

Abundance, distribution pattern and health risk assessment of polycyclic aromatic hydrocarbons in size-segregated aerosols during Diwali festival in Delhi (India)

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ABSTRACT

Size-segregated aerosol samples were collected in Delhi during the Diwali festival (3-5 November, 2021) to evaluate Polycyclic Aromatic Hydrocarbons (PAHs) concentrations, molecular distribution, sources, and associated health risk. 3 samples (each with nine size ranges) were collected using an eight-stage Andersen cascade impactor, i.e., before-Diwali (BD), Diwali day (DD), and after-Diwali (AD). The Σ PAHs concentrations across different aerosol size fractions were in the range 1.2-147.4 ng/m³, with a sharp spike on Diwali day, and remained high in the after-Diwali sample. The nine size ranges were classified into submicron (PM_{-0.43-1.1}), fine (PM_{1.1-2.1}), and coarse (PM_{2.1-9}) fractions. Submicron fraction dominated PAHs loading (61.4%), followed by coarse (21.0%) and fine (17.6%) fractions. Naphthalene, benzo[b]fluoranthene, and Chrysene were observed to be the most abundant PAHs. The lognormal size distribution was bimodal, with peaks in the submicron and coarse fractions. Molecular diagnostic ratios indicated firecracker burning, vehicular emissions, coal/biomass burning, and cooking as the dominant PAHs sources. Inhalation cancer risk assessment revealed significantly higher carcinogenic risk in the submicron fraction, with risk exceeding acceptable limits by several orders of magnitude on Diwali day, underscoring the severe health implications of festival-related emissions.

Keywords: Diwali; Size-segregated aerosols; Polycyclic Aromatic Hydrocarbons (PAHs); Size distribution; Molecular Diagnostic Ratios; Health risk assessment

INTRODUCTION

Diwali is one of the main festivals in India and is celebrated with widespread cultural activities, including decorating houses with lights, lighting diyas/candles, and performing Goddess Lakshmi pooja, along with intense firecracker burning for a very short duration (Rastogi et al., 2019). Several studies have reported abrupt spikes in fine and coarse particulate matter, gaseous pollutants, and a wide range of inorganic and organic compounds due to firecracker burning during this period, indicating the short-lived, but strong impact of firecracker emissions on urban air quality (Kulshrestha et al., 2004; Singh et al., 2016; Kumar et al., 2020; Rani et al., 2023). Previous studies have also emphasized the health implications during such short-term episodic events (Chandu et al., 2023; Kumar et al., 2023). PAHs are ubiquitous organic compounds composed of two or more fused aromatic rings, and many are strong carcinogens and mutagens. PAHs are primarily formed by incomplete combustion and pyrolysis of carbonaceous fuels, as well as by the evaporation of petroleum products (Shen et al., 2012). Epidemiological and toxicological studies indicate that long-term exposure to particle-bound PAHs, even at low levels, can increase risks of lung cancer, DNA damage, and respiratory problems, while short-term exposure during pollution episodes can aggravate asthma and other acute health outcomes (Kim et al., 2013). Therefore, PAHs are categorised as persistent organic pollutants, and understanding their atmospheric levels, sources, and size distributions is critical for protecting air quality and human health.

In India, Diwali-related size-segregated aerosol studies have examined various particulate components, including water-

soluble ions, trace metals, elemental and organic carbon, and selected organic marker compounds (Rastogi et al., 2019; Mahilang et al., 2020). Regarding PAHs, many studies have examined PM₁₀- and PM_{2.5}-associated PAHs during the Diwali festival (Sarkar et al., 2010; Perrino et al., 2011; Kurwadkar et al., 2023). But there is a scarcity of research examining the distribution of PAHs across different particle size ranges during Diwali, despite the fact that particle size governs both the lifetime and respiratory deposition of particulate matter (PM). Possibly no previous study has quantified particle-bound PAHs in size-segregated aerosols during the Diwali festival in Delhi. The present study addresses this gap by elucidating their molecular and size distributions and associated human health risks.

METHODOLOGY

Study area

Delhi, the capital of India, is situated in the upper Indo-Gangetic Plain. It is one of the world's most polluted cities, especially in the Indo-Gangetic Plain, primarily due to its location and dense population (World Air Quality Report, 2024). Size-segregated aerosol sampling for this study was carried out at CSIR-National Physical Laboratory located in central Delhi (28°37'52" N, 77°10'01" E). The site is surrounded by agricultural fields, forest areas, residential and institutional areas, commercial centres, and a nearby major road, which contributes to vehicular emissions (Singh and Kulshrestha, 2024; Rani and Kulshrestha, 2025). Figure 1 shows the location of the sampling site.

Size-segregated aerosol collection

Size-segregated aerosol samples were collected using an 8-stage Andersen Cascade Impactor (ACI; TISCH), which