Understanding The Impact Of Ventilation Setting On In-Car Commuter Exposure To Qufp, $Pm_{0.5}$ And Pm_1 In Nct Of Delhi

Vasu Mishra [1*]

[1] *Department of Environmental Engineering, Delhi Technological University, Delhi, India.*

[1]vasumishra_2k19ene14@gmail.com

Abstract

People living in the NCT of Delhi are at constant risk of exposure to air pollutants like PMs, qUFP, UFP, SO_X, NO_X, CO, CO_2 etc. and this exposure risk is further increased during the commute. This research aims to study the impact of ventilation settings on the in-cabin exposure to Fine particles during commute via car. The data for the study were collected on the same route for two days, in the month of January, using a portable Optical Particle Counter. During the study, it was observed that by simply changing the car's in-cabin ventilation settings from RC-off to RC-On, we can reduce our exposure to qUFP, $PM_{0.5}$ and PM_1 by 44%, 48% and 50%.respectively. The study also showed that qUFP contributed most to the PNC of Fine Particulates inside the car.

Keywords: Particulate Matters, PM_1, Fine Particulate, quasi-UFP, Commuter exposure.

*Corresponding Author: Vasu Mishra: Email: Vasumishra_2k19ENE14@dtu.ac.in; Contact +91-9899886570

1. Introduction:

During commuting, exposure to the Particulate Matters (PMs) has become a significant health concern for people living in urban areas. Many studies show that even if we don’t spend a major duration of our day commuting, it still makes up for the highest contribution to our daily exposure to air pollutants [1], [2]. A study by Zhu found out that 1 hour of commuting can contribute up to 50% of a person’s daily exposure to fine particles [3].

Today, the health risks associated with air pollutants (especially PMs) are well known, PMs have been directly or indirectly attributed to causing almost 9 million deaths per year worldwide [4] and almost 2.7% of global illnesses can be linked to respirable PM [5], [6]. This problem is even more prominent in India, whose 22 cities make it to the list of top-30 most polluted cities in the world [7], [8] while an estimated number almost 1.67 million people (including 500,000 infants) lost their life to PM [9], [10]

While most government organizations, the institution have focused primarily on the PM_{10} and $PM_{2.5}$, recent studies have shown that the finer sub-fractions of PMs are of greater concern due to their smaller size, which allows them to penetrate deeper into respiratory tract and tissues as well as their greater surface area makes them more reactive and toxic [4], [11]–[13].

These sub-fraction includes PM_1 (Dp <1µm), $PM_{0.5}$ (Dp<0.5µm), Quasi Ultrafine particles (0.35µm<Dp<0.01µm) [14] and UltraFine Particles (Dp<0.01µm) [15]. The health risk posed by these fine particles, coupled with the elevated exposure risk during commuting [16], makes it eminent to study the in-cabin commuter exposure in urban traffic. This study aims to understand how vehicle ventilation settings impact the in-cabin commuter exposure to PM_1, $PM_{0.5}$ and Quasi Ultra-fine particles (qUFP).

2. Methodology

The study was conducted in January on a 50km stretch in Delhi, India (the most polluted capital in the world in terms of air pollution [7]). The study route was selected to provide a realistic representation of the traffic scenario NCT of Delhi and contain a variable traffic density. As shown in Fig-1 the route covered the North-west-south-east Delhi as well as the NCR region of Ghaziabad, connecting the Delhi Technological University (DTU) to Vaishali metro station via Hauz Khas.

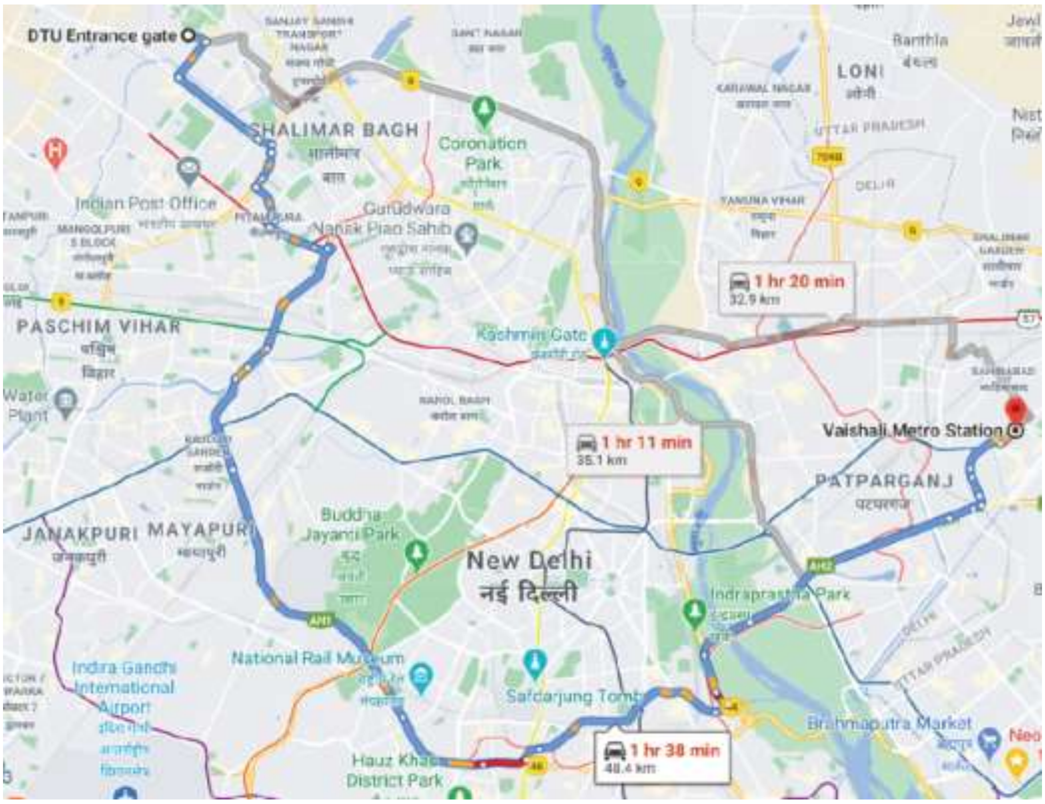

Figure 1 Selected route of the study (DTU- Vaishali via Hauz Khas)

The sampling was done using a study vehicle (a 2010 model, pearl white Maruti Suzuki Swift Dezire, petrol variant) using a portable Optical Particle Counter (GRIMM Technik, model 11-A portable aerosol spectrometer). The instrument was kept on the front passenger seat of the vehicle; the sampling probe was set up at a distance similar to the passenger breathing zone to measure the driver exposure.

The study vehicle was properly vacuum cleaned before the start of each trip. For the data collection, OPC was set to the minimum reading interval value, which was 6 seconds, and the data was collected over 12 bins (<0.25μm, 0.25-0.28μ,0.28-0.30μm, 0.30-0.35 μm, 0.35-0.40 μm, 0.40-0.45 μm, 0.45-0.50 μm, 0.50-0.58 μm, 0.58-0.65 μm, 0.65-0.7 μm, 0.7-0.8 μm, 0.8-1.0 μm).

The data was collected for 2 days (20th and 21st Jan 2021) during morning peak hours 9:30 am to 11:00 am [17] on weekdays, with different ventilation settings used on each trip. The study vehicle and instrument were allowed to run for 15mins before a trip to get the background concentration of the car. The sampling was done with windows closed (as it is the most common setting in winters) while two different ventilation settings used were “Day-1) fan-on, re-circulation (RC)-on, AC-off and Day-2) fan-on, re-circulation (RC)-off, AC-off” [18]. [18](Leavey <i>et al.</i>, 2017)(Leavey <i>et al.</i>, 2017)(Leavey et al. 2017)(Leavey et al., 2017)(Leavey et al. 2017)(Leavey <i>et al.</i>, 2017)[18]The car was driven by the same driver to m minimize the variation due to the driver behaviour; also efforts were made to keep the speed of the car so that a constant wind flow can be maintained inside the car [19], [20].

The data was collected in the form of Particle Number Concentration (number per cm^3) and stored in the form of an MS Excel spreadsheet. The data filtering/ sorting and analysis was carried using data analysis tools of excel.

3. Result:

The study showed that ventilation settings have a significant impact on the in-cabin PNC of fine particles. As it can be observed from figure 2, during the 1st ventilation setting when outside air was allowed in (i.e RC-OFF), the higher average PNC was found inside the cabin (qUFP- 8.2×10^5#/cc, $PM_{0.5}$- 10.1×10^5 #/cc, PM_1- 10.6×10^5 #/cc) while the 2nd ventilation setting (RC-ON) showed a significant reduction in the in-cabin fine particulates (qUFP- 4.5×10^5#/cc, $PM_{0.5}$- 5.2×10^5#/cc, PM_1- 5.3×10^5#/cc). The similar trend was also observed in terms of the peak PNC, with 1^{st} ventilation setting showing a much higher PNC (qUFP- 1.2×10^6#/cc, $PM_{0.5}$- 1.47×10^6#/cc, PM_1- 1.5×10^6#/cc) as compare to 2^{nd} ventilation setting (qUFP- 5.8×10^5#/cc, $PM_{0.5}$- 6.8×10^5#/cc, PM_1- 7.1×10^5#/cc). These results are in accord with the result found by [21]–[23]

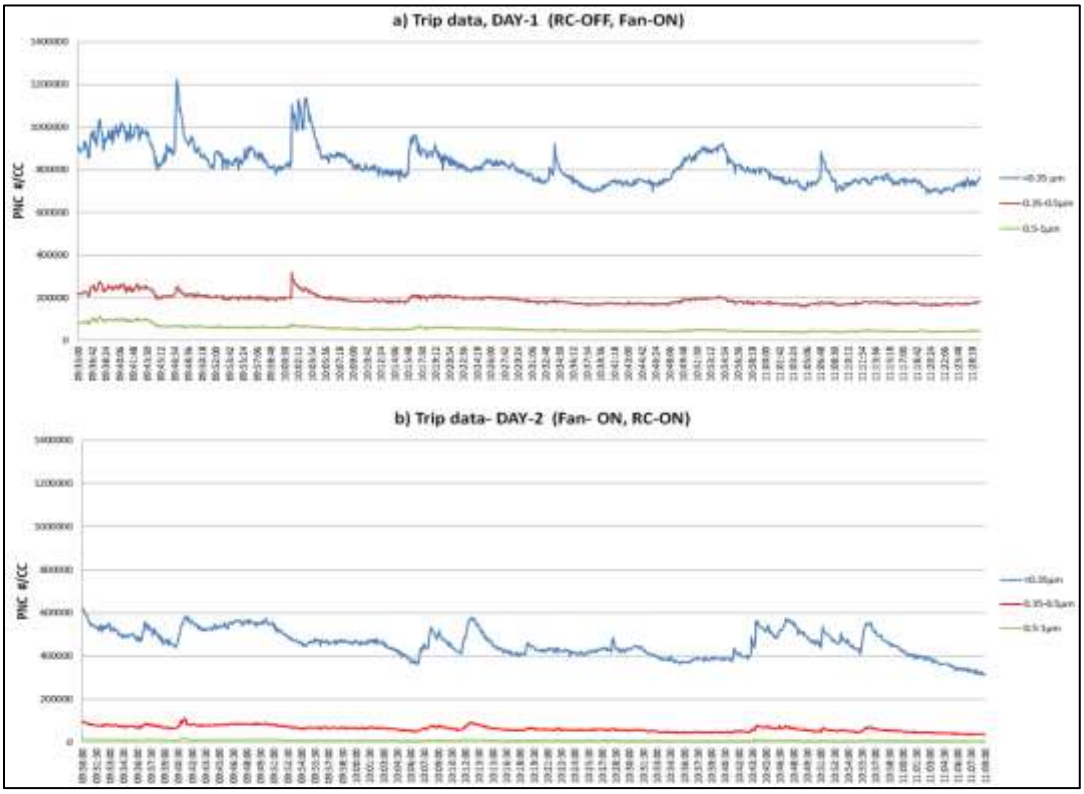

Figure 2 In-cabin PNC during the experiment trips

During the study, it was also observed that while the contribution of larger fine particles (0.35µm<Dp<1µm) to the PNC was very small in both the ventilation cases, during the 2nd ventilation setting, the PNC of larger fine particles was reduced by 82% and 67% for the particles having size range of 0.35µm <Dp<0.5µm and 0.5µm<Dp<1µm, respectively. While the qUFP showed a reduction of 44% due to RC-ON. The study also showed that, when outside air was allowed to flow in RC-Off condition, a much sharper and steeper spike was observed in PNC, while during the second ventilation setting (RC-On), when outside air was not allowed to flow inwards, we saw a comparatively steadier graph. This difference in PNC may be because, during ventilation setting-2, when outside airflow is restricted, the penetration of larger size particles is restricted to a greater extent than smaller-sized particles [22].

4. Conclusion:

Health risks associated with exposure to fine particulates are well known amongst academia. These risks are further aggravated during commuting. Multiple studies have identified commuting as the most significant contributor to a person's daily exposure to air pollutants as one hour of commuting could contribute to almost 50% of a person's daily exposure to PMs

To better understand the in-cabin exposure, this study was conducted to study the impact of ventilation settings on the PNC of fine particles. This study observed that qUFP makes up most of the PNC of fine particulates found inside the cabin, making almost 80% of the total PNC of $PM_{1.}$ The study also shows that ventilation setting plays a decisive role in the in-cabin concentration of fine particles. During the study, it was observed that when outside air was allowed to flow in (RC-Off), the overall PNC was much higher (qUFP- 8.2×10^5#/cc, $PM_{0.5}$- 10.1×10^5 #/cc, PM_1- 10.6×10^5 #/cc), with qUFP making up 77% of total PNC, while by restricting the outside airflow (RC-On), the overall PNC was reduced considerably (qUFP- 4.5×10^5#/cc, $PM_{0.5}$- 5.2×10^5#/cc, PM_1- 5.3×10^5#/cc) with qUFP making up 86% of total PNC. It shows that by simply selecting the correct ventilation setting and limiting the inflow of outside air, one can reduce their average exposure to Fine particulates during a commute by almost 44% for qUFP, 48% for $PM_{0.5}$ and 50% for PM_1.

5. References:

[1] S. Fruin, D. Westerdahl, T. Sax, C. Sioutas, and P. M. Fine, "Measurements and predictors of on-road ultrafine particle concentrations and associated pollutants in Los Angeles," *Atmos. Environ.*, vol. 42, no. 2, pp. 207–219, Jan. 2008, doi: 10.1016/j.atmosenv.2007.09.057.

[2] E. Dons *et al.*, "Impact of time-activity patterns on personal exposure to black carbon," *Atmos. Environ.*, vol. 45, no. 21, pp. 3594–3602, 2011, doi: 10.1016/j.atmosenv.2011.03.064.

[3] Y. Zhu, A. Eiguren-Fernandez, W. C. Hinds, and A. H. Miguel, "In-cabin commuter exposure to ultrafine particles on Los Angeles freeways," *Environ. Sci. Technol.*, vol. 41, no. 7, pp. 2138–2145, 2007, doi: 10.1021/es0618797.

[4] M. Loxham *et al.*, "Upregulation of epithelial metallothioneins by metal-rich ultrafine particulate matter from an underground railway," *Metallomics*, vol. 12, no. 7, pp. 1070–1082, 2020, doi: 10.1039/d0mt00014k.

[5] M. Junaid, J. H. Syed, N. A. Abbasi, M. Z. Hashmi, R. N. Malik, and D. S. Pei, "Status of indoor air pollution (IAP) through particulate matter (PM) emissions and associated health concerns in South Asia," *Chemosphere*, vol. 191, pp. 651–663, 2018, doi: 10.1016/j.chemosphere.2017.10.097.

[6] R. B. Hetland, M. Refsnes, T. Myran, B. V. Johansen, N. Uthus, and P. E. Schwarze, "Mineral and/or metal content as critical determinants of particle-induced release of IL-6 and IL-8 from A549 cells," *J. Toxicol. Environ. Heal. - Part A*, vol. 60, no. 1, pp. 47–65, 2000, doi: 10.1080/009841000156583.

[7] IQAir, "World Air Quality Report," *2020 World Air Qual. Rep.*, pp. 1–35, 2020, [Online]. Available: https://www.iqair.com/world-most-polluted-cities/world-air-quality-report-2019-en.pdf.

[8] IQAir, "World Air Quality Report," *2019 World Air Qual. Rep.*, pp. 1–35, 2019, [Online]. Available: https://www.iqair.com/world-most-polluted-cities/world-air-quality-report-2019-en.pdf.

[9] A. Pandey *et al.*, "Health and economic impact of air pollution in the states of India: the Global Burden of Disease Study 2019," *Lancet Planet. Heal.*, vol. 5, no. 1, pp. e25–e38, Jan. 2021, doi: 10.1016/S2542-5196(20)30298-9.

[10] Health Effects Institute and Institute for Health Metrics and Evaluation´s Global Burden of Desease project, "State of Global Air 2020." p. 28, 2020, [Online]. Available: https://www.stateofglobalair.org/resources.

[11] J. Sotty *et al.*, "Mitochondrial alterations triggered by repeated exposure to fine (PM2.5-0.18) and quasi-ultrafine (PM0.18) fractions of ambient particulate matter," *Environ. Int.*, vol. 142, no. May, p. 105830, 2020, doi: 10.1016/j.envint.2020.105830.

[12] C. Arden Pope, J. C. Hansen, R. Kuprov, M. D. Sanders, M. N. Anderson, and D. J. Eatough, "Vascular function and short-term exposure to fine particulate air pollution," *J. Air Waste Manag. Assoc.*, vol. 61, no. 8, pp. 858–863, 2011, doi: 10.3155/1047-3289.61.8.858.

[13] A. Das, A. Kumar, G. Habib, and P. Vivekanandan, "Insights on the biological role of ultrafine particles of size PM<0.25: A prospective study from New Delhi," *Environ. Pollut.*, vol. 268, p. 115638, 2020, doi: 10.1016/j.envpol.2020.115638.

[14] F. Li *et al.*, "Spatial and temporal variation of sources contributing to quasi-ultrafine particulate matter PM0.36 in Augsburg, Germany," *Sci. Total Environ.*, vol. 631–632, pp. 191–200, 2018, doi: 10.1016/j.scitotenv.2018.03.041.

[15] P. Kumar, A. Robins, S. Vardoulakis, and R. Britter, "A review of the characteristics of nanoparticles in the urban atmosphere and the prospects for developing regulatory controls," *Atmos. Environ.*, vol. 44, no. 39, pp. 5035–5052, 2010, doi: 10.1016/j.atmosenv.2010.08.016.

[16] M. Zuurbier, G. Hoek, M. Oldenwening, K. Meliefste, P. Van Den Hazel, and B. Brunekreef, "Respiratory effects of commuters'exposure to air pollution in traffic," *Epidemiology*, vol. 22, no. 2, pp. 219–227, 2011, doi: 10.1097/EDE.0b013e3182093693.

[17] Tomtom, "Traffic Index Traffic Index results," p. 23, 2019.

[18] A. Leavey, N. Reed, S. Patel, K. Bradley, P. Kulkarni, and P. Biswas, "Comparing on-road real-time simultaneous in-cabin and outdoor particulate and gaseous concentrations for a range of ventilation scenarios," *Atmos. Environ.*, vol. 166, pp. 130–141, 2017, doi: 10.1016/j.atmosenv.2017.07.016.

[19] S. Zhu, J. D. Marshall, and D. Levinson, “Population exposure to ultrafine particles: Size-resolved and real-time models for highways,” *Transp. Res. Part D Transp. Environ.*, vol. 49, pp. 323–336, 2016, doi: 10.1016/j.trd.2016.09.010.

[20] D. Campagnolo *et al.*, “In-vehicle airborne fine and ultra-fine particulate matter exposure: The impact of leading vehicle emissions,” *Environ. Int.*, vol. 123, no. January, pp. 407–416, 2019, doi: 10.1016/j.envint.2018.12.020.

[21] Z. Tong, Y. Li, D. Westerdahl, G. Adamkiewicz, and J. D. Spengler, “Exploring the effects of ventilation practices in mitigating in-vehicle exposure to traffic-related air pollutants in China,” *Environ. Int.*, vol. 127, no. April, pp. 773–784, 2019, doi: 10.1016/j.envint.2019.03.023.

[22] B. .Xu, X. Chen, and J. Xiong, “Air quality inside motor vehicles’ cabins: A review,” *Indoor Built Environ.*, vol. 27, no. 4, pp. 452–465, 2018, doi: 10.1177/1420326X16679217.

[23] E. S. Lee, M. K. Stenstrom, and Y. Zhu, “Ultrafine particle infiltration into passenger vehicles. Part I: Experimental evidence,” *Transp. Res. Part D Transp. Environ.*, vol. 38, pp. 156–165, 2015, doi: 10.1016/j.trd.2015.04.025.