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Elemental Variation and Health Risk Assessment of $PM_{2.5}$ at Delhi during North-East Monsoon and South-West Monsoon †

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Abstract: This study elucidates the variation of $PM_{2.5}$ concentrations in Delhi during the north-east monsoon (NEM) and the south-west monsoon (SWM) period of 2014-2019. The average concentrations of $PM_{2.5}$ were 113 ± 48 μg/m³ and 50 ± 19 μg/m³ during NEM and SWM, respectively. Further, the elemental composition of $PM_{2.5}$ was analyzed using wavelength dispersive X-ray Fluorescence (WD-XRF). During NEM, it was observed that the Na, Cl and S dominating over the region, whereas, Na, S, Al, dominated during the SWM season. Backward trajectories analysis suggested the long-range transportation of air mass from the Sahara Desert (SD), Arabian Sea (AS), and Bay of Bengal (BOB) for both the seasons (NEM and SWM), thus significantly affecting the loading of mass concentration of $PM_{2.5}$ at the study site of Delhi. We have also evaluated the hazard quotient (HQ) of elements present in $PM_{2.5}$ over Delhi during this period.

Keywords: $PM_{2.5}$, North east monsoon (NEM), South west monsoon (SWM), WD-XRF

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1. Introduction

Delhi, India's capital, has been named one of the world's worst megacities for air quality [1]. The NCR is the nation's hub, with a significant commercial, economic, defensive, industrial, and political institution [2]. In the ambient air, fine particulate matter ($PM_{2.5}$) has a significant influence on human health, causing tenderness on the lung's surface [3] because fine particle has a higher surface area than coarse particles. It is more prone to captivate hazardous or toxic components like heavy metals. The concentration of toxic heavy metals (like Cd, Pb, As, Cr, etc.) in $PM_{2.5}$ is high and can be breathed straight into the respiratory system and become bioavailable [4]. Several metals, including Mn, Fe, Cu, Al, Ba, and Pb, are extensively disseminated in PM and are thus suspected of being a significant cause of PM toxicity [5]. Heavy metal concentrations in atmospheric aerosols have increased intensely in recent years, owing primarily to substantial anthropogenic activity, secondary sources, and forest fires [6]. Ni, Cd, and Cr are all listed as class I carcinogenic pollutants by the International Agency for Research on Cancer (IARC) [7]. Heavy metals contribute only a minor portion of $PM_{2.5}$. Through inhalation, metals cause health risks to humans [4]. In this given study, we observed the mass concentration of $PM_{2.5}$, its elements and health risk

2. Location and sample collection

Fine particulate ($PM_{2.5}$) samples were collected at CSIR- National Physical Laboratory (NPL), New Delhi (28° 38′ N, 76° 22′) (Figure 1). The sampling location depicts a typical metropolitan area surrounded by agricultural land and roadside traffic in the southwest direction. During the north-east monsoon (winter) air mass movement is from north-east to the north-west and south-west monsoon (summer) from the south-east to the southwest [1]. Delhi suffers from a significant haze, fog, and cheap visibility during winter and summer. Mineral dust contributes considerably to the formation of aerosol due to dust storms [8]. $PM_{2.5}$ samples were collected using fine particulate sampler with a flow rate of 1 $m^3 h^{-1}$ on QMA filters with a diameter of 47 mm. Before sampling, to eliminate all traces of organic pollutants and moisture, QMA filters were pre-baked for 4-6 hours at 500 ^0C. Details are given in previous publications [9,10].

3. Methodology

3.1 Chemical analysis

The non-destructive elemental analysis of 15 elements (S, Na, Cl, Ca, Al, K, Mg, P, Cu, Fe, Cr, Zn, Ag, As, and Cd) deposited on $PM_{2.5}$ filters were performed using Wavelength Dispersive X-ray Fluorescence Spectrometer (WD-XRF) the Rigaku ZSX Primus. Blank filters were used for the measurements, and loaded filter intensities were corrected. Detailed description is available in previous paper [1].

3.2 Human health risk assessment

The United States Environmental Protection Agency (EPA) provided this model [4]. Human health risk assessment can assess the health impacts of environmental pollutant exposure (both non-carcinogenic and carcinogenic). When inhaled, elements bounded with $PM_{2.5}$ in the ambient air can easily permeate deep into human lung tissues. Heavy metals have different effects depending on their toxicity, period of exposure, and concentration [11].

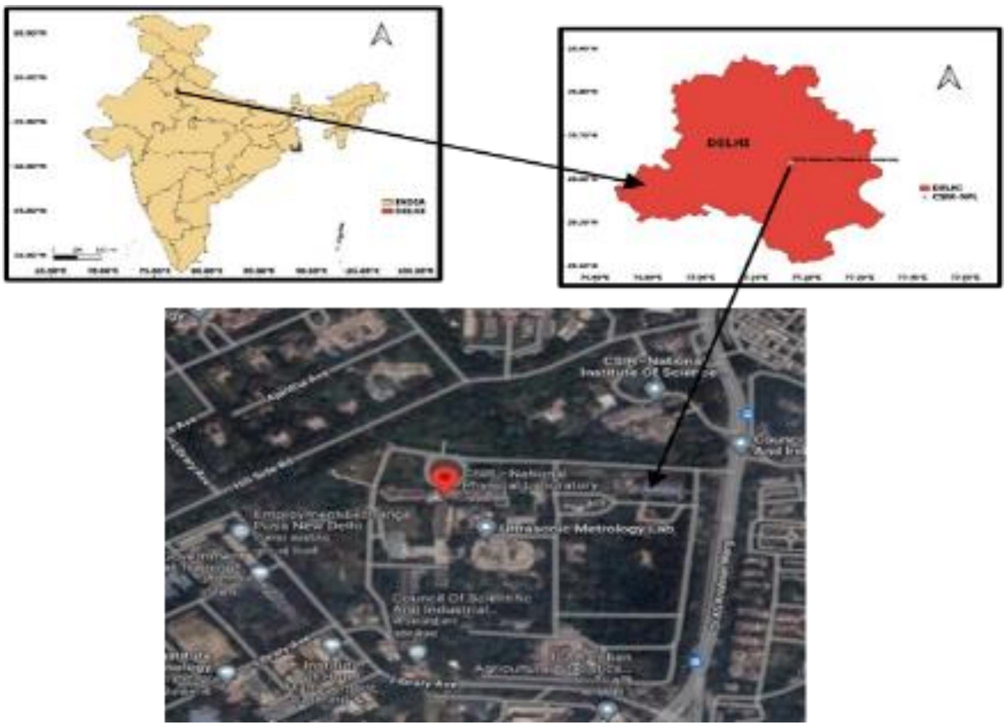


Figure 1. Location of the sampling site CSIR-NPL, New Delhi, India

4. Results

4.1 $PM_{2.5}$ concentration and elemental concentration

Ambient air mass concentrations of $PM_{2.5}$ during NEM and SWM were 113± 48 µg/m³ and 50 ± 19 µg/m³ (Figure 2) respectively, which were lower than earlier reported observations [1, 8, 12]. Concentrations of dominant elements Na, Cl, S were higher during NEM than during SWM (Figure 3). In earlier reports [13,14] concentration of K and Ca were noticed maximum during winter and summer.

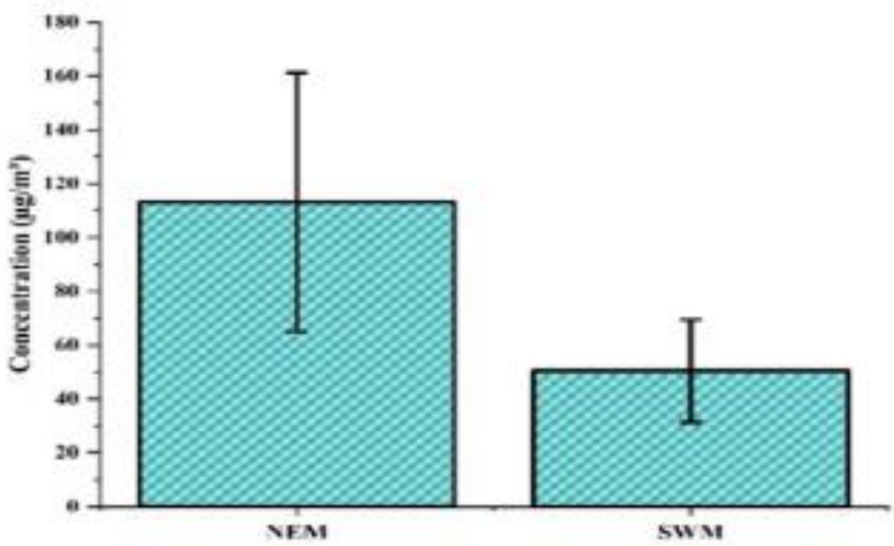
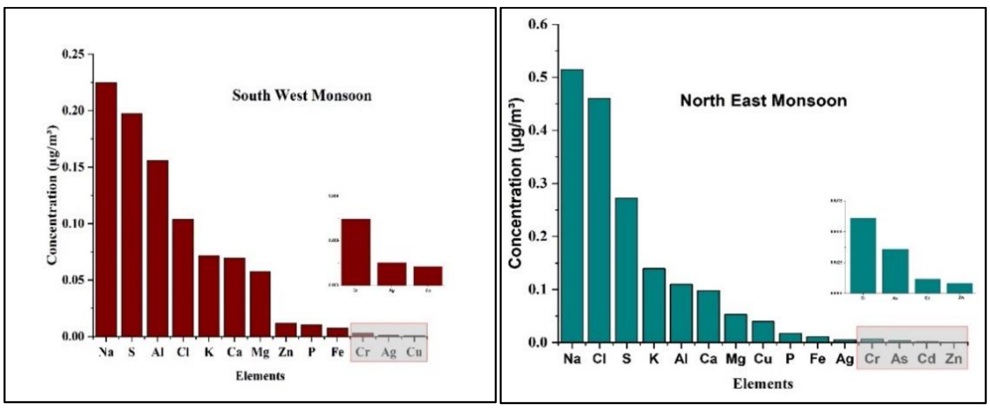


Figure 2. $PM_{2.5}$ concentrations during NEM and SWM



(**a**) (**b**)

Figure 3. Concentration of elements present in $PM_{2.5}$ during (a) NEM and (b) SWM

4.2 Human health risk assessment

Health risk assessment was also performed for toxic elements Cd, As Cr, shown in Table 1. The hazard quotient (HQ) and carcinogenic risk (CR) for children and adults for the elements Cd, As, and Cr was less than 1indicates the non-hazardous elements.

Table 1. Carcinogenic and non-carcinogenic risk over Delhi

Season	Elements	Non carcinogenic	Carcinogenic	
		HQ	Children	Adults
NEM	Cd	9.78E-03	7.04501E-07	1.76125E-07
	As	6.52E-05	3.36595E-07	8.41487E-08
	Cr	1.19E-03	5.7296E-09	1.4324E-09
SWM	Cr	3.28E-03	2.78149E-09	6.95372E-10

5. Conclusion

In the present study the concentration of $PM_{2.5}$ and the metals associated with it shows the seasonal variations during the NEM and SWM and higher concentration of $PM_{2.5}$ occurred during NEM. Health risk assessments for carcinogenic and non-carcinogenic for Cd, As, and Cr are under the safe limit.

Author Contributions: MR, SG, RB, AR, SC, RA, PY have collected $PM_{2.5}$ samples at CSIR-NPL, Delhi. MR, SA, SG analyzed the metal data using ED-XRF. MR has analyzed data and taken lead in drafting manuscript. TKM and SKS has conceptualized the program and involved in data analysis, reviewing, proofreading and overall supervision.

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Conflicts of Interest: The authors declare no Conflict of interest.

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