Seasonal Variation of $PM_{2.5}$-bound Metal Elements and Associated Health Risk in Central Bangkok, Thailand

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ABSTRACT

$PM_{2.5}$ pollution remains a top environmental priority in urban areas, with $PM_{2.5}$ concentrations heavily influenced by emission sources, meteorological conditions, and atmospheric dynamics. The continuous measurement of $PM_{2.5}$ and associated metal elements was carried out on the rooftop of Department of Environmental and Sustainable Engineering, Chulalongkorn University, Pathumwan district of Bangkok, Thailand. The study was carried out during the dry season in the month of January to March, and wet season in the month of June to August, 2025. The 24 hours continuous monitoring of $PM_{2.5}$ and the metal elementals was conducted using an automated X-ray fluorescence analyzer (PX-375, Horiba Ltd.). The carcinogenic and non-carcinogenic health risk of metal elements was determined. The concentration of $PM_{2.5}$ frequently exceed the Thailand National Air Quality Standard (37.50 µg/m^3) and World Health Organization (WHO) guidelines (15.00 µg/m^3). The mean concentration of $PM_{2.5}$ in the dry season was 31.79 ± 13.61 µg/m^3. On the hand, the average $PM_{2.5}$ concentration in the wet season was 11.04±3.81 µg/m^3. The $PM_{2.5}$ concentration in the dry season month was approximately 2.88 times higher than that in the wet season month. The concentration profiles of metal elements exhibited a similar decreasing trend across both seasons: S > Si > K > Al > Mg > Fe > Ca > Cl > P > Cu > Pb > Zn > Ni > Mn > Ba > Te > Ti > Sr > Ag > La > Co > Sn > V > Cr > Zr > Rb > Ce > Cd > Bi > Sb > Y > Hg > Ge > In > Ga > As. Among the $PM_{2.5}$-bound metal elements, sulfur (S) was the most abundant element, accounting for 52.64% (4,409.27±2,757.02 ng/m^3) and 29.26% (1286.32±906.79 ng/m^3) of the total $PM_{2.5}$ mass in the months of dry and wet seasons, respectively. According to the health risk assessment of $PM_{2.5}$-bound metal elements via the inhalation pathway. The non-carcinogenic risk of metal elements in both dry and wet season monitored months exceeded the safe threshold ($HQ \leq 1$), indicating significant non-carcinogenic risks for adults and children. Furthermore, the Total Lifetime Cancer Risk (TLCR) of $PM_{2.5}$-bound metals ranged from 2.34×10^{-3} to 2.77×10^{-3} for adults and children during both months, slightly exceeded the acceptable limit ($TLCR \leq 10^{-6}$- 10^{-4}). Additionally, children are at a significantly higher risk, with potential carcinogenic vulnerabilities being higher than adults under the same urban environmental conditions.

Keywords: Inhalation exposure/ Health risk/ Total Lifetime Cancer Risk