Tehran UFP Study: Spatial and Temporal Distribution

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Introduction

Background

- Exceeding growth of urban traffics along with the use of low standard vehicles and high sulfur content fuels has exacerbated Tehran's air pollution crisis in recent years.
- Ultrafine particles (UFP, <100 nm) are expected to carry more toxic materials compared to larger PMs due to their high surface area-to-mass ratio [1].
- Understanding the dynamic behavior and exposure effects of UFPs require long–term studies which still remain unclear in the most populous areas, especially in the city of Tehran [2].

Objectives

- To measure fall-time spatiotemporal variation of UFP metrics (number concentration and size) across the city of Tehran using a combination of stationary and mobile monitoring.
- To investigate the effect of meteorological and urban parameters in UFP dispersion.
- To evaluate the correlation of UFP concentration with other pollutants e.g. larger PMs.

Methodology

Stationary Monitoring

Diurnal variation of UFP metrics were measured in seven air quality monitoring stations:

- 3 roadside
- 4 residential background

Mobile Monitoring

Mobile monitoring of UFP metrics was conducted in a typical downtown area during evening rush hour (5-7 pm).

Meteorological and Traffic Data

- Wind direction and speed, temperature and relative humidity were simultaneously measured in 4 meteorological stations.
- Traffic data were collected as number of vehicles passing a reference point per hour.

Instrumentation

- DiSCmini (Matter Aerosol, AG)
- Garmin Handheld GPS

Results

Wind Effect

Wind speed and direction were adjusted based on the line that connects nearest major road to each monitoring station:

$$wind\_speed_{adj} = wind\_speed \times \cos(\theta)$$

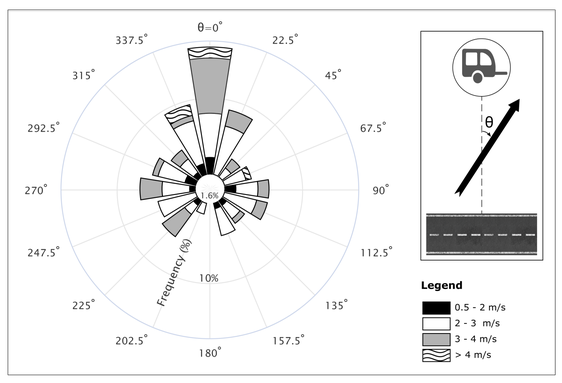
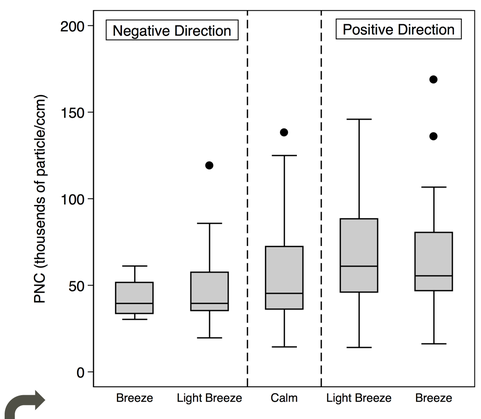


Figure 1. Adjusted wind rose diagram for all diurnal measurements at monitoring stations

- Diurnal samplings were mostly affected by proximity to a major road and wind direction



Wind type	Wind Speed (m/s)
Calm	0 – 0.5
Light Breeze	0.5 – 2
Breeze	>2

Figure 2. Box plot of particle number concentration (PNC) as a function of adjusted wind direction and speed

- PNC level of UFPs proportionally increased with the wind speed in positive direction (i.e. when a monitoring station is in the downwind direction of the nearest major road)

Traffic-distance Effect

Traffic density and distance of nearest major road to each sampling station were taken into account as a single parameter, k (vehicles/(hr.m)):

$$K = traffic\ volume/distance$$

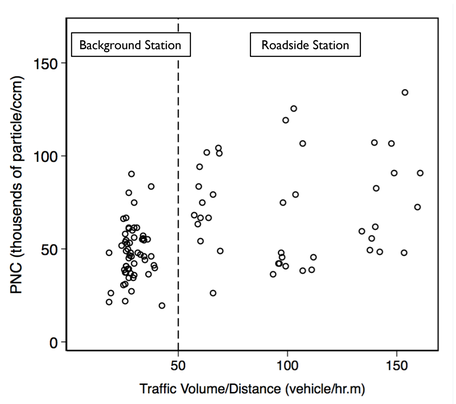
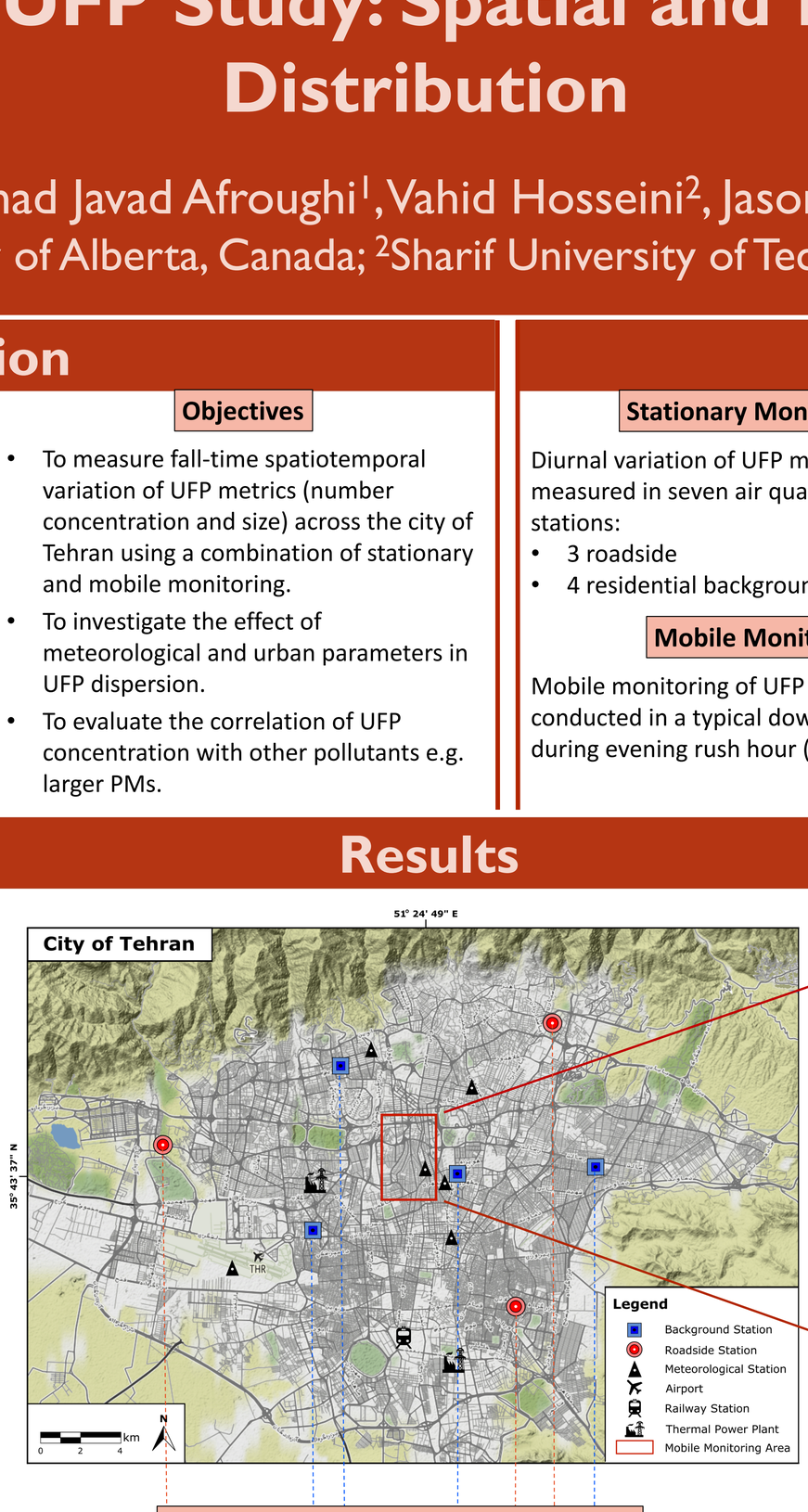


Figure 3. PNC as a function of K

- PNC level of UFPs proportionally increased with K
- PNC was significantly higher at roadside (K>50) compared to background stations (K<50)



Temporal Variation of Ultrafine Particles

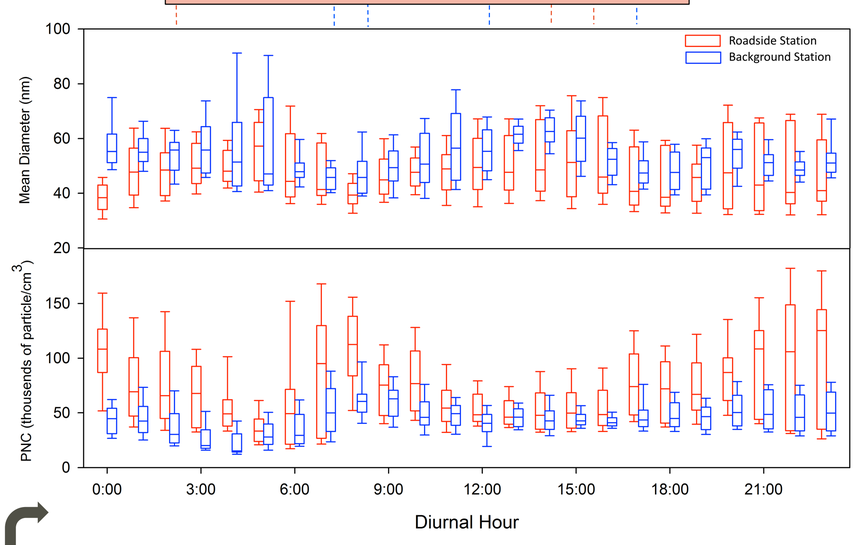


Figure 4. Diurnal variation of PNC and count mean diameter of UFPs

- Daily average of PNC reached to 75,000 cm^{-3} with a mean diameter of 48 nm at roadside, compared to 45,000 cm^{-3} with a mean diameter of 54 nm at background stations.
- PNC increased monotonically during morning and evening rush hour peaks (~ 1.5 times of the PNC daily average).

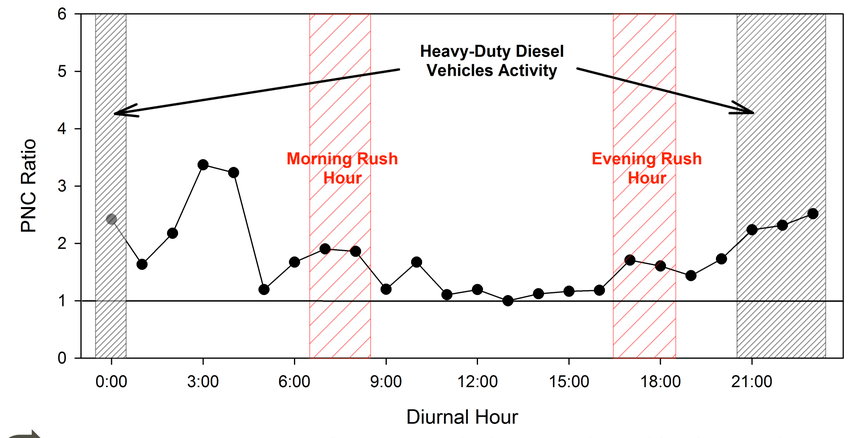


Figure 5. Ratio of PNC at roadside to residential background stations per hour

- Hourly average of PNC was approximately twice higher near major roads than residential areas during rush hour.
- Hourly average of PNC at roadside stations increased monotonically between 2100h-0100h, due to increase of heavy-duty vehicle activities.

Spatial Variation of Ultrafine Particles

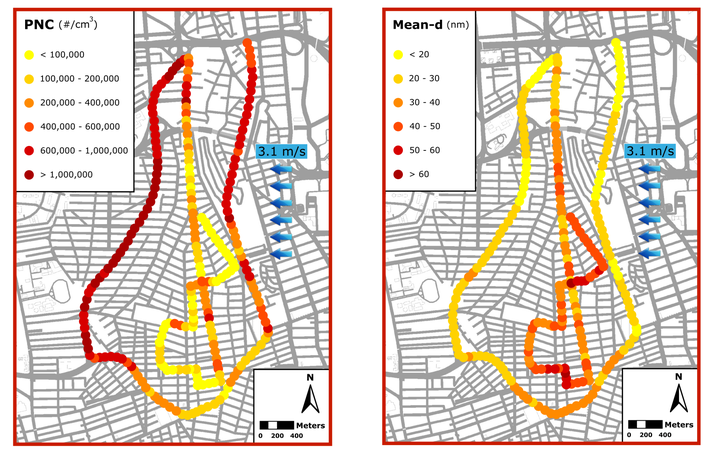


Figure 6. GIS-based mapping of PNC (left) and count mean diameter (right) of UFPs in mobile monitoring study area

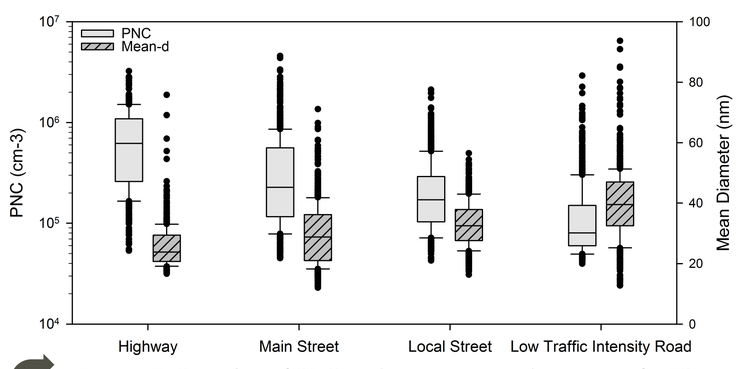


Figure 7. Box plot of PNC and count mean diameter of UFPs as a function of road type

- PNC increased (mean-d decreased) drastically from streets with low traffic intensities (80,000 cm^{-3} and 40 nm) towards highways (622,000 cm^{-3} and 24 nm).

Spearman Correlation of Pollutants

The non-parametric spearman's ρ was used to correlate PNC with the concentration of other urban-derived pollutants and meteorological parameters.

Table 1. Spearman correlations

	$PM_{2.5}$	PM_{10}	CO	NO_2	O_3	SO_2	Temp.	R.H.	Adjusted Wind Speed
PNC	0.72	0.62	0.55	0.20	-0.42	-0.51	-0.43	0.21	0.35

↑ ↑ strong relationship

Conclusions

- The diurnal pattern of UFPs revealed higher concentrations at both roadside and background stations, compared to clean large cities (e.g. Zurich).
- Wind and traffic intensity play a crucial role in dispersion of UFPs, especially in highway environments.
- Taking a low traffic intensity road can decrease UFP exposure up to orders of magnitude.
- Heavy-duty vehicles are seemingly responsible for a large amount of UFP emissions, particularly around midnight.
- UFPs and larger PMs likely have similar source of emission and mechanisms of atmospheric dispersion in the city of Tehran.

References

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[2] Shannahan, J. H., Kodavanti, U. P., & Brown, J. M. (2012). Manufactured and airborne nanoparticle cardiopulmonary interactions: a review of mechanisms and the possible contribution of mast cells. *Inhalation Toxicology*, *24*(5), 320–339.

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