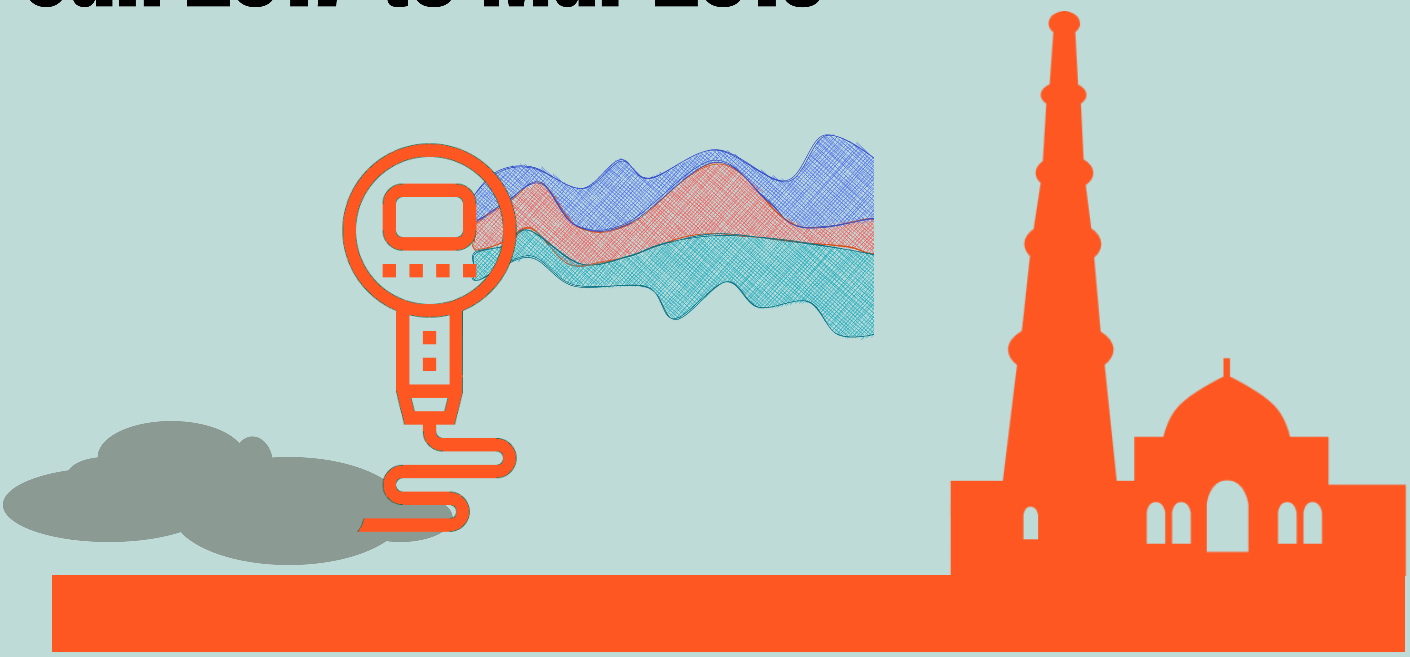
Aerosol Speciation & Meteorology Data Sets From Delhi Supersite Study

Jan'2017 to Mar'2018



URBAN emissions .info

Dr Shahzad Gani

SIM-air working paper series # 45-2021

URBAN emissions .info

(UEinfo) was founded in 2007 with the vision to be a repository of information, research, and analysis related to air pollution. There is a need to scale-up research applications to the secondary and the tertiary cities which are following in the footsteps of the expanding mega-cities. Advances in information technology, open-data resources, and networking, offers a tremendous opportunity to establish such tools, to help city managers, regulators, academia, and citizen groups to develop a coordinated approach for integrated air quality management for a city.

UEinfo has four objectives: (1) sharing knowledge on air pollution (2) science-based air quality analysis (3) advocacy and awareness raising on air quality management and (4) building partnerships among local, national, and international airheads.

This report was drafted by Dr Gani and designed by the members of UEinfo. The data article was first published online @ https://shahzadgani.medium.com/air-pollution-in-delhi-india-aerosol-and-meteorology-data-sets-b272a2f703e5

All the working papers and more are accessible @ www.urbanemissions.info/publications

Send your questions and comments to simair@urbanemissions.info

Air pollution in Delhi, India

In this paper[1], I share some resources (open access) related to air pollution in Delhi. This is not an exhaustive list of resources and primarily focus on aerosol data collected as part of the collaboration between my alma maters — the University of Texas at Austin and the Indian Institute of Technology Delhi.

This work was part of my PhD titled **Urban Aerosol: Role of Sources and Atmospheric Processes** (University of Texas at Austin, 2019)

Urban aerosol: Role of sources and atmospheric processes

by

Shahzad Gani

DISSERTATION

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

THE UNIVERSITY OF TEXAS AT AUSTIN

December 2019

This work was made possible by an awesome team of scientists at the University of Texas at Austin and the Indian Institute of Technology Delhi. Some of these people are Sahil Bhandari, Kanan Patel, Sarah Seraj, Zainab Arub, Prashant Soni, Gazala Habib, Lea Hildebrandt Ruiz, and Joshua Apte.

[1] This data resource article was first published online @ https://shahzadgani.medium.com/air-pollution-in-delhi-india-aerosol-and-meteorology-data-sets-b272a2f703e5

Abbreviations used

PSD: Particle Size Distribution

PN: Particle Number (total particle number concentration)

$PM_{2.5}$: particulate Matter (mass concentration of particles < 2.5 μm)

UFP: Ultrafine Particles (number concentration of particles < 100 nm)

Dp: Particle diameter

The Particle Size Distribution: Mass vs Number?

Particles in the atmosphere exist over a size continuum. Most of these particles are smaller than 100 nm (UFP). However, most of the aerosol mass is made up of particles larger than 100 nm even though these particles are usually fewer in number.

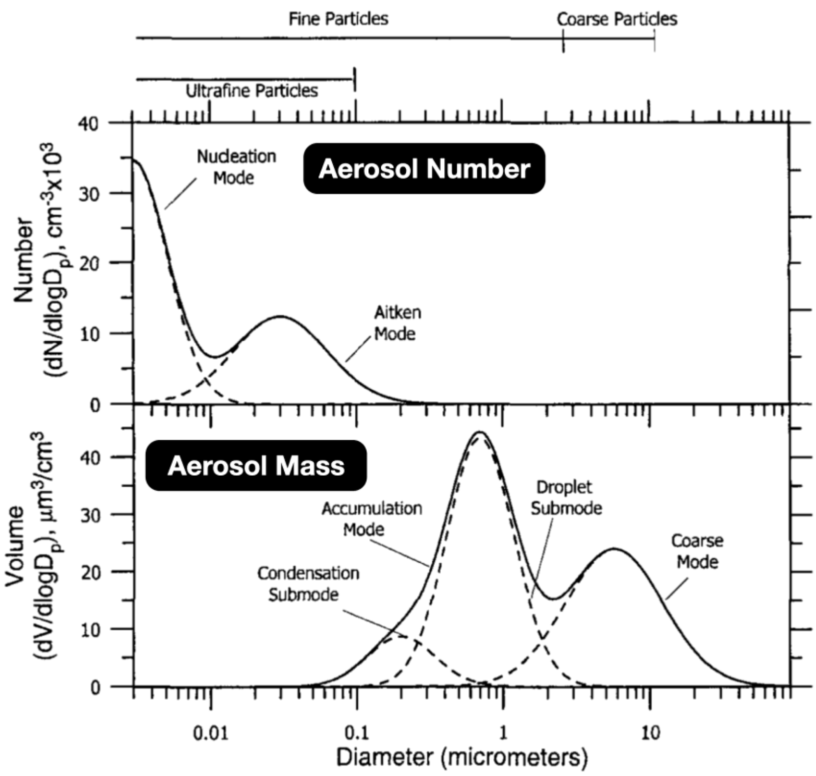


Figure 1: Typical number and volume distributions of atmospheric particles with the different modes. Mass can be obtained by multiplying volume with particle density. Figure reproduced from Seinfeld and Pandis, 2006

For example, assuming spherical and uniform density, the following definitions have the same mass:

One 1000 nm (1 µm) particle = $1 \times \rho\pi/6 \times (1000)^3 = (10)^9 \times \rho\pi/6$

One-thousand 100 nm particles = $(10)^3 \times \rho\pi/6 \times (100)^3 = (10)^9 \times \rho\pi/6$

One-million 10 nm particles = $(10)^6 \times \rho\pi/6 \times (10)^3 = (10)^9 \times \rho\pi/6$

Figure 1 is a typical size distribution shown in the number domain and in the volume/mass domain. Understanding the physical and chemical properties of the particles can help us better understand the sources and sinks of these particles.

The Delhi Aerosol Supersite Study

In this study, we used research-grade aerosol instrumentation to measure PSD and the submicron aerosol composition.

> *"We measured PSDs using a scanning mobility particle sizer (SMPS; TSI, Shoreview, Minnesota, USA) consisting of an electrostatic classifier (model 3080; TSI, Shoreview, Minnesota, USA), a differential mobility analyzer (DMA; model 3081; TSI, Shoreview, Minnesota, USA), an x-ray aerosol neutralizer (model 3088; TSI, Shoreview, Minnesota, USA), and a water-based condensation particle counter (CPC; model 3785; TSI, Shoreview, Minnesota, USA). Chemical composition of nonrefractory PM1 (NR–PM1) was obtained using an aerosol chemical speciation monitor (ACSM; Aerodyne Research, Inc., Billerica, Massachusetts, USA), and black carbon (BC) was measured using a multichannel Aethalometer (model AE33; Magee Scientific, Berkeley, California, USA). The inlet had a $PM_{2.5}$ cyclone, followed by a water trap and a Nafion membrane diffusion dryer (sample stream dryer; Magee Scientific, Berkeley, California, USA)."*

Repositories of the Study Data

The following figure shows the average size-resolved particle number concentrations and the chemically resolved mass concentrations by season measured at our site in Delhi.

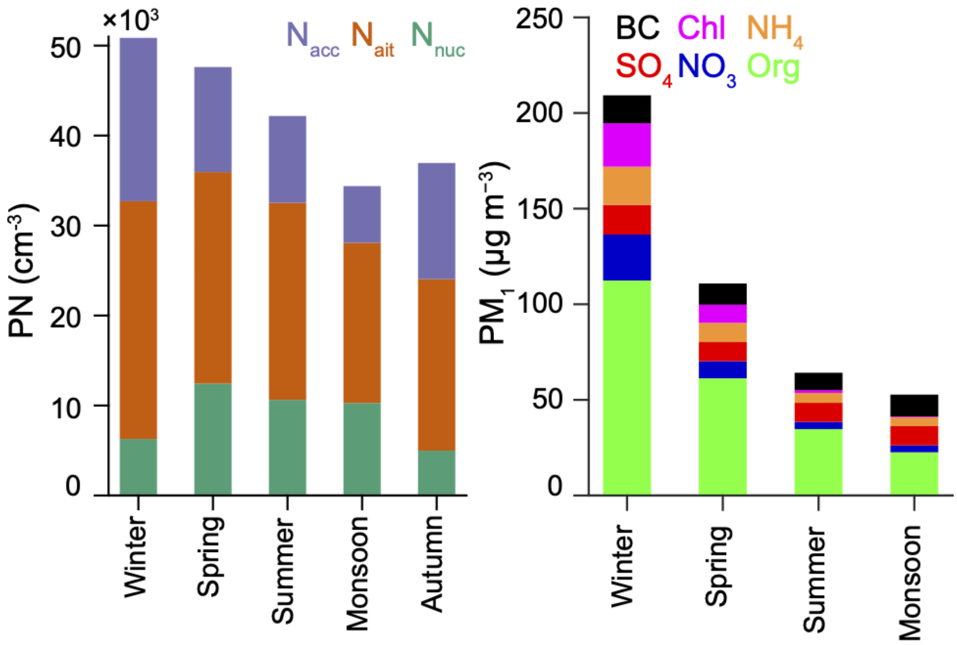


Figure 2: **Average PN levels for each season by mode – nucleation (12 < Dp < 25 nm), Aitken (25 < Dp < 100 nm) and accumulation (100 < Dp < 560 nm) modes. The PM1 species are organics (Org), chloride (Chl), ammonium (NH4), nitrate (NO3), sulfate (SO4), and black carbon (BC). Figure reproduced from Gani, et al., 2020**

Aerosol number and size distribution data for Delhi

Particle number concentrations and size distribution in a polluted megacity: the Delhi Aerosol Supersite study (a peer-reviewed paper in the journal *Atmospheric Chemistry and Physics*).

In this study we reported on 1.25 years of highly time-resolved particle size distribution data in the size range of 12–560 nm collected in South Delhi (IIT Delhi).

> *"We observed that the large number of accumulation mode particles — that constitute most of the $PM_{2.5}$ mass — also contributed substantially to the PN concentrations. The UFP fraction of PN was higher during the traffic rush hours and for daytimes of warmer seasons, which is consistent with traffic and nucleation events being major sources of urban UFPs. UFP concentrations were found to be relatively lower during periods with some of the highest mass concentrations. Calculations based on measured PSDs and coagulation theory suggest UFP concentrations are suppressed by a rapid coagulation sink during*

> *polluted periods when large concentrations of particles in the accumulation mode result in high surface area concentrations."*

The hourly size distribution data for the entire period discussed in this paper is online and free to use.

Submicron aerosol composition data for Delhi

Submicron aerosol composition in the world's most polluted megacity: the Delhi Aerosol Supersite study (a peer-reviewed paper in the journal *Atmospheric Chemistry and Physics*).

In this study we reported on 1.25 years of highly time-resolved speciated submicron particulate matter (PM1) data, including black carbon (BC) and nonrefractory PM1 (NR-PM1), which we combine to develop a composition-based estimate of PM1 ("C-PM1" = BC + NR-PM1) concentrations.

The hourly aerosol composition data for the entire period discussed in this paper is online and free to use.

> *"We estimated the contribution of primary emissions and secondary processes to Delhi's submicron aerosol. Secondary species contributed almost 50–70 % of Delhi's C-PM1 mass for the winter and spring months and up to 60–80 % for the warmer summer and monsoon months. For the cooler months that had the highest C-PM1 concentrations, the nighttime sources were skewed towards primary sources, while the daytime C-PM1 was dominated by secondary species. Overall, these findings point to the important effects of both primary emissions and more regional atmospheric chemistry on influencing the extreme particle concentrations that impact the Delhi megacity region."*

The estimates of primary and secondary fraction of aerosol was based on a source apportionment technique called positive matrix factorization. The details of the source apportionment for Delhi can be found in Bhandari et al. (2020): *Sources and atmospheric dynamics of organic aerosol in New Delhi, India: insights from receptor modeling* (a peer-reviewed paper in the journal *Atmospheric Chemistry and Physics*). Findings for the autumn period are presented in Patel et al. (2021): *Sources and Dynamics of Submicron Aerosol during the Autumn Onset of the Air Pollution Season in Delhi, India* (a peer-reviewed paper in the journal *ACS Earth and Space Chemistry*).

Data from regulatory agencies

Supplementary air pollution data such as PM2.5, NO, SO2, etc. can be obtained through local regulatory agencies. OpenAQ is an excellent resource for obtaining such datasets. Checkout their blog for information on accessing data older than 90 days. Also see: *How do I cite the OpenAQ platform in peer-reviewed literature*.

Meteorological data

Meteorological parameters (temp, RH, wind speed/direction, boundary layer height, etc.) are extremely important in understanding air pollution dynamics. In this section I will discuss some useful resources to obtain met data. While I have discussed these in the context of Delhi, these resources can be used to obtain met data for any place on the planet.

- **Ground-based observations:** Met data collected at an observation stations such as those regularly collected at all airports. Iowa Environmental Mesonet (IEM) has an intuitive tool that lets you download met data for any airport around the world. For e.g., to obtain met data for Indira Gandhi International Airport (Delhi), select the **India ASOS** network on the IEM webpage and select VIDP.
- **Reanlaysis met data:** Uniform (spatially and temporally) datasets obtained by combining models with observations. Two great reanalysis datasets that also include met data are:
    - NASA's **MERRA2**
    - European Centre for Medium-Range Weather Forecasts' **ERA5**

Applications of Aerosol Size and Composition Data

Aerosol physical and chemical properties can have a wide range of applications from understanding the effects of aerosol on cloud formation to the performance of low-cost air pollution sensors. The following are some studies that relied on the aerosol data sets discussed above:

1. Understanding aerosol physical and chemical properties can be useful for understanding aerosol hygroscopicity and cloud condensation nuclei formation. Arub et al. (2020) discussed the *Air mass physiochemical characteristics over New Delhi: Impacts on aerosol hygroscopicity and cloud condensation nuclei formation* (a peer-reviewed paper in the journal *Atmospheric Chemistry and Physics*).

2. Aerosol properties also have an impact on low-cost sensor performance . Crilley et al. (2020) discussed the *Effect of aerosol composition on the performance of low-cost optical particle counter correction factors* (a peer-reviewed paper in the journal *Atmospheric Measurement Techniques*).

3. Comparing data collected using low-cost sensors and research-grade instruments, Hagan et al. (2019) provided insights into using low-cost sensors for inferring sources of air pollution in *Inferring aerosol sources from low-cost air quality sensor measurements: A case study in Delhi, India* (a peer-reviewed paper in the journal *Environmental Science & Technology Letters*).

Useful References for Further Reading

Brines, M., M. Dall'Osto, D. C. S. Beddows, R. M. Harrison, F. Gómez-Moreno, L. Núñez, B. Artíñano, F. Costabile, G. P. Gobbi, F. Salimi, L. Morawska, C. Sioutas, and X. Querol, 2015: Traffic and nucleation events as main sources of ultrafine particles in high-insolation developed world cities. *Atmospheric Chemistry and Physics*, 15(10), 5929–5945.

Chowdhury, Z., M. Zheng, J. J. Schauer, R. J. Sheesley, L. G. Salmon, G. R. Cass, and A. G. Russell, 2007: Speciation of ambient fine organic carbon particles and source apportionment of PM2.5 in Indian cities. *Journal of Geophysical Research: Atmospheres*, 112(D15).

Guttikunda, S. K. and B. R. Gurjar, 2012: Role of meteorology in seasonality of air pollution in megacity Delhi, India. *Environmental Monitoring and Assessment*, 184(5), 3199–3211.

Hussein, T., M. Dal Maso, T. Petäjä, I. K. Koponen, P. Paatero, P. P. Aalto, K. Hämeri, and M. Kulmala, 2005: Evaluation of an automatic algorithm for fitting the particle number size distributions. *Boreal Environment Research*, 10, 337–355.

Jaiprakash, A. Singhai, G. Habib, R. S. Raman, and T. Gupta, 2017: Chemical characterization of PM1.0 aerosol in Delhi and source apportionment using positive matrix factorization. *Environmental Science and Pollution Research*, 24(1), 445–462.

Kangasluoma, J. and M. Attoui, 2019: Review of sub-3 nm condensation particle counters, cali- brations, and cluster generation methods. *Aerosol Science and Technology*, 53(11), 1277–1310.

Kulmala, M., T. Petäjä, T. Nieminen, M. Sipilä, H. E Manninen, K. Lehtipalo, M. Dal Maso, P. Aalto, H. Junninen, P. Paasonen, I. Riipinen, K. E J Lehtinen, A. Laaksonen, and V.-M. Ker- minen, 2012: Measurement of the nucleation of atmospheric aerosol particles. *Nature protocols*, 7, 1651–67.

Mönkkönen, P., I. Koponen, K. Lehtinen, R. Uma, D. Srinivasan, K. Hämeri, and M. Kulmala, 2004a: Death of nucleation and Aitken mode particles: observations at extreme atmospheric conditions and their theoretical explanation. *Journal of Aerosol Science*, 35(6), 781–787.

Ng, N. L., S. C. Herndon, A. Trimborn, M. R. Canagaratna, P. L. Croteau, T. B. Onasch, D. Sueper, D. R. Worsnop, Q. Zhang, Y. L. Sun, and J. T. Jayne, 2011c: An Aerosol Chemical Speciation Monitor (ACSM) for routine monitoring of the composition and mass concentrations of ambient aerosol. *Aerosol Science and Technology*, 45(7), 780–794.

Pant, P., A. Shukla, S. D. Kohl, J. C. Chow, J. G. Watson, and R. M. Harrison, 2015: Characterization of ambient PM2.5 at a pollution hotspot in New Delhi, India and inference of sources. *Atmospheric Environment*, 109, 178–189.

Pio, C. A. and R. M. Harrison, 1987: The equilibrium of ammonium chloride aerosol with gaseous hydrochloric acid and ammonia under tropospheric conditions. *Atmospheric Environ- ment*, 21(5), 1243–1246.

Schraufnagel, D. E., J. R. Balmes, C. T. Cowl, S. D. Matteis, S.-H. Jung, K. Mortimer, R. Perez- Padilla, M. B. Rice, H. Riojas-Rodriguez, A. Sood, G. D. Thurston, T. To, A. Vanker, and D. J. Wuebbles, 2019a: Air pollution and noncommunicable diseases: A review by the Forum of International Respiratory Societies' Environmental Committee, Part 1: The damaging effects of air pollution. *Chest*, 155(2), 409–416.

—, 2019b: Air pollution and noncommunicable diseases: A review by the Forum of Interna- tional Respiratory Societies' Environmental Committee, Part 2: Air pollution and organ systems. *Chest*, 155(2), 417–426.

Sun, Y. L., Z. F. Wang, P. Q. Fu, T. Yang, Q. Jiang, H. B. Dong, J. Li, and J. J. Jia, 2013: Aerosol composition, sources and processes during wintertime in Beijing, China. *Atmospheric Chemistry and Physics*, 13(9), 4577–4592.

www.urbanemissions.info