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Assessment Of Vehicle Emissions Associated With The Covid-19 Pandemic In Parts Of Greater Chennai Regime

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Abstract:
Air pollution caused by vehicles has been described as the "disease of wealth". Particulate matter $PM_{2.5}$ and PM_{10}, is a primary contaminant released by motorized vehicles. Since 2005, the number of motorised vehicles has increased by a factor of 24 and in recent years, private vehicles have accounted for over half of all daily trips taken by all individuals. In order to provide a clear understanding of emission sources and trends. Using real-time data on vehicle counts, types, fuel consumption, vehicle kilometers travelled (VKT), and ARAI emission factors, the study evaluated vehicle emissions associated to COVID-19 periods in ten locations across greater Chennai. The study also revealed that the modal share for vehicles ranged from 33% for two-wheeled vehicles to 25% for buses, 24% for three and four-wheeled vehicles and 18% for goods vehicles. The highest emission concentration of $PM_{2.5}$ was observed in Koyambedu region with values of 0.000158 g/s-m^2 and PM_{10} with the values of 0.000329 g/s-m^2 followed by Ambattur and T. Nagar region.

Keywords: *Particulate Matter, PM2.5 & PM10, COVID 19 Lockdown, Emission Factors, Vehicle Kilometers Travelled (VKT).*

1. INTRODUCTION

Urbanization in India is more rapid around the major cities in India. With increasing population and improving economy the population levels in urban areas has increased drastically[1]. The purchasing power of individuals have also paved way for increased vehicle ownership. The average households with at least one vehicle stand at 54%. It has been noted that the pollution due t[1]o vehicular traffic and its influence varies from megacity to megacity. Vehicle emissions contribute to poor air quality in these cities [2]. Although improvements in air quality with respect to the criteria pollutants (SPM, SO_2 and NO_x) have been reported for some metropolitan cities, the air pollution situation in the majority of Indian cities remains unknown and is a growing cause for concern[3].

The National Ambient Air Quality Standards (NAAQS) set by the Central Pollution Control Board (CPCB) and the World Health Organization guidelines for air pollution levels are generally exceeded in urban areas. The problem is exacerbated by the high vehicle-to-population ratios in these cities [4]. In India, the road sector consumes 25% of total energy (of which 98% is derived from oil). A gradual shift in passenger and freight movement from rail to road-based transportation has also resulted in a significant increase in fuel consumption by the road sector, which in turn has led to an increase in the emissions of various pollutants. Vehicles in major metropolitan cities in India are estimated to account for 30% of SPM of the total pollution load of these cities (Goyal and Yusuf 2006).

Increase in urban population, which accounts for about 31% of India's population has led to a greater concentration of vehicles in urban cities, especially in Delhi, Mumbai, Chennai and Kolkata, which account for more than 15% of the country's total vehicle population[6]. Moreover, it has been observed that the majority of megacities are

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overpopulated and that this high growth rate of population is largely dependent on personalised vehicles as well as mass transportation, both of which have effects on the environment due to maximum automobile exhaustion and the resultant occurrence of various carcinogenic diseases[7].

1.2. Need for emission characterization of vehicular pollution

Air pollution caused by vehicles has been described as the "disease of wealth". The tremendous increase in the number of vehicles is the major source of the excessive level of RSPM/PM_{10} in Chennai[8]. According to the National Ambient Air Quality Monitoring of India, 2014-15, the high level of particulate matter in Chennai is due to vehicle emissions and traffic dust. Since 2005, the number of motorised vehicles has increased by a factor of 24 and in recent years, private vehicles have accounted for over half of all daily trips taken by all individuals (Basic Road Statistics of India, Urban Infrastructure: Twelfth Five Year Plan). Every day, at least 700 new vehicles go to the Chennai streets triggering the level of pollution (Sharma et al. 2019). The mean annual concentration of RSPM/PM_{10} exceeds the permissible limit of $60 g/m^3$ by at least 1.5 times and air quality deteriorates. Emissions monitoring provides insight into the contribution of transportation to modelled air pollution [10]. Thus, the current state of air quality prompted us to work on estimating the emissions of particulate matter pollutants from vehicles and determining the impact of these emissions on air quality.

2. STUDY AREA

The study area is parts of Greater Chennai, India which covers 44 wards and 6 zones with 10 sampling stations as indicated in the figure 1.

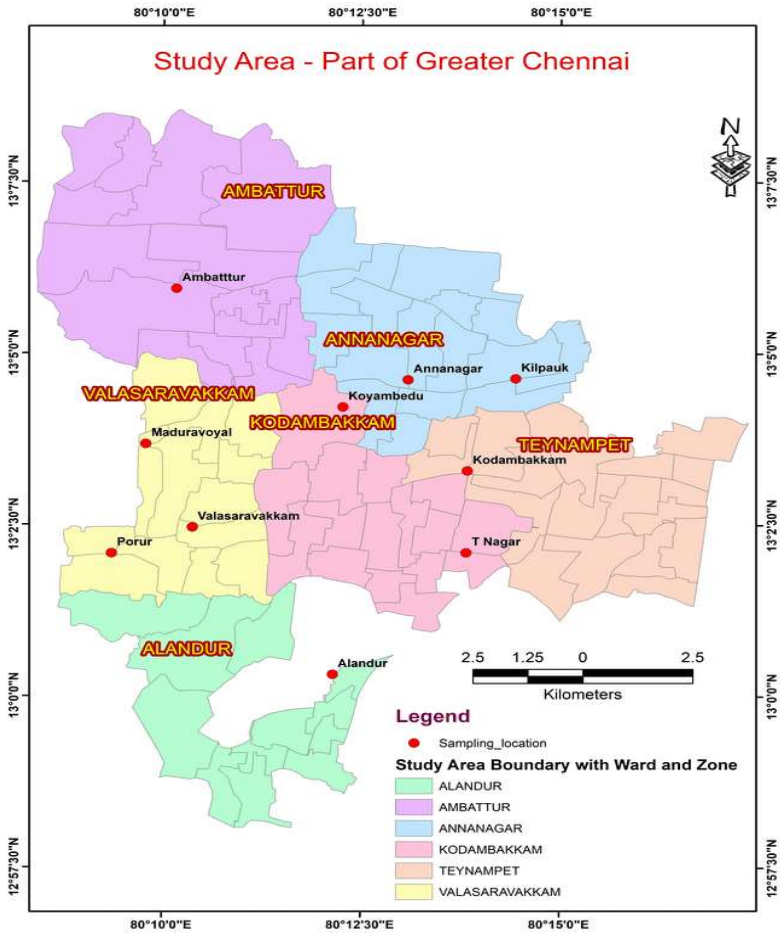


Figure 1: Study Area map – Part of Greater Chennai

3. MATERIAL AND METHODOLOGY

3.1 Emission characterisation and quantification based on vehicular traffic

The amount of pollutant dispersion into the atmosphere is computed using the emission rate of vehicles figure. 2 depicts the estimation methodology for vehicle exhaust emission rate.

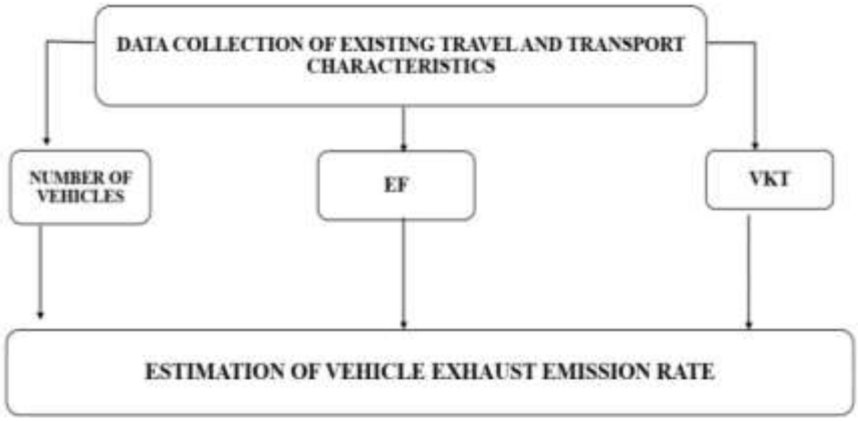


Figure 2. Methodology for Estimation of Vehicle Emission Rate

Using primary surveys, the existing travel and transport characteristics of the study area were evaluated in order to comprehend the traffic pattern and mode preference. A screen line volume survey estimated the number of vehicles crossing screen lines. The survey was conducted during peak hours (8 a.m. to 11 a.m.) in the morning and evening (4 p.m. to 7 p.m.) figure 3.

Figure 3. Field investigations using high volume APM550 air sampler and traffic survey

From these traffic counts, peak-hour traffic volume was determined and the data was then analysed to determine the composition of traffic by vehicle type. The number of vehicles, the distance travelled by those vehicles and the Emission Factor (EF) were used to calculate traffic emissions, as shown in [11]. The collected daily average VKT per vehicle category was used to calculate emissions Table 1.

Using emission factors specified by ARAI for Indian vehicles Table 1 vehicle exhaust emission rates have been estimated (https://www.teriin.org/sites/default/files/files/Indian-Emission-Inventory-Report.pdf). These emission factors are developed based on the standard Indian driving condition and average speed. The emission rates were calculated using the standard equation (https://urbanemissions.info/tools/sim-air/ Simple Interactive Models for Better Air Quality: Four Simple Equations for Vehicle Emissions Inventory).

Emissions (tons/year) = Number of Vehicles * Vehicle km travelled(km/year) * Emission factor(gm/km) * 10-6 (tons/gm)

Vehicle emission rate was calculated in g/s for $PM_{2.5}$ and PM_{10} for all the ten stations and indicated below depending on the vehicular type.

Table 1. Emission Factor for different vehicle types

Sl. NO	VEHICULAR MODE/ VEHICLE CATEGORY	$PM_{2.5}$ - EF (gm/km)	PM_{10} - EF (gm/km)	FUEL USED	VKT (Km/Day/Vehicle)
1	Buses	0.8	1.50	Petrol	75
2	Two wheelers	0.05	0.10	Petrol	120
3	Three heelers	0.08	0.20	Petrol/Diesel	90
4	Four Wheelers	0.03	0.10	Diesel/CNG*	210
5	Taxis	0.03	0.10	Petrol/ Diesel/CNG	120
6	Goods Vehicles	0.5	1.25	Diesel	150

Further the calculated emission is divided by the line source area (1000 x 1000m) to obtain the emission rate in g/s-m$^{2.}$ during 2019, 2020 and 2021 for pre and post lockdown periods. This calculated emission rate was redesigned for other periods using ambient data gathered from ten sampling locations.

4. RESULTS AND DISCUSSION

4.1 Estimation of Emission Rate

According to the field inventory, the number of vehicles travelling to the Koyambedu study region is between 2.5 and 5 times that of other locations. The study also revealed that the modal share for vehicles figure. 4. ranged from 33% for two-wheeled vehicles to 25% for buses, 24% for three and four-wheeled vehicles and 18% for goods vehicles. Table 2 demonstrates that the daily volume of traffic on some major roads (i.e., four road segments) in the study locations exceeds 100,000 vehicles. The calculated emission rates for $PM_{2.5}$ and PM_{10} during the year 2019,2020 and 2021 covering four different periods i.e, pre- and post- lockdowns, semi lockdowns, lockdown periods are represented in the following figure. 5 (a-j). The figures indicated that the concentration of particulate matter pollution from the pre and post lockdown periods was significantly reduced during the semi and lockdown periods[12].

The highest emission concentration was observed in Koyambedu region due with values of 0.000158 g/s-m^2 which is well correlated with the vehicular inventory for the region[13]. According to the observed data during pre- and post-lockdown periods, PM_{10} levels are twice as high as $PM_{2.5}$ levels in the majority of the study region[14]. For each of the ten stations, Table 2 shows the vehicle emission rate calculated in g/s-m^2 for $PM_{2.5}$ and PM_{10} during 2019, 2020 and 2021 pre lockdown periods and Table 3 shows modified and recalculated emissivity for various time period based on pollutant concentration measurements. The findings from the ambient pollutant data collected at 10 sample stations present a compelling narrative about the impact of lockdown measures on air quality. The substantial decline in $PM_{2.5}$ concentrations by 73% and 76%, respectively, throughout the lockdown periods of 2020 and 2021, demonstrates the efficacy of stringent measures in mitigating the spread of fine particulate matter[15]. Similarly, the significant reduction in PM10 levels of 67 percent and 84.5 percent during the same lockdown periods reflects a significant improvement in overall air quality[16]. Furthermore, the observation of a 2% reduction in particulate matter levels (both PM2.5 and PM10) during the semi-lockdown period in 2020 highlights the ongoing positive impact of mobility restrictions on air quality, even in less stringent circumstances.

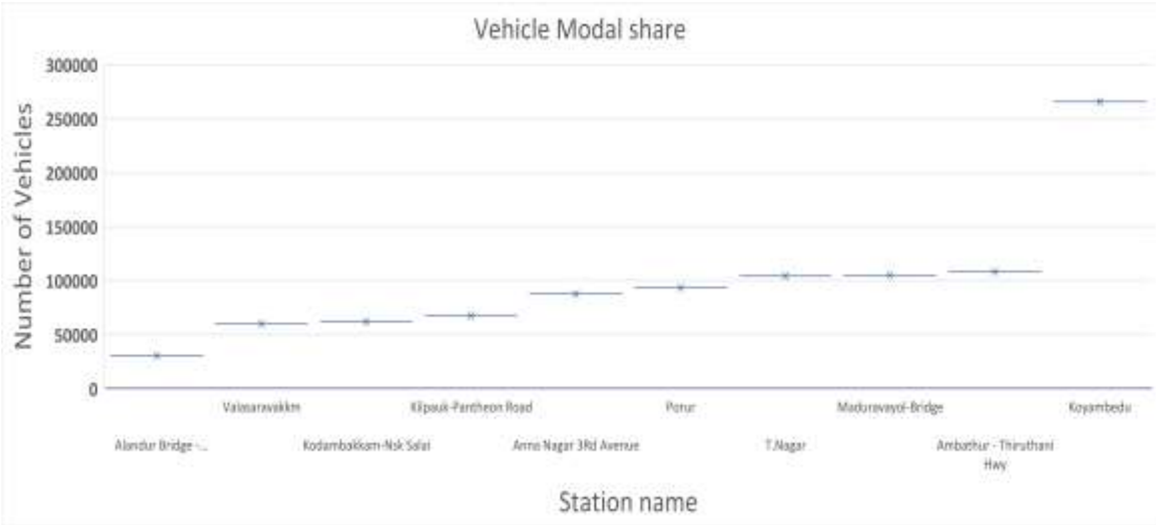
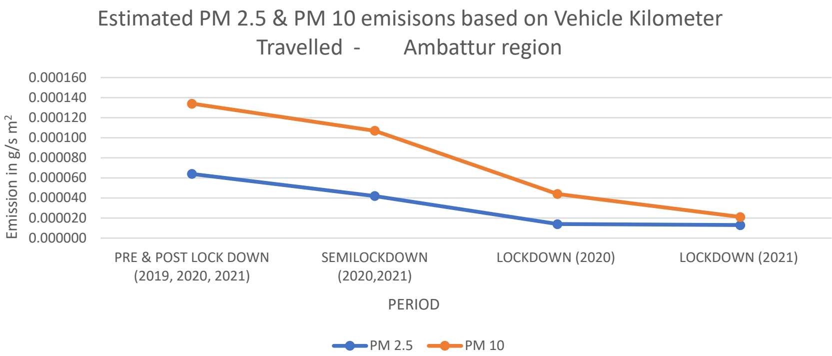


Figure 4. Vehicle Modal Share



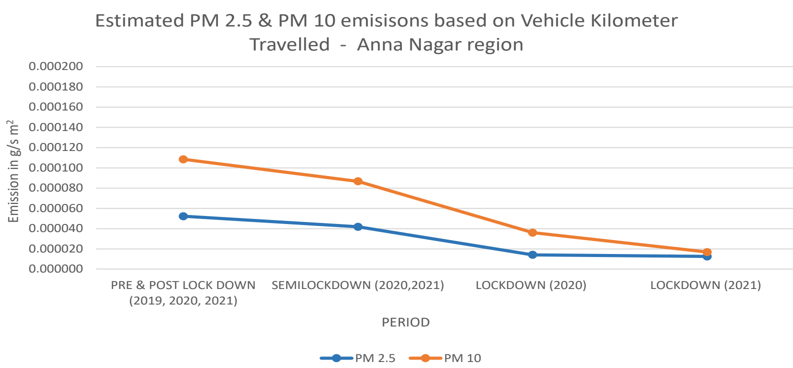
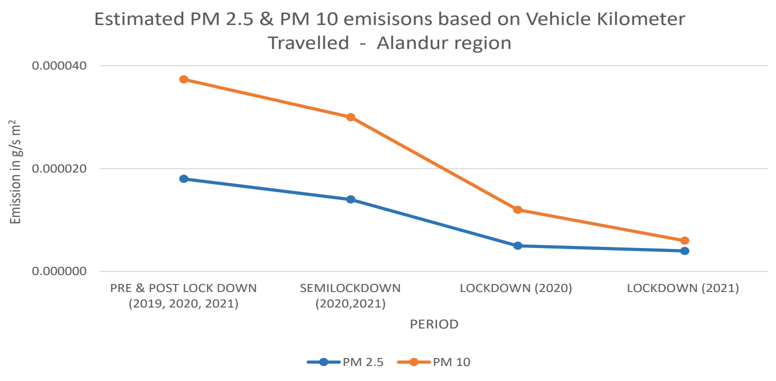


Figure 5 (a). Estimated PM $_{2.5}$ and PM $_{10}$ emissions - Ambattur Anna Nagar

Figure 5 (b). Estimated PM $_{2.5}$ and PM $_{10}$ emissions –



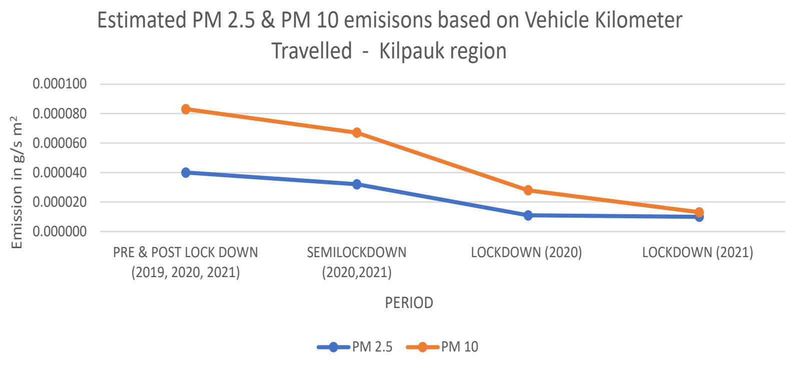
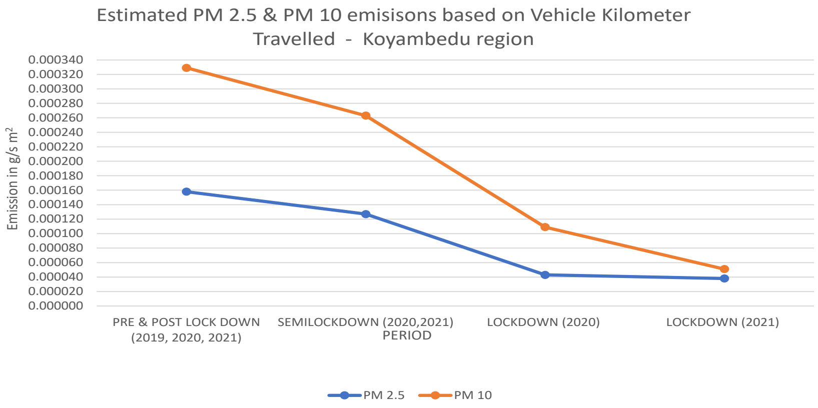


Figure 5 (c). Estimated PM $_{2.5}$ and PM $_{10}$ emissions –Alandur

Figure 5 (d). Estimated PM $_{2.5}$ and PM $_{10}$ emissions - Kilpauk



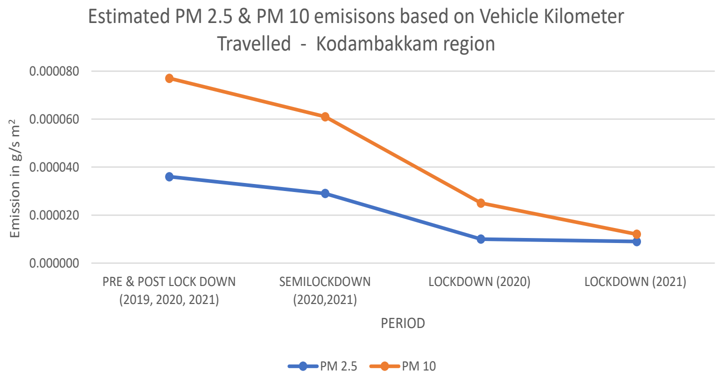
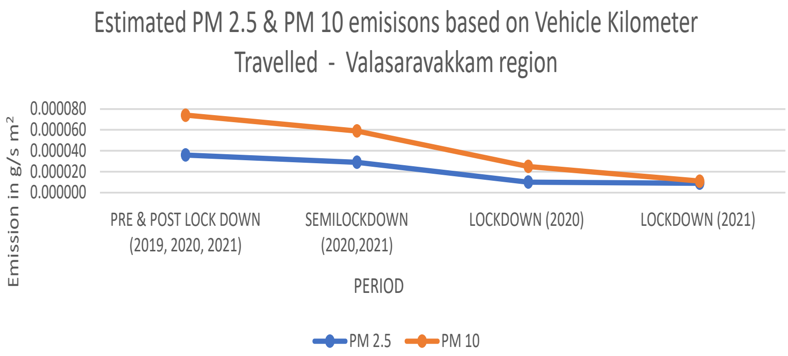


Figure 5 (e). Estimated PM $_{2.5}$ and PM $_{10}$ emissions – Koyembedu

Figure 5 (f). Estimated PM $_{2.5}$ and PM $_{10}$

emissions –Kodambakkam



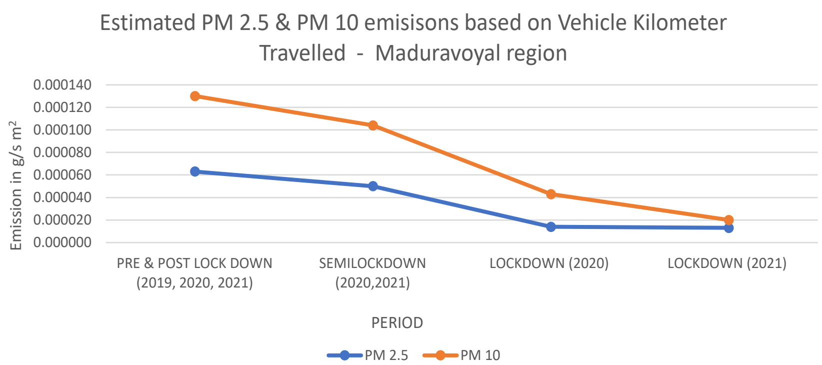
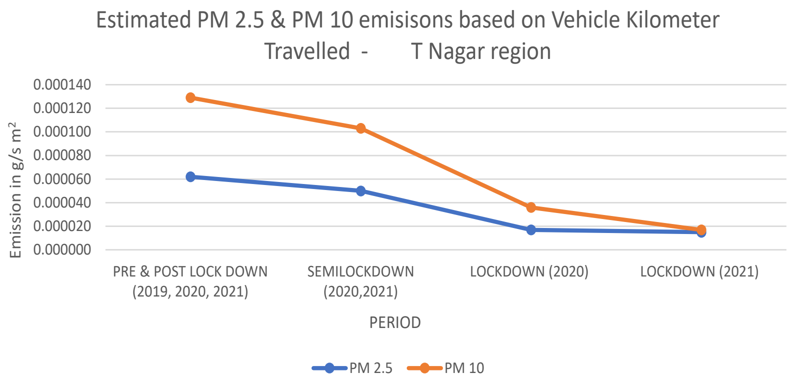


Figure 5 (g). Estimated PM $_{2.5}$ and PM $_{10}$ emissions - Maduravayol

Figure 5 (h). Estimated PM $_{2.5}$ and PM $_{10}$

emissions - Valasaravakkam



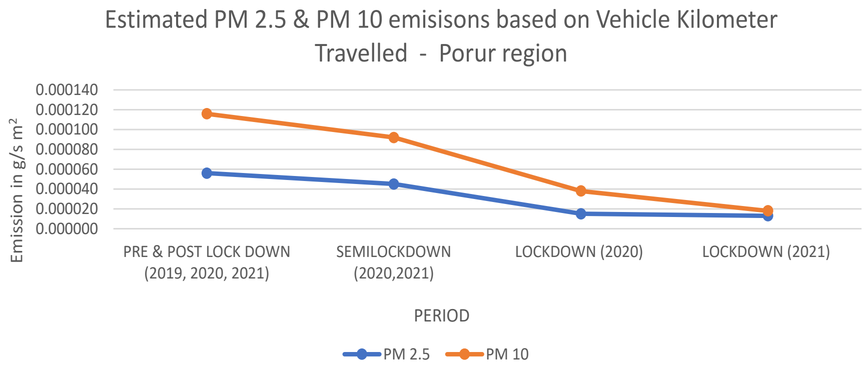


Figure 5 (i). Estimated PM $_{2.5}$ and PM $_{10}$ emissions –T. Nagar

Figure 5 (j). Estimated PM $_{2.5}$ and PM $_{10}$ emissions – Porur

Table 2. Modal share distribution for the study area and Calculated Emission rate in g/s-m^2

LOCATION NAME	**NO. OF VEHICLES**	**BUS**	**2W**	**3W/4W/ TAXI**	**GVs**	**PRE-LOCKDOWN 2020, 2019 & 2021 EMISSION RATE IN g/s-m^2**	
						$PM_{2.5}$	**PM_{10}**
ALANDUR BRIDGE - NEAR GUINDY INDUSTRIAL ESTATE	30184	7612	9970	7172	5421	0.000018	0.000037
PORUR	93412	23559	30854	22195	16777	0.000056	0.000116
KILPAUK-PANTHEON ROAD NEAR CO–OPTEX	67355	16987	22247	16004	12097	0.00004	0.000083
ANNA NAGAR - 3RD AVENUE NEAR K3 POLICE STATION	87647	22105	28950	20825	15741	0.000052	0.000108
KOYAMBEDU	265591	66982	87725	63104	47700	0.000158	0.000329
KODAMBAKKAM- RAILWAY STATION NEAR NSK SALAI	62000	15636	20479	14731	11135	0.000037	0.000077
VALASARAVAKKM	59862	15097	19772	14223	10751	0.000036	0.000074
MADURAVAYOL-BRIDGE AT VANAGARAM - AMBATTUR ROAD	104858	26445	34635	24914	18832	0.000063	0.00013
T. NAGAR	104238	26289	34430	24767	18721	0.000062	0.000129
AMBATHUR - THIRUTHANI HIGHWAY	108078	27257	35698	25679	19411	0.000064	0.000134

Table 3. Modified Emission Rate based on vehicular traffic reductions and movements

LOCATION NAME	PM2.5				PM10			
	Pre-Lockdown & Post lockdown 2019,2020,2021	Lockdown 2020	Semi Lockdown 2020	Lockdown 2021	Pre-Lockdown & Post lockdown 2019,2020,2021	Lockdown 2020	Semi Lockdown 2020	Lockdown 2021
		73% Reduction	2% Reduction	76% Reduction		67% Reduction	2% Reduction	84.5% Reduction
ALANDUR	0.000018	0.000005	0.000014	0.000004	0.000037	0.000012	0.00003	0.000006
PORUR	0.000056	0.000015	0.000045	0.000013	0.000116	0.000038	0.000092	0.000018
KILPAUK	0.00004	0.000011	0.000032	0.00001	0.000083	0.000028	0.000067	0.000013
ANNANAGAR	0.000052	0.000014	0.000042	0.000013	0.000108	0.000036	0.000087	0.000017
KOYEMBEDU	0.000158	0.000043	0.000127	0.000038	0.000329	0.000109	0.000263	0.000051
KODAMBAKKAM	0.000037	0.00001	0.00003	0.000009	0.000077	0.000025	0.000061	0.000012
VALASARAVAKKAM	0.000036	0.00001	0.000029	0.000009	0.000074	0.000025	0.000059	0.000011
MADURAVAYOL	0.000063	0.000017	0.00005	0.000015	0.00013	0.000043	0.000104	0.00002
TNAGAR	0.000062	0.000017	0.00005	0.000015	0.000129	0.000043	0.000103	0.00002
AMBATTUR	0.000064	0.000017	0.000052	0.000015	0.000134	0.000044	0.000107	0.000021

5. CONCLUSIONS

In conclusion, the findings of this study shed light on the diverse modal share within the transportation system, with two-wheeled vehicles dominating at 33%, followed by buses at 25%, and three/four-wheeled vehicles and goods vehicles at 24% and 18%, respectively. These statistics underscore the need for a comprehensive approach to transportation planning that considers the varied modes of transport in a region.

Moreover, the study identified Koyambedu as the region with the highest emission concentration of PM2.5 and PM10, signalling potential environmental concerns. The estimated values of 0.000158 g/s-m2 for $PM_{2.5}$ and 0.000329 g/s-m2 for PM_{10} highlight the importance of targeted air quality management strategies in this area. During the semi and lockdown periods the study resulted with the reduction of particulate matter pollution from the pre and post lockdown values.

The substantial decline in $PM_{2.5}$ concentrations by 73% and 76%, respectively, throughout the lockdown periods of 2020 and 2021, demonstrates the efficacy of stringent measures in mitigating the spread of fine particulate matter. Additionally, the findings demonstrate the natural variability of the correlation between human activities and air pollution. The observed correlation between lockdown protocols and reduced levels of pollutants implies that the implementation of focused policies to mitigate air pollution problem is feasible.

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CRediT authorship contribution statement:

RM Narayanan*: Conceptualization, Methodology, Writing-original draft. Correcting draft, Processing and Interpretation of results.
S Laxmipriya: Processing and Interpretation of results.
C Benedict Rosario: Field Work, Data Collection.

Declaration of competing interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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