Characterization of Atmospheric Fine Particulate Matter at Indoor Environment of Several Residential Homes in Dhaka, Bangladesh

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Introduction

In recent years, public concern over Indoor Air Quality (IAQ) has increased dramatically, as hundreds of air pollutants from various indoor and outdoor sources have been identified in indoor environment. When considering human exposure to airborne pollutants, of particular importance is the exposure to fine particulate matter ($PM_{2.5}$), as it has a higher probability of penetration into the deeper parts of the respiratory tract of human body. The indoor particulate matter may originate from (a) indoor sources such as tobacco smoke, combustion devices (e.g. stoves and kerosene heaters), cooking, cleaning, dusting, synthetic building materials and (b) infiltration of outdoor air. Indoor air quality in Dhaka, Bangladesh has been severely deteriorated due to presence of particulate matters and gaseous air pollutants in an extremely high extent. Hence it is imperative to characterize indoor fine particulate matter, investigate the sources of its components and assess the health risk imposed by it in order to adopt effective measures for reducing the severity of indoor air pollution.

Methodology

Four different locations across Dhaka, Bangladesh, namely- **Dholaipar**, **Khilkhet**, **Mirpur** and **Rampura** were selected for this study. Indoor $PM_{2.5}$ samples were collected from the living room of residential homes during August to October, 2017 using dual channel dust sampler (Model: IPM- FDS 2510) from 7:00 a.m. to 9:00 p.m. for three consecutive days. Samples were deposited on pre- weighed and pre- combusted (6 h at 450 °C) 47 mm diameter quartz filters. The samples were subjected to SEM and FTIR analysis. Later extraction of indoor $PM_{2.5}$ samples was carried out and the filtrates were used for quantification of water-soluble cations, sulphate ion and total organic carbon (TOC) using Flame Photometer, UV- Visible spectrometer and TOC analyzer respectively.
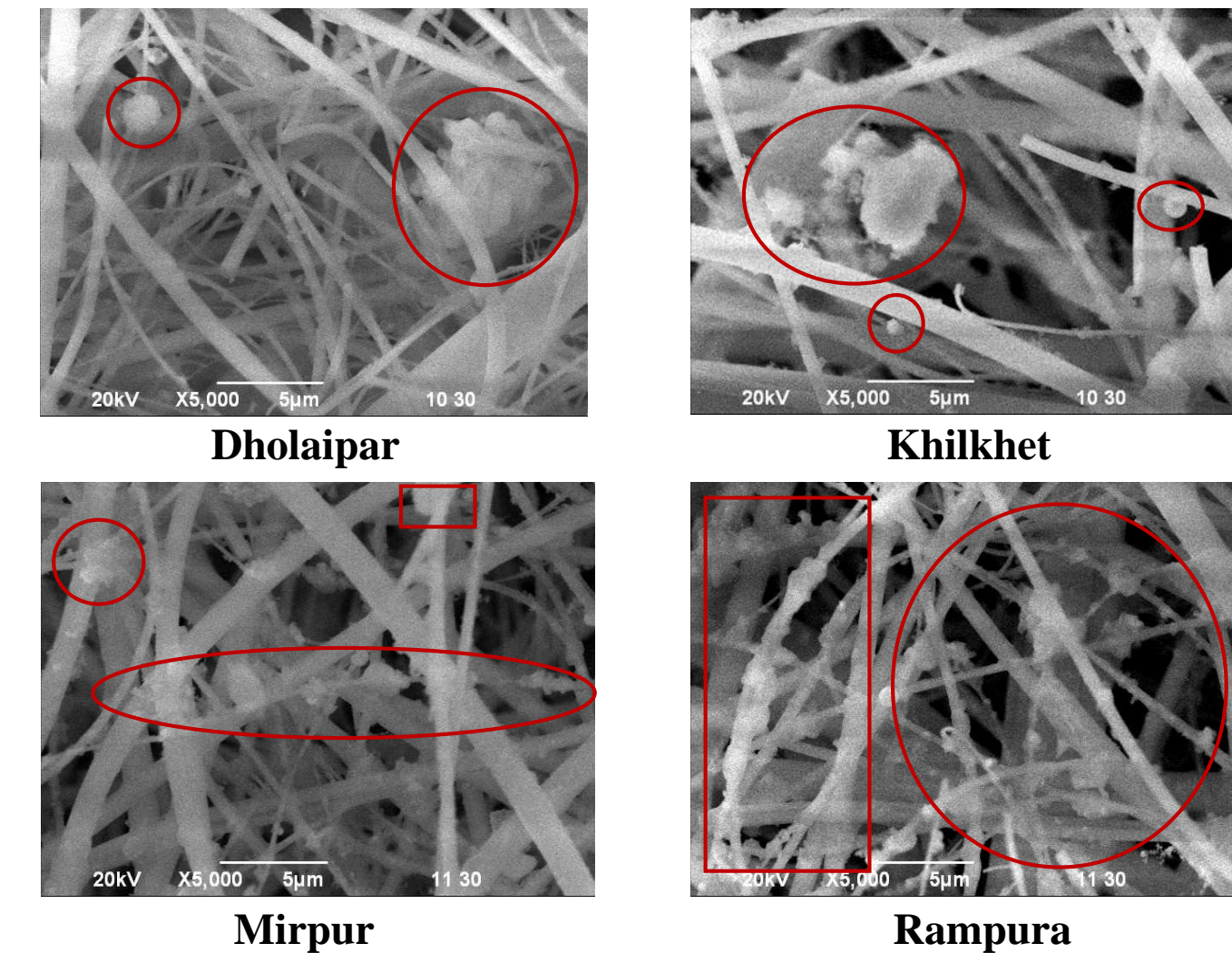
Results & discussion

1. SEM analysis:

Dholaipar   **Khilkhet**

Mirpur   **Rampura**

Figure- 1: SEM images of $PM_{2.5}$ of indoor air at various sampling sites in Dhaka

2. FTIR analysis:

Sampling locations	Characteristic bands of functional groups	Functional groups present in indoor $PM_{2.5}$
Dholaipar	3373.50 cm^{-1} (-O-H stretching), 2887.44 cm^{-1} (-C-H stretching), 1641.42 cm^{-1} and 1508.33 cm^{-1} (aromatic C=C stretching) and 1346.31 cm^{-1} (-CH$_3$ bending)	-O-H, -C-H, aromatic C=C and -CH$_3$
Khilkhet	3373.50 cm^{-1} (-O-H stretching), 2899.01 cm^{-1} (-C-H stretching), 1645.28 cm^{-1} and 1489.05 cm^{-1} (aromatic C=C stretching), 1350.17 cm^{-1} (-CH$_3$ bending) and 1232.51 cm^{-1} (-C-O-H bending)	-O-H, -C-H, aromatic C=C, -CH$_3$ and -C-O-H
Mirpur	3377.36 cm^{-1} (-O-H stretching), 2883.58 cm^{-1} (-C-H stretching), 1641.42 cm^{-1} and 1498.69 cm^{-1} (aromatic C=C stretching), 1350.17 cm^{-1} (-CH$_3$ bending) and 1234.44 cm^{-1} (-C-O-H bending)	-O-H, -C-H, aromatic C=C, -CH$_3$ and -C-O-H

Sampling locations	Characteristic bands of functional groups	Functional groups present in indoor $PM_{2.5}$
Rampura	3381.21 cm^{-1} (-O-H stretching), 2885.51 cm^{-1} (-C-H stretching), 1641.42 cm^{-1} and 1502.55 cm^{-1} (aromatic C=C stretching), 1352.10 cm^{-1} (-CH$_3$ bending) and 1232.51 cm^{-1} (-C-O-H bending)	-O-H, -C-H, aromatic C=C, -CH$_3$ and -C-O-H

3. Quantification of water-soluble cations in samples:

The indoor $PM_{2.5}$ samples were analyzed for water soluble cations (Na^+, K^+ and Ca^{2+}) using Flame Photometer. The average concentration of Na^+ and Ca^{2+} ions were 19.04 and 20.86 μgm^{-3}. The concentration of K^+ ion was almost same for Dholaipar and Khilkhet whereas that for Mirpur and Rampura was below the detection limit of Flame Photometer employed.
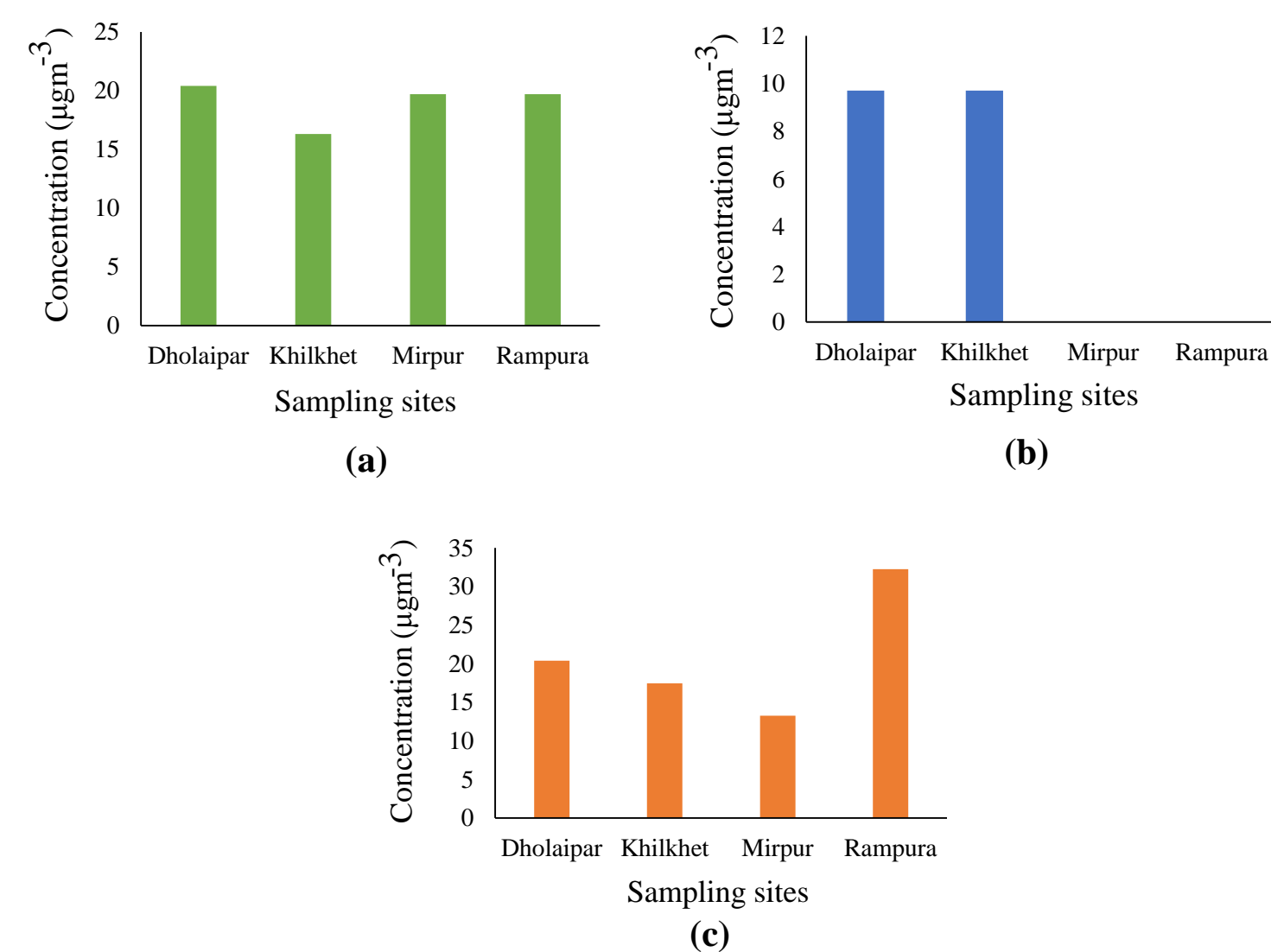

(a)   (b)

(c)

Figure- 2: Variation of concentration of **(a)** Na^+, **(b)** K^+ and **(c)** Ca^{2+} ions at different sampling sites in Dhaka

Source contribution of water- soluble cations in indoor $PM_{2.5}$:

Locations	Water- soluble cations	Sea salt fraction (% SSF)	Crustal fraction (%CF)	Anthropogenic source fraction (%AF)
Dholaipar	Na$^+$	67.32	32.68	-
	K$^+$	81.05	18.95	-
	Ca^{2+}	4.88	95.12	-
Khilkhet	Na$^+$	64.99	35.01	-
	K$^+$	64.84	35.16	-
	Ca^{2+}	4.55	95.45	-
Mirpur	Na$^+$	77.94	22.06	-
	K$^+$	*ND	ND	ND
	Ca^{2+}	7.22	92.78	-
Rampura	Na$^+$	46.41	53.59	-
	K$^+$	ND	ND	ND
	Ca^{2+}	2.97	97.03	-

*ND= Not Determined

Enrichment factor (EF) of metals:

The enrichment factors (EF) were derived for selected metals (Na, K and Ca) in the indoor environment of Dhaka relative to the composition of the earth crust using Ca as the reference element. Hence, **EF= (X/ Ca) $_{Aerosol}$ / (X/ Ca) $_{Crust}$** [1]

In this study, potassium had minimal enrichment (EF of < 2) in the indoor fine particulate matter at all the sampling locations whereas sodium had moderate enrichment (EF of 2< 5) at all the locations except Rampura (EF of < 2). Calcium had a EF value of 1 for all the sites.
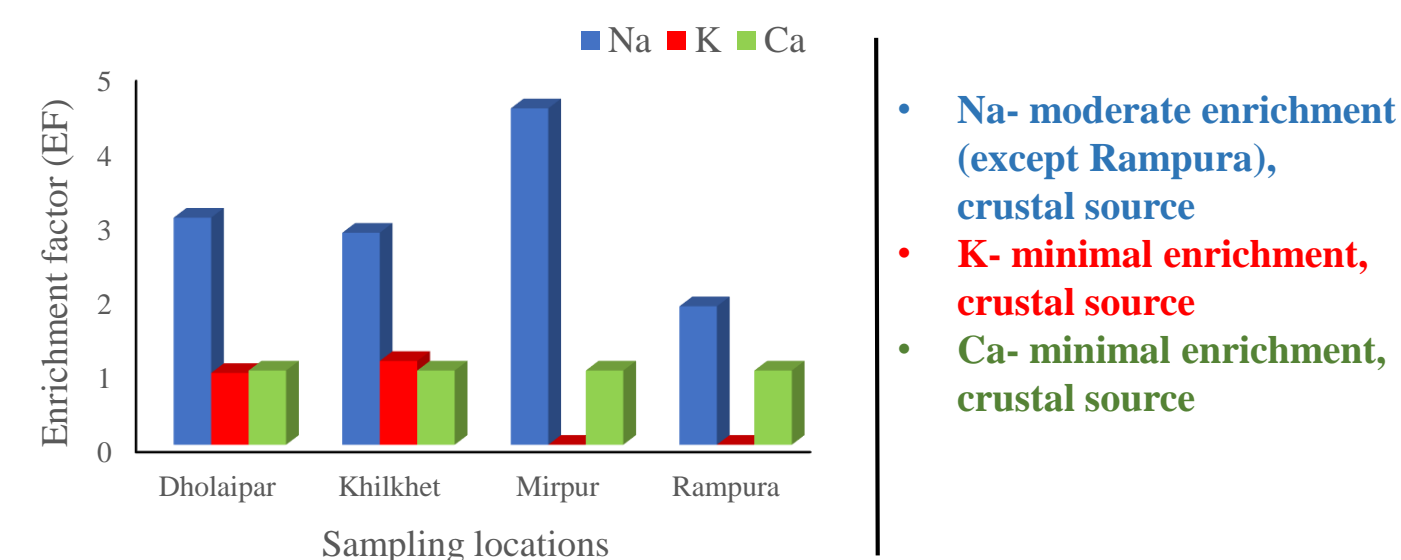

- Na- moderate enrichment (except Rampura), crustal source
- K- minimal enrichment, crustal source
- Ca- minimal enrichment, crustal source

Figure- 3: Enrichment factor of metals in indoor $PM_{2.5}$ at various sampling locations in Dhaka

4. Quantification of sulphate in samples:

The indoor $PM_{2.5}$ samples were analyzed for sulphate ion using UV- Visible spectrometer. The average concentration of SO_4^{2-} for all the monitoring sites was 1472.40 μgm^{-3}.
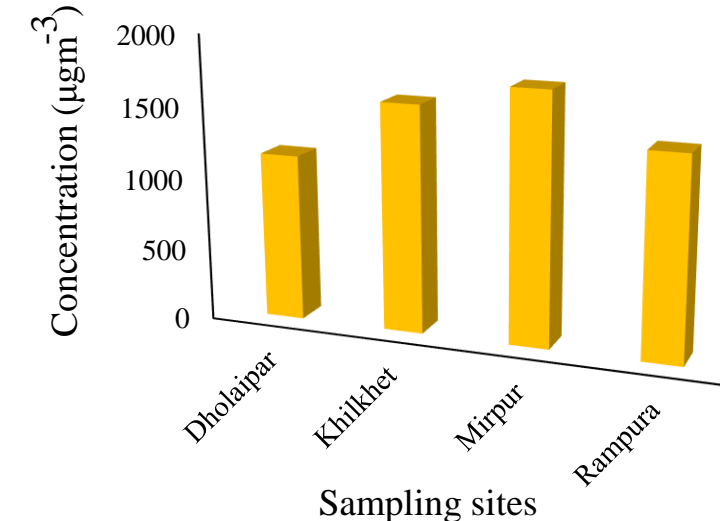

Figure- 4: Variation of concentration of SO_4^{2-} ion at different sampling sites in Dhaka

Source contribution of sulphate in indoor $PM_{2.5}$:

If the contributions from volcanic eruption, earth's crust and other natural sources were negligible, then sulphate mainly originates from anthropogenic sources and sea salt spray. Assuming that all Na is of marine origin and using Na as a tracer of sea salt, excess non-sea salt origin (NSS) sulphate can be calculated as:

NSS- sulphate = [sulphate]− [Na]× 0.2516 [2]

Locations	Concentration of NSS- sulphate (μgm^{-3})	Sea salt fraction (%SSF)	Crustal Fraction (% CF)	Anthropogenic source fraction (% AF)
Dholaipar	1160	0.91	-	99.09
Khilkhet	1580	0.54	-	99.46
Mirpur	1736	0.59	-	99.41
Rampura	1395	0.73	-	99.27

5. Quantification of Total Organic Carbon in samples:

The concentration of Total Organic Carbon (TOC) in Dholaipar, Khilkhet, Mirpur and Rampura were found to be 295.07, 360.73, 58.32 and 26.83 μgm^{-3} respectively.
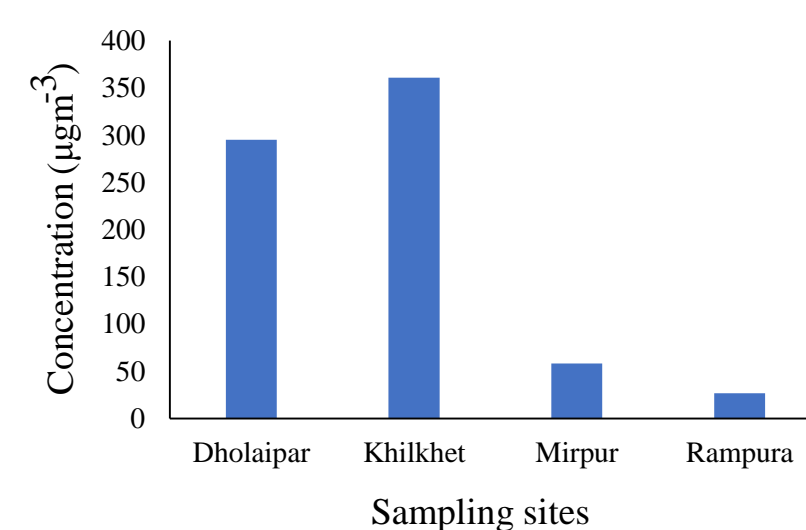

Figure- 5: Variation of concentration of TOC at different sites in Dhaka

Conclusion

- In Rampura, the indoor fine particulate matter was less aggregated and more distributed whereas that in Dholaipar had greater aggregation and less distribution. Indoor $PM_{2.5}$ in Khilkhet and Mirpur had intermediate distribution.
- The composition of the $PM_{2.5}$ of indoor air at all the monitoring sites were assumed to be almost same as they possessed the same organic functional groups (-O-H, -C-H, aromatic C=C, -C-O-H and -CH$_3$).
- Enrichment factor and source contribution showed that both sea salt spray and crustal sources contributed to the presence of sodium and potassium ions in indoor $PM_{2.5}$ whereas earth's crust was assumed to be the major source of calcium ion. On the contrary, over 99% of sulphate originated from anthropogenic sources at all the sampling locations.

References

[1] Puxbaum, H. (1993). Luftchemie. Schriftenreihe "Modern Analytical Chemie," Band Institutfür Analytical Chemie, Technische Universät Wien.
[2] Ho, K., F., Lee, S., C., Chan, C., K., Yu, J., C., Chow, J., C., Yao, X., H. (2003). Characterization of Chemical Species in $PM_{2.5}$ and PM_{10} Aerosols in Hong Kong. Atmospheric Environment, 37, 31-39.