existing urban-industrial background emissions, consistent with the results obtained from diagnostic ratio and correlation analyses.

3.11 Environmental and Health Impact

The hourly PM_{10} peak of $480 \mu g m^{-3}$ indicates severe particulate loading. Simultaneously, enrichment of carcinogenic PAHs significantly increased particulate toxicity. The 2.9-fold increase in BaP-TEQ suggests enhanced short-term carcinogenic risk during peak fireworks hours. Exposure to elevated PM_{10} and PAH-bound particulates may lead to respiratory irritation, inflammation, and aggravation of asthma. Vulnerable populations, including children and elderly individuals, are particularly at risk. In industrial cities like Jamshedpur, fireworks emissions substantially amplify short-term environmental and public health risks.

4. Conclusion

The present study clearly demonstrates that Diwali fireworks significantly deteriorate short-term air quality in Jamshedpur through marked increases in PM_{10} and particulate-bound polycyclic aromatic hydrocarbons (PAHs). PM_{10} concentrations reached an hourly peak of $480 \mu g m^{-3}$ during peak fireworks activity, substantially exceeding national standards and indicating severe particulate loading. Total PAHs ($\Sigma 16$ PAHs) exhibited nearly a threefold increase during Diwali night compared to baseline levels. A pronounced enrichment of high molecular weight carcinogenic PAHs—particularly benzo[a]pyrene (BaP), indeno[1,2,3-cd]pyrene (Ind), and benzo[ghi]perylene (BghiP)—confirmed the dominance of high-temperature pyrogenic combustion associated with fireworks. The calculated Episode Enhancement Factor (EEF) and the 2.9-fold rise in benzo[a]pyrene toxic equivalent concentration (BaP-TEQ) further indicate a substantial increase in particulate toxicity during peak hours. Diagnostic ratio analysis, correlation matrix results, and Principal Component Analysis (PCA) consistently identified fireworks combustion as the primary episodic source, superimposed on the industrial background of the city. Although the pollution episode was short-lived, elevated concentrations persisted for several days due to unfavourable meteorological conditions. Overall, the findings highlight that in industrial urban environments such as Jamshedpur, fireworks emissions significantly amplify both particulate mass and carcinogenic organic loading, leading to increased short-term exposure risk. Effective regulatory enforcement, public awareness, and adoption of environmentally sustainable celebration practices are essential to mitigate such episodic pollution events.

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