

Evaluation of Trace Metals and Metalloids in PM_{2.5}, Exploration of Source Contributions Using PCA and PMF, and Health Risk Assessment for People in Dhaka

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Introduction

Dhaka is exposed to severe health hazards due to air pollution caused by PM_{2.5} and vehicle emissions, industrial processes, and burning biomass, which lead to respiratory diseases, cardiovascular and cancer. Children are an especially vulnerable group, especially children. This requires round-the-clock observation and proper control of air pollution to reduce health hazards and enhance air quality. This paper measures the concentration of heavy metals and metalloids (Pb, As, Be, Cd, Co, Cr, Cu, Hg, Mn, Ni, Se, V, Zn, Fe) in the air particulate matter of Dhaka, showing health risks and their sources apportionment.

Sampling method

Location: The experiment was done on the rooftop of the Mukarram Hussain Khundker Biggyan Bhaban, University of Dhaka (75-76 ft above ground) to reduce local pollution interference.

Objective: To measure the concentrations of heavy metals & metalloids in PM2.5.

Sampling Equipment: TH-150H air sampler and 90 mm quartz filter, which gathers samples at 24hour intervals (8:00 a. m. to 8:00 a.m.).

Pollution Representation: The place was selected as the general air quality in Dhaka that is overly industrialized and car-reliant.

Methodology: Filters were preheated at 450°C and then sampled after 12 hours and weighed under controlled conditions. Ion analysis Filters were stored post-sampling.

Research Period: The collected samples were taken between November 5,2023 and March 19, 2024, and 20 valid samples were analyzed.

Policy Implications: Results will be used to influence policy to decrease exposure to polluting substances and enhance human wellbeing in Dhaka.

Sample preparation & Analysis

10 mL of 70% nitric acid (HNO₃) was used to digest a quarter of the filter paper after which 5 mL of 35% hydrogen peroxide (H₂O₂) was added. 10 mL of deionized water was added to the solution that was acid-digested. After that, 1 mL of this solution was diluted again by 9 mL of deionized water. The air-based dust samples were analyzed to determine the heavy metals by Inductively Coupled Plasma Mass Spectrometry (ICP-MS), namely, the PerkinElmer NexION®2000 ICP-MS model.



Health risk Assessment

According to the findings, the respective mean concentrations of Pb , As , Be , Cd , Co , Cr , Cu , Hg , Mn , Ni , Se , V , Zn & Fe were determined to be 510.79±286.38, 18.05±12.39, 0.096±0.039, 32.45±23.51, 1.34±1.08, 145.555±126.379, 47.386±18.753, 0.165±0.129, 133.498±71.758, 24.835±23.838, 5.723±3.026, 8.444±5.659, 1272.94±947.86 & 2328.54±940.88 ng/m³

$$ADD_{I-inhalation} = \frac{C_i \times IR_{I-inh} \times ED \times EF \times 10^{-3}}{BW \times AT \times PEF} \dots\dots\dots (1)$$
$$ADD_{I-ingestion} = \frac{C_i \times IR_{I-ing} \times ED \times EF \times 10^{-3}}{BW \times AT} \dots\dots\dots (2)$$
$$ADD_{I-dermal} = \frac{C_i \times SA \times AF \times ABS \times ED \times EF \times CF \times 10^{-3}}{BW \times AT} \dots\dots\dots (3)$$
$$HQ_i = \frac{ADD_i}{RfD_i} \dots\dots\dots (4)$$
$$Total\ HQ_i = HQ_i-inhalation + HQ_i-ingestion + HQ_i-dermal \dots\dots\dots (5)$$
$$HI_{inhalation/ingestion/dermal} = \sum HQ_i-inhalation/ingestion/dermal \dots\dots\dots (6)$$
$$Total\ HI = THI + HI_{inhalation} + HI_{ingestion} + HI_{dermal} \dots\dots\dots (7)$$

$$LADD_{I-inhalation} = \frac{C_i \times IR_{I-inh} \times ED \times EF \times 10^{-3}}{BW \times AT \times PEF} \dots\dots\dots (8)$$
$$LADD_{I-ingestion} = \frac{C_i \times IR_{I-ing} \times ED \times EF \times CF \times 10^{-3}}{BW \times AT} \dots\dots\dots (9)$$
$$LADD_{I-dermal} = \frac{C_i \times SA \times AF \times ABS \times ED \times EF \times CF \times 10^{-3}}{BW \times AT} \dots\dots\dots (10)$$
$$CR_{inhalation/ingestion/dermal} = LADD_i \times CSF_i \dots\dots\dots (11)$$
$$LCR = Cumulative\ CR_{inhalation} \times \frac{1}{70} + Cumulative\ CR_{inhal} \times \frac{11}{70} + Cumulative\ CR_{inhalation} \times \frac{6}{70} + Cumulative\ CR_{inh} \times \frac{52}{70} \dots\dots\dots (12)$$

Table 1: Total Hazard Index (THI) for noncarcinogenic risk for different groups			
Age Group	Total Hazard Index (THI)	Summary of Risk Level	
Newborn	0.00651636	Highest cumulative noncarcinogenic risk.	
Child	0.004451817	Moderate risk, lower than newborns.	
Adolescent	0.002496517	Lower risk than children and newborns.	
Adult	0.001057	Lowest noncarcinogenic risk among groups.	

Table 2: Lifetime Cancer Risk (LCR) for different metals for different groups							
Group	Pb	As	Cd	Co	Cr	Ni	
Newborns	4.77E-10	3.23E-09	1.30E-09	9.18E-14	2.10E-08	1.45E-13	
Child	2.79E-09	1.95E-08	7.44E-09	6.53E-13	1.56E-07	1.04E-12	
Adolescent	6.40E-10	4.67E-09	1.66E-09	2.03E-13	4.64E-08	3.22E-13	
Adult	2.32E-09	1.66E-08	6.12E-09	1.48E-12	1.52E-07	2.35E-12	

In comparison, Table 1 shows the Total Hazard Index (THI) for noncarcinogenic risks decreases with age from 0.0065 in newborns to 0.0011 in adults. Table 2 reveals that Lifetime Cancer Risk (LCR) is higher in children and adults, particularly for metals like arsenic (1.95E-08 in children) and chromium (1.52E-07 in adults).



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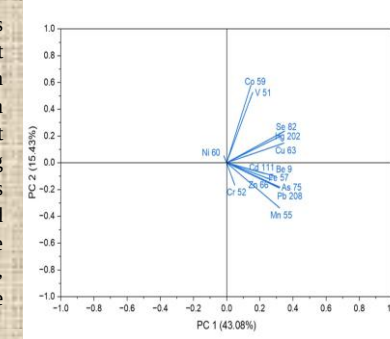
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Source Apportionment

PCA Analysis

The PCA plot shows the relationships between various metals based on their concentration patterns. The first principal component (PC1) explains the most variation in the data, with metals like Nickel (Ni) and Cadmium (Cd) strongly correlating with it. The second component (PC2) adds another layer of variability, highlighting metals such as Selenium (Se) and Mercury (Hg). Metals positioned close to each other, like Copper (Cu) and Zinc (Zn), exhibit similar concentration trends, while those farther apart, like Nickel (Ni) and Selenium (Se), show distinct patterns. This analysis reveals how these metals interact and vary within the dataset.



PMF Analysis

PMF Run 14 reveals six major sources of pollution:

Factor 1: Emissions from industries and traffic, linked to metals like Cobalt, Chromium, and Iron.

Factor 2: Combustion sources, particularly from power plants, contributing to Nickel and Manganese.

Factor 3: Industrial emissions and brake wear, with elements like Beryllium and Copper.

Factor 4: Pollution from oil combustion and smelting, involving Lead, Arsenic, and Vanadium.

Factor 5: Tire wear and manufacturing activities, affecting Zinc and Cobalt levels.

Factor 6: Waste incineration and industrial waste, releasing Cadmium, Selenium, and Zinc.

These findings shed light on the main pollution sources, helping to guide effective air quality management strategies

