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Spatial Variability of Finer Particulate Matter ($PM_{2.5}$) Mass Concentrations over the Jammu Urban Area

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Abstract Atmospheric fine aerosols ($PM_{2.5}$) have become a major concern in the context of rapidly deteriorating urban air quality by significantly affecting air quality, visibility, human health, and the earth's climate. In this work, $PM_{2.5}$ aerosol samples were collected during the summer (May-June) season at three different sites of Jammu urban area, Jammu and Kashmir. Significant site-specific spatial variation in $PM_{2.5}$ mass concentrations was observed. The highest mass concentration of $PM_{2.5}$ was observed at Site-2, a commercial hub with an average concentration 89.8 $\mu g/m^3 \pm 34.7$, and at Site-3, an Institutional area having an average $PM_{2.5}$ concentration 67.9 $\mu g/m^3 \pm 28.7$ while the lowest concentrations were reported at Site-1, a residential area having an average concentration of 49.4 $\mu g/m^3 \pm$ 22.7. Besides, 22.2%, 77.8%, and 44.4% of the samples at Site-1, Site-2, and Site-3, respectively exceeded National Ambient Air Quality Standards (NAAQS) of 60 $\mu g/m^3$ prescribed by CPCB. The high $PM_{2.5}$ in the commercial area can be attributed to higher vehicular movement and commercial activities. Site-3, University of Jammu, is an Institutional area where high concentrations of $PM_{2.5}$ are possibly due to high vehicular movement in the campus and the use of generators for power backup.

Keywords: *$PM_{2.5}$, NAAQS, spatial variation*

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1. Introduction

Rapid industrialization and urbanization have led to a fast deterioration of the air quality and consequently the public health in Indian cities. Air pollution in India has found its place near or at the top of the list of all known risk factors for ill health. Annually, 2 million premature deaths are reported in India due to both ambient and household air pollution [1]. With the rapid phase of urbanization, vehicular pollution has become the major contributor to urban atmospheric pollution. Fuel combustion (diesel, gasoline, etc.) in vehicular engines emit various harmful pollutants in the ambient atmosphere [2]. According to [3], concentrations of regulated air pollutants often exceed National Ambient Air Quality Standards (NAAQS) in major cities of India thus, posing serious health risks to the residents.

Atmospheric suspended particulates are commonly classified based on their aerodynamic diameter. Particles having an aerodynamic diameter of greater than 2.5 micrometers are known as coarser particulates, while those having a diameter less than 2.5 micrometers are classified as finer particulates or $PM_{2.5}$. In the last few decades, $PM_{2.5}$, particulates having a diameter of 2.5 micrometers or less have caught significant scientific attention. These finer particles not only impact human health, but also reduce visibility, adversely impact air quality, ecosystem processes, and the earth's climate. Suspended particles provide reaction sites for pollutant gases, influence and play a fundamental role in cloud formation, and modifies precipitation by functioning as condensation nuclei besides acting as carriers for pollutant transport. Today, many research efforts are underway to measure, characterize and model these $PM_{2.5}$ aerosols.

Mostly the $PM_{2.5}$ aerosols are derived from natural (e.g., sea salt, volcanic dust, forest fires, soil dust, biological debris) as well as anthropogenic (e.g., industrial dust, mining, vehicular emissions, power plants) sources. Common indoor sources of $PM_{2.5}$ include cooking, tobacco smoke, operating fireplaces, and fuel-burning space heaters (e.g., kerosene heaters). Besides, $PM_{2.5}$ may be primary or secondary (due to chemical reactions that take place in the atmosphere) in origin. Chemically, particulate matter is composed of water-soluble inorganic ions (Ca^{2+}, Mg^{2+}, Na^+, K^+, NH_4^+, Cl^-, NO_3^-, SO_4^{2-}), carbonaceous matter [elemental carbon (EC), organic carbon (OC) and water-soluble organic carbon (WSOC)], the mineral matter of crustal origin and the trace elements such as Ba, Zn, Pb, Sr, Cr, Ni, etc. Besides, the regional topography, meteorology (such as wind velocity, mixing height), and emission sources to a larger extent influence the temporal and spatial variability of mass concentrations of $PM_{2.5}$ aerosols.

Noteworthy that $PM_{2.5}$ aerosols have become a matter of huge concern because of the severe health effects caused by them as they are so fine that they are most liable to enter the human respiratory system and get lodged in the air spaces of the lungs or can even be transferred to the blood circulation system resulting in severe health impacts. $PM_{2.5}$ is known to increase the age-specific mortality risk, particularly from cardiovascular causes. Exposure to the high concentration of $PM_{2.5}$ can exacerbate lung and heart diseases, significantly affecting the quality of life, and increasing deaths.

Thus, to maintain air quality within the prescribed regulatory limits (NAAQS), continuous monitoring of the airborne concentrations of particulate matter is required. In this study, a quantitative assessment of the mass concentrations of $PM_{2.5}$ aerosols at three different locations of Jammu Urban Area has been done and a comparison of the observed concentrations has been made with the National Ambient Air Quality Standards (NAAQS) of India.

2. Materials and Methods

2.1. Description of the Study Area

Jammu city is the winter capital of Union Territory Jammu and Kashmir (JKUT). It is the largest city in the Jammu district covering approximately 240 km^2 area. The city is located on the banks of the river Tawi along the Siwalik foothills of the Himalaya (Lat: 32.7266 °N, Long: 74. 8570 °E, 300 MSL). Jammu region experiences typical monsoon tropical climate varying from sub-humid to sub-tropical type of climate characterized by (a) summer season extending from March to June, (b) monsoon period from July to October, and (c) winters from November to February. The average annual rainfall received by Jammu is approximately about 1,113.6 mm [4] The city of Jammu is also the most populous city of the union territory. The population of Jammu city in 2011 was reported to be 502,197 (Census, 2011). The city has expanded rapidly in the last three decades. As a result of the growing population and fast urbanization, Jammu city has also become one of the most polluted cities in India with automobiles as the major culprits of urban air pollution. The huge number of motor vehicles are added to the traffic load of Jammu city daily. According to Motor Vehicle Department, J&K, 2018 report, traffic in J&K is increasing significantly with the addition of the large number of vehicles annually (1657433) with maximum contribution (724270) from Jammu city alone.

In this work, the $PM_{2.5}$ sampling was done at three different locations of Jammu urban area which included (a) Site-1 is Channi Rama (32.7015 °N, 74.9238 °E) a residential area, (b) Site-2 is Nai Basti (32.6951 °N, 74.8518 °E), a commercial area located along Jammu airport highway, and (c) Site-3 is University of Jammu (32.7202 °N, 74.8682 °E), a residential Institutional area.

2.2. Sample Collection and Analysis

The sampling of $PM_{2.5}$ was conducted using a fine particulate sampler (Envirotech APM 550 MFC) based on design standardized by USEPA and runs at a constant flow rate of 16.7 LPM maintained by a mass flow controller. Sampling was carried out during the summer (May-June) season every week at each site for 24 hours. $PM_{2.5}$ samples were collected on pre-weighed quartz fiber filter papers of diameter 47 mm. Before sampling, quartz fiber filter papers were combusted for 3 hours at 900 °C. Conditioning of quartz fiber filter papers was done at 30 ±1 °C and 50 ±5% relative humidity for 24 hours both before sampling and after sampling. A total of 27 samples were collected. Sampling was done during the dry meteorological conditions. $PM_{2.5}$ mass load was calculated gravimetrically according to guidelines of CPCB (Central Pollution Control Board) [5].

The air mass backward trajectory analysis was done to identify sources and the transport pathways of the $PM_{2.5}$ aerosols collected at the sampling sites during the sampling period. Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model based on GDAS (Global Data Assimilation System) and developed by the National Oceanic and Atmospheric Administration (NOAA)/Air Resources Laboratory (ARL) was used [6]. The airmass backward trajectories were calculated for 100, 500, and 1000 m altitudes above the ground level. The trajectory timescale was 48 hours for each. Windrose was also plotted depicting the frequency of intensity of winds in particular wind direction with wind speed modules over the study area.

3. Results and Discussions

The average mass concentrations of $PM_{2.5}$ along with standard deviation, minimum concentration, maximum concentration, and percentage of samples exceeding NAAQS (60 μg/m^3) during the summer season at the study sites have been tabulated as Table 1. $PM_{2.5}$ mass concentrations exhibited significant site-specific as well as spatial variability. Average $PM_{2.5}$ mass concentrations were found to vary in the order from high to low as; Site-2 > Site-3 > Site-1. Results showed that the $PM_{2.5}$ mass concentration ranged from 24.8 to 88.3 μg/m^3 (avg: 49.4 μg/m^3 ± 22.7) at Site-1, 48.9 to 152.1 μg/m^3 (avg: 89.8 μg/m^3 ± 34.7) at Site-2 and from 27.5 to 120.8 μg/m^3 (avg: 67.96 μg/m^3 ± 28.7) at Site- 3 (Figure 1). Besides, the mass concentrations of 22.2%, 77.8%, and 44.4% of the samples exceeded the NAAQS limit (60 μg/m^3) stipulated by Central Pollution Control Board (CPCB), India at Site-1, Site-2, and Site- 3, respectively.

Table 1. Statistical description of $PM_{2.5}$ mass concentrations at study sites in Jammu urban area

	Site-1	Site-2	Site-3
Mass Concentrations (μg/m^3)			
Mean	49.4	89.8	67.9
Max.	88.3	152.1	120.8
Min.	24.8	48.9	27.5
Std dev.	22.7	34.7	28.7
Samples (%)			
Above NAAQS	22.2%	77.8%	44.4%

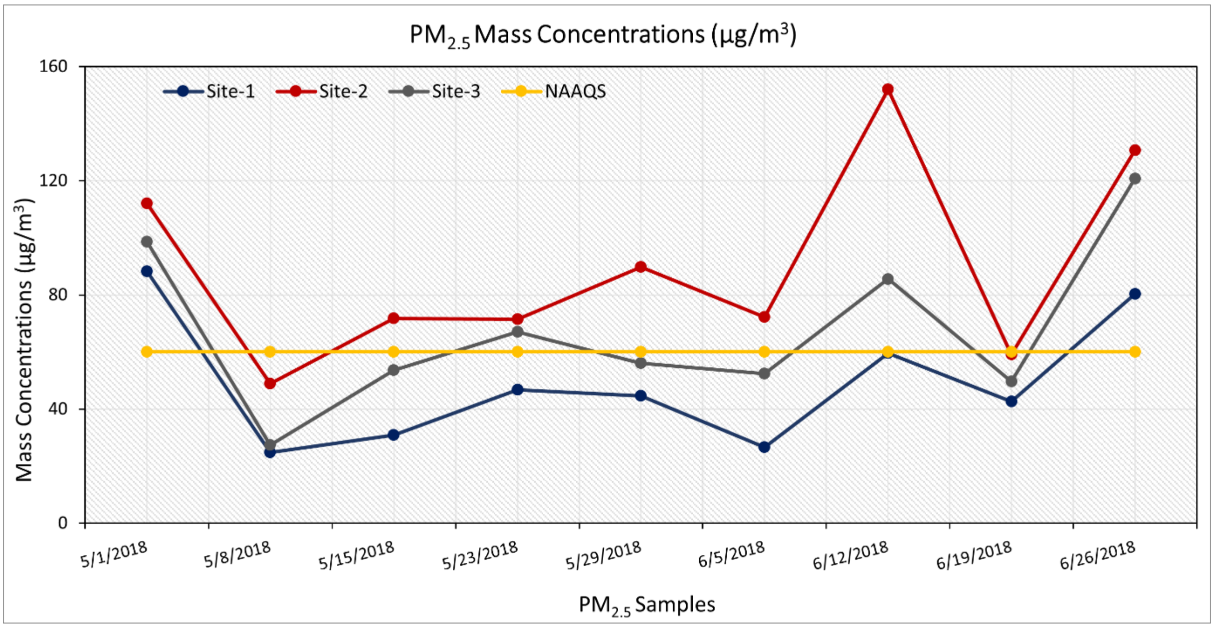

Figure 1. $PM_{2.5}$ mass concentrations at sampling sites on different sampling dates. Horizontal line represents National Ambient Air Quality Standard (NAAQS; 60 µg/m^3 for 24-hour average)

Higher average mass concentration of $PM_{2.5}$ at Site-2 can possibly be attributed to higher vehicular movement with frequent traffic jams, narrow road, slow speed of vehicles during rush hours, resuspension of road dust from vehicular movement, and use of generators during frequent power cuts [4]. Moreover, the proximity to Jammu airport, connectivity to the major roads, and commercial activities aggravate the load of particulates in the air. Results showed that 77.8% of the samples at Site-2 exceeded the NAAQS limit, while the highest value of $PM_{2.5}$ mass concentration (152.14 µg/m^3) observed at Site-2 was approximately 2.54 times higher than NAAQS prescribed limit of 60 µg/m^3. Site-1 is the residential location near the highway and close to Transport Nagar and Narwal Mandi. The high $PM_{2.5}$ mass concentration observed at Site-1 may be ascribed to the movement of a large number of vehicles on the highway, a large number of repairs and automobile workshops and nearby commercial activities. Traffic volume being higher in morning and evening rush hour [7], while commercial activities and repairs and service operation during daytime are the major processes contributing to $PM_{2.5}$ pollution. Site-3 being an Institutional area, receives a high volume of traffic during the daytime, which possibly seems to be the major source of $PM_{2.5}$ concentration. A large number of construction activities happening in the University campus as well as usage of diesel generators for power backup could potentially be other sources of overall $PM_{2.5}$ concentrations in the campus. Moreover, being in the city centre, the contribution of $PM_{2.5}$ from the surrounding high traffic density locations and commercial centres can't be ruled out. However, Site-3 was found to have lower concentrations than Site-2 which may be attributed to the greenery in the campus, good road condition, limited working hours, etc. Overall, Site-1 was found to have the lowest $PM_{2.5}$ concentration among the selected study sites.

In similar studies, vehicular emissions have been found as one of the most important $PM_{2.5}$ sources [8,9,10,11,12]; in cities such as Chennai [12], Beijing [13]; Shanghai [14]; Nanjing [7]. In the work of [7], exhaust emission was found to be relatively too high due to the all-weather heavy traffic volume in commercial land. The vehicular emissions are even higher due to traffic congestion; inadequate public transport and inept management; obsolete vehicular technology; haphazard urban development and poor fuel quality [15,16]. Besides, poor maintenance of vehicles and the age of vehicle further exacerbate vehicular emissions [4]. Source apportionment studies have shown that the vehicular emissions make major contribution to $PM_{2.5}$ concentrations in the urban environments [17,18]. Moreover, less green cover on roadsides, road dust and exponential growth in the number of vehicles registering every day are some other major reasons contributing to $PM_{2.5}$ pollution in the atmosphere [7].

Representative backward trajectories of air masses were calculated for the study area corresponding to the days when the highest concentrations of $PM_{2.5}$ were observed. Airmass backward trajectories in Figure 2(a) and Figure 2(b) suggest that long-range atmospheric transport from Indo-Gangetic plains as well as from Central Asia through north-easterly and north-westerly winds influence the overall particulate budget of the Jammu urban area. However, the influence of local and long-range has not been quantified. Earlier studies have reported that a huge amount of pollution through long-range transport enters the Indian subcontinent from Middle East, Europe, the Indian Ocean, Africa, and nearby countries [19].

The wind rose for the sampling period depicted that Jammu Urban area was affected by strong south-western winds (Figure 3). Such strong winds to a large extent are responsible for the re-suspension of street dust, especially in the urban area. Moreover, the sampling is done during the pre-monsoon times, when the fields in the vicinity are plowed and prepared for the next crop. The crustal dust from the agricultural land appears to be one of the larger sources contributing to the urban $PM_{2.5}$ load. Besides, the long-range transport of air pollutants cannot be ruled out.

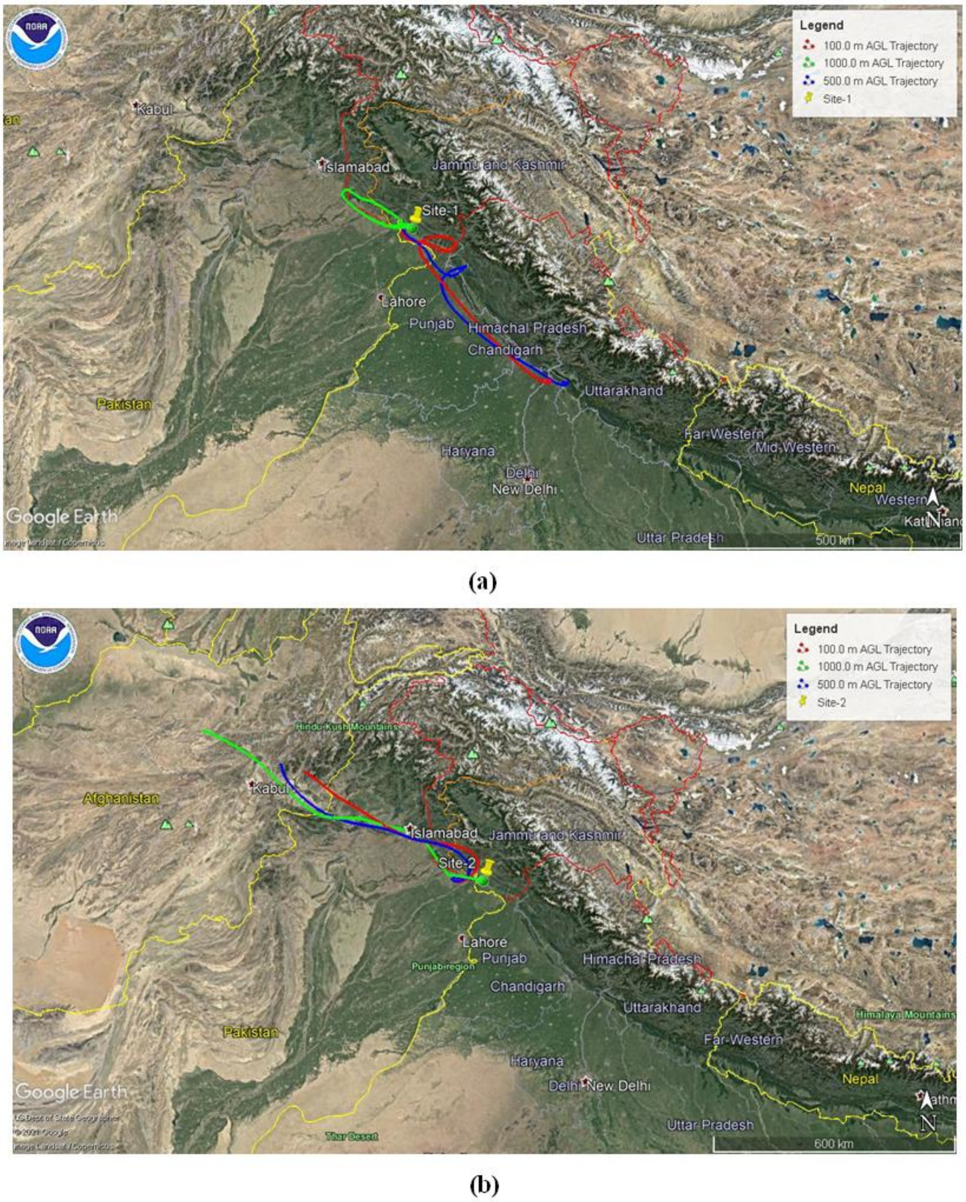

Figure 2. Representative air mass backward trajectories arriving at study area (http://www.arl.noaa.gov/HYSPLIT.php)

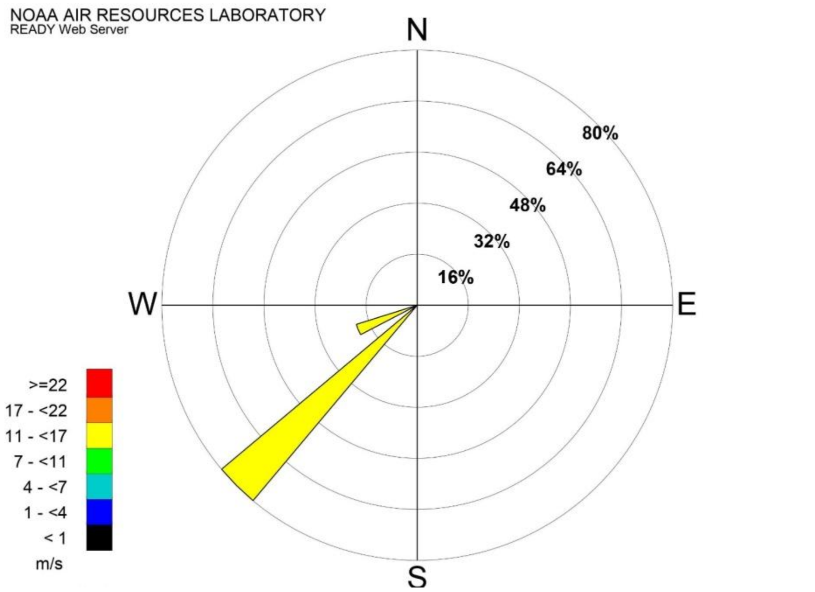

Figure 3. Windrose plot depicting wind speed and direction at study area (https://www.ready.noaa.gov/READYamet.php)

4. Conclusions

This study revealed that the Jammu urban area has a high mass concentration of $PM_{2.5.}$ Results showed that average $PM_{2.5}$ mass concentration at sampling sites varied in the order from high to low as Site-2 (89.8 $\mu g/m^3 \pm$ 34.7) > Site-3 (67.96 $\mu g/m^3 \pm 28.7$) > Site-1 (49.4 $\mu g/m^3 \pm$ 22.7). The 22.2% of the samples at Site-1, 77.8% at Site-2, and 44.4% at Site-3 exceeded NAAQS (60 $\mu g/m^3$) suggesting the severity of $PM_{2.5}$ air pollution. Vehicular traffic and resuspension of street dust by the strong winds and vehicular movements appear to be the major source of $PM_{2.5}$ mass in the study area. Besides, enhanced crustal inputs under drier conditions from the surrounding area and agricultural field seem to have also contributed to the $PM_{2.5}$ load. This is emphasized that proper measures for air pollution abatement especially due to $PM_{2.5}$ should be taken, especially the encouragement of public transportation systems, use of electrical vehicles, enhancement of urban green cover, maintenance of roads to minimize the impacts of street dust, etc. to control the $PM_{2.5}$ pollution in the area.

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References

[1] Gordon, T., Balakrishnan, K., Dey, S., Rajagopalan, S., Thornburg, J., Thurston, G., Agrawal, A., Collman, G., Guleria, R., & Limaye, S. (2018). Air pollution health research priorities for India: Perspectives of the Indo- U. S. Communities of Researchers. *Environment International*, *119*(June), 100-108.

[2] Mahalakshmi, D. V, Sujatha, P., Naidu, C. V, & Chowdary, V. M. (2014). Contribution of vehicular emission on urban air quality: Results from public strike in Hyderabad. *43*(x), 340-348.

[3] Garaga, R., & Kota, S. H. (2018). Characterization of PM10 and impact on human health during the annual festival of lights (Diwali). *Journal of Health and Pollution*, *8*(20).

[4] Sharma, A., & Raina, A. K. (2013). Assessment of the Status of SPM in Jammu City and its Control Strategies. *Journal Of Environmental Science, Toxicology And Food Technology (IOSR-JESTFT)*, *7*(1), 8-12.

[5] Pollution, C., & Board, C. (2011). *Guidelines for Manual Sampling & Analyses*.

[6] Stein A.F., et al. (2015). NOAA's HYSPLIT atmospheric transport and dispersion modeling system. *Bull. Amer. Meteor. Soc.*

[7] Xu, P., Wang, W., Ji, J., & Yao, S. (2014). Analysis of the Contribution of the Road Traffic Industry to the PM2 . 5 Emission for Different Land-Use Types. *Computational Intelligence and Neuroscience*, 2014.

[8] Wang, X., Bi, X., Sheng, G., & Fu, J. (2006). Chemical composition and sources of PM10 and PM2.5 aerosols in Guangzhou, China. *Environmental Monitoring and Assessment*, *119*(1-3), 425-439.

[9] Venkataraman, C., Brauer, M., Tibrewal, K., Sadavarte, P., Ma, Q., Chaliyakunnel, S., Frostad, J., Klimont, Z., Martin, R. V, Dylan, B., Philip, S., Walker, K., & Wang, S. (2017). Source influence on emission pathways and ambient PM 2. 5 pollution over India (2015-2050). *Atmospheric Chemistry and Physics*, *December*.

[10] Karagulian, F., Belis, C. A., Francisco, C., Dora, C., Prüss-ustün, A. M., Bonjour, S., Adair-rohani, H., & Amann, M. (2015). Contributions to cities' ambient particulate matter (PM): A systematic review of local source contributions at global level. *Atmospheric Environment*, *120*, 475-483.

[11] Ying Gong, X. Z. (2018). The Impact of Vehicle Exhaust on PM2. 5 Concentration in Cities in Northeast China The Impact of Vehicle Exhaust on PM2. 5 Concentration in Cities in Northeast China. *IOP Conference Series: Materials Science and Engineering PAPER*.

[12] Jose, J., Srimuruganandam, B., & Nagendra, S. M. S. (2019). Characterization of PM 10 and PM 2 . 5 Emission Sources at Chennai, India. *Nature Environment and Pollution Technology*, *18*(2), 555-562.

[13] Song, Y., Xie, S., Zhang, Y., Zeng, L., Salmon, L. G., & Zheng, M. (2006). Source apportionment of PM2.5 in Beijing using principal component analysis/absolute principal component scores and UNMIX. *Science of the Total Environment*, *372*(1), 278-286.

[14] Feng, J., Chan, C. K., Fang, M., Hu, M., He, L., & Tang, X. (2006). Characteristics of organic matter in PM2.5 in Shanghai. *Chemosphere*, *64*(8), 1393-1400.

[15] Badami, M. G. (2005). Transport and urban air pollution in India. *Environmental Management*, *36*(2), 195-204.

[16] Nesamani, K. S. (2010). Estimation of automobile emissions and control strategies in India. *Science of the Total Environment*, *408*(8), 1800-1811.

[17] Andrade, M. D. F., Miranda, R. M. De, Fornaro, A., Kerr, A., Oyama, B., Andre, P. A. De, & Saldiva, P. (2012). *Vehicle emissions and PM 2 . 5 mass concentrations in six Brazilian cities*. 79-88.

[18] Iqbal, A., Afroze, S., & Rahman, M. M. (2020). Vehicular PM emissions and urban public health sustainability: A probabilistic analysis for Dhaka City. *Sustainability (Switzerland)*, *12*(15).

[19] Kulshrestha, U., & Kumar, B. (2014). Airmass trajectories and long range transport of pollutants: Review of wet deposition scenario in South Asia. *Advances in Meteorology*, *2014*.