# LOCATING URBAN HOT-SPOTS WITH MOBILE ON-LINE SIZE-RESOLVED NANOPARTICLE MEASUREMENT

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**Abstract**

This work investigates the spatial distribution of particulate matter in Spořilov, a Prague residential neighborhood completely surrounded by three freeways, two of which are major heavy truck thoroughfares.

Internal combustion engines are often the prime source of air pollution. The emissions of PM are not distributed uniformly; a small fraction of high emitting vehicles account for a large share of fleet PM, and for a given vehicle, PM emissions tend to be concentrated into short high-emissions episodes (e.g. accelerations, hard transitions or high load following a period of extended idling).

Size-resolved (5-500 nm) measurements of particles were taken with an online particle classifier (EEPS, TSI) mounted, along with batteries, GPS and other accessories, on a hand cart and pushed around the neighborhood on five separate days, making one-minute or longer stops at places of interest. Meteorological data from a nearby observatory and ambient air quality data from the national monitoring network were used.

The average concentrations of particles ranged from under or around $10^4$ #/cm$^3$ on quiet residential streets to 2-8 x $10^4$ #/cm$^3$ on streets next or close to a freeway to 1-2 x $10^5$ #/cm$^3$ on walkways over and near the freeway, with peak concentrations over $10^6$ #/cm$^3$. Low concentrations of nanoparticles in the inner neighborhood and general absence of a significant accumulation mode throughout the area suggest that woodstoves or other stationary sources were not likely a major contribution to the concentrations. The measured concentrations near the freeways were much higher than elsewhere in Prague.

**Key words:**

Nanoparticle exposition, air pollution, traffic related immission, airborne nanoparticles, urban emission

## 1. INTRODUCTION

Spořilov is a Prague neighborhood with an exceptionally high traffic density, completely surrounded by three freeways, two of which are major heavy truck thoroughfares. Residents have been complaining about worsened health, mainly cardiovascular issues, breathing difficulties, and unspecified inconveniences such as vertigo or fatigue, since transit traffic was re-routed to a freeway passing directly through the high population density part of the neighborhood.

Internal combustion engines are often the prime source of air pollution, notably of particulate matter, which is responsible, both in EU and in CZ, for ~10x more premature deaths than traffic accidents [1]. Of highest concern are very small particles. Particles emitted by vehicle engines are a major health concern not only because of the direct proximity of recipients from the sources, but also because they are generally very fine [2,3], efficiently deposit in human lung alveoli [4,5], penetrate cell membranes [6,7], and cause or contribute to a variety of ailments [8]. Proximity to sources of internal combustion engine exhaust has been associated with increased risks of various chronic health problems [9-11]. The emissions of PM are not distributed uniformly; a small fraction of high emitting vehicles account for a large share of fleet PM, and for a given vehicle, PM emissions tend to be concentrated into short high-emissions episodes, such as accelerations, hard transitions, or high load following a period of extended idling [12-15]. Neither it seems that particles in ambient air are distributed evenly along the roadways. On the contrary, disproportionately more particles could be in places such as intersections or freeway entrances.

This study investigates spatial particle distribution in Spořilov area by a mobile measurement apparatus.

## 2. METHODS

Instantaneous number concentrations of particles in 32 size categories in range from 5 to 560 nm were measured by a fast electric mobility classifier (Engine Exhaust Particle Sizer™, Model 3090, TSI). Instantaneous position was recorded by a GPS. All data were logged by a laptop computer in 1 s intervals. The device was powered by lithium ion batteries. The apparatus described above was placed on a dismountable hand chart pushed within the Spořilov area by 1-2 persons.

The apparatus was transported along routes identified by the authors and by local citizens. Concentrations during transportation of the apparatus were monitored for the occurrence of the local maxima concentration (hot-spots), however, to avoid an artifact due to instrument vibration, only data taken during stops of half to several minutes of duration were considered for subsequent processing. Longer stops were taken when the concentrations fluctuated or there was an expectation of passage of a high emitting vehicle.

## 3. RESULTS

Figure 1 shows average, median, and geometric mean of all measured particle fractions during a typical measurement day, normalized to the total count detected. From this graph, a two mode distribution with peaks around 10 and 40 nm in particle diameter can be observed. The distribution falls within typical distributions of particles emitted by internal combustion engines [16]. In particular, it corresponds to particle size distribution found in thermodenuded diesel exhaust [17].

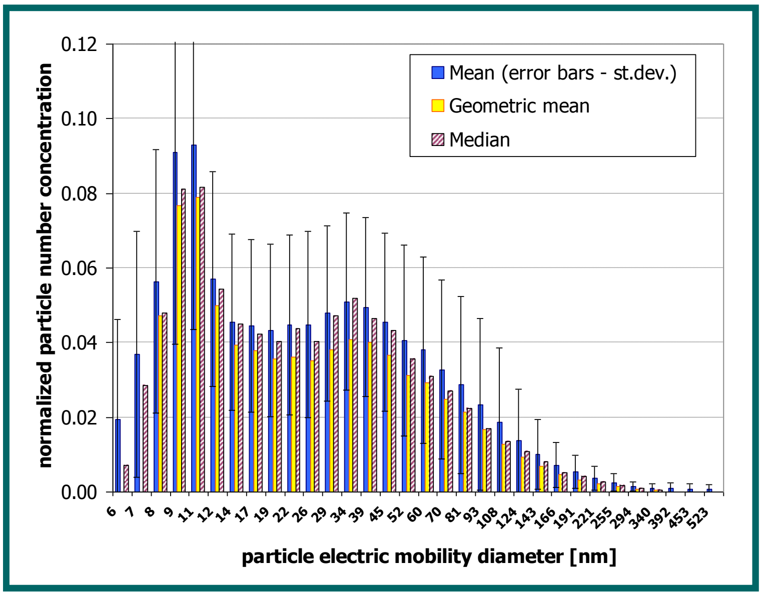


**Figure 1: Mean, median, and geometric mean of normalized measured particle size distribution during a typical day**

The average concentration of nanoparticles (total count of particles with an electric mobility diameter from 5 to 100 nm) in the thousands of particles per $cm^3$ for every stop is plotted in Figures 2-4. Each point represents mean concentration recorded during one stop, with point size proportional to the measured concentration. Outdoor temperature, humidity, and wind speed and direction are plotted in the figures.

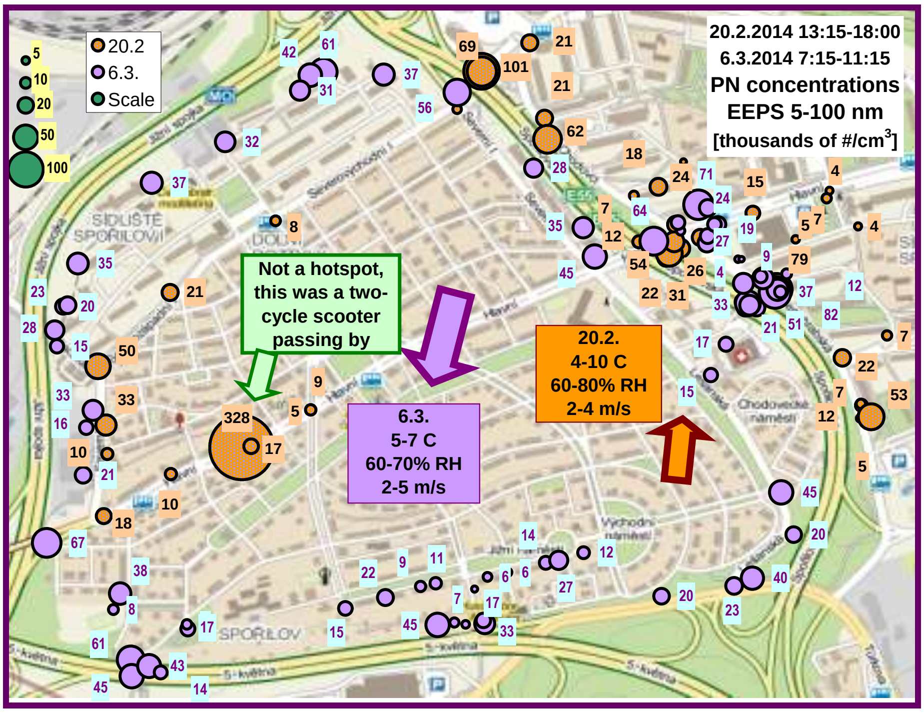


**Figure 2: Average total concentrations of particles 5-100 nm, Feb. 20 (orange) and March 3 (violet)**

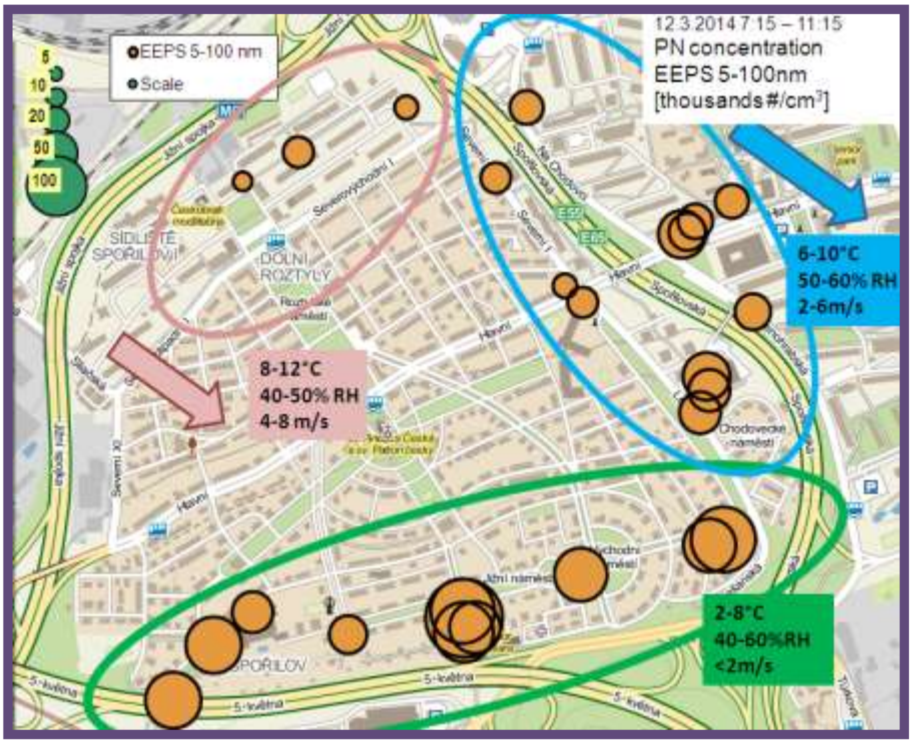


**Figure 3: Average total concentrations of particles 5-100 nm, March 12**

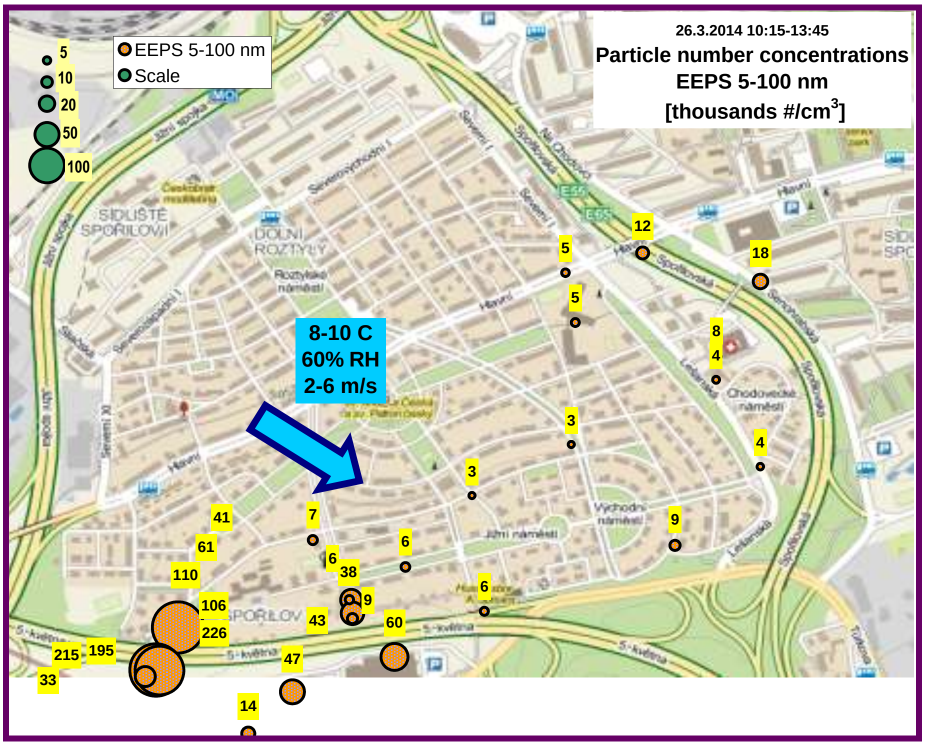


Figure 4: Average total concentrations of particles 5-100 nm, March 28

At many stops, the maximum instantaneous concentrations were more than order of magnitude higher than the average due to passage of an individual vehicle or vehicles. For this reason, some stops were prolonged in order to minimize the bias due to a high emitter. One such example, plotted on Figure 5, demonstrates the dominance of high emitters on a graph of total particle counts during a series of stops on and near the pedestrian bridge above "5. května" street (a freeway), near the point where truck traffic accelerates from an on-ramp up an incline. As apparent from the figure, virtually all particles are nanoparticles, mostly below 20 nm electric mobility diameter.

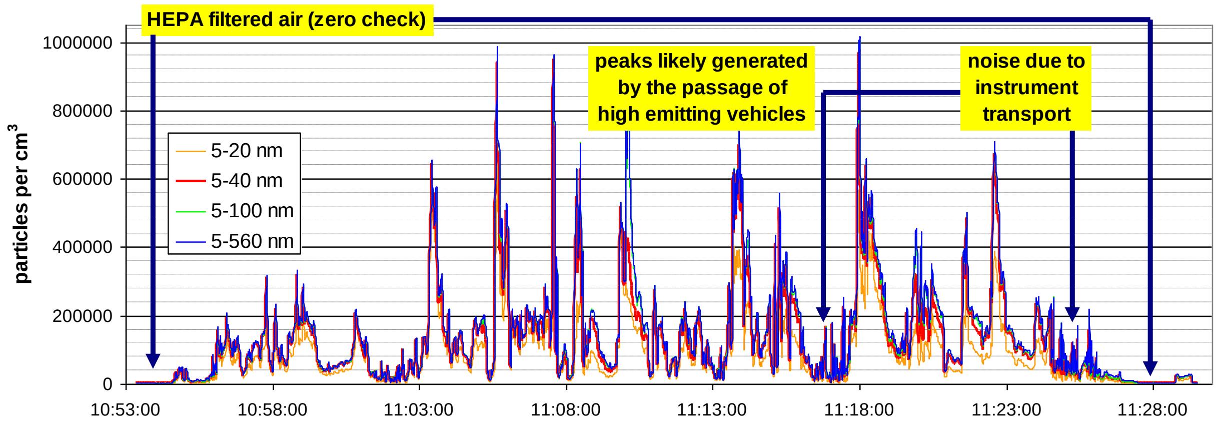


Figure 5: Total particle number concentrations along a freeway (5. kvetna), March 28

The total concentrations of 5-100 nm diameter measured in this study were in range from thousands to hundreds of thousands particles per $cm^3$, peak concentrations reached a million particles per $cm^3$. In previous studies in Prague, mean urban background concentrations were 7 000 #/cm$^3$, around 14 thousands #/cm$^3$ were found near an intersection, and tens of thousands of #/cm$^3$ were measured on one of the highways passing through Spořilov, however, in a section closed to heavy-duty trucks [18-19].

Measured concentrations might thus be considered to be relatively very high. This is especially true near the section of a freeway where heavy trucks accelerate uphill after having passed through a notoriously congested area along the inner Prague ring road. It could therefore be that increased particle emissions associated with “urban creep” (very low-speed operation in a heavily congested area) [20] also yield increased particle emissions during subsequent acceleration, a finding consistent with a laboratory study [21].

## 4. CONCLUSIONS

Local concentration of ultrafine particles and nanoparticle hotspots were assessed by walking around the neighborhood with local citizens with a mobile fast particle electric mobility classifier. Peaks around 10 nm and in tens of nm were observed near urban highways. In many cases, the average concentrations above and near roadways exceed “urban background” (7000 #/cm$^3$ in Prague) by an order of magnitude. In particular, local hotspots were found where trucks accelerate out of a congested area. The results also show high variability of particle emissions among individual vehicles and suggest that engines are not “black boxes producing emissions” evenly along the way, but that operating conditions and their history are important and should be considered.

## ACKNOWLEDGMENTS

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