Assessment of Traffic Related Air Pollution and Ambient Air Quality of Metropolitan Cities (Case Study of Pune City)

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Abstract: - *The rapid growth in motor vehicles activity in India and other rapidly industrializing low-income countries is contributing to high levels of urban air pollution, among other adverse socioeconomic, environmental, health, and welfare impacts. The purpose of the study was to investigate the relation between air quality and traffic with respect to Pune city from Jan 2008 to Dec 2011. Vehicle count and air quality was analyzed. Analytical and statistical method was applied. It was found that the strong correlation of increasing vehicles with nitrogen oxides (NOx), sulphur dioxide (SO$_2$) and suspended particulate matters (SPM). Study shows that there is tremendous growth in vehicles from 2008 to 2011. Particulate matter (PM10), NOx concentrations levels were exceeding standards. Study found that there is increase in SO$_2$ concentration levels. Air quality correlation also analyzed with the fuel types and it was observed that petrol vehicles contribute more pollution than diesel.*

Keywords: *Air pollution, fuel, air quality, vehicle emissions.*

Introduction

Air Pollution:

Air pollution has been aggravated by developments that typically occur as countries become industrialized: growing cities, increasing traffic, rapid economic development and industrialization, and higher levels of energy consumption. The high influx of population to urban areas, increase in consumption patterns and unplanned urban and industrial development has led to the problem of air pollution. Currently, in India, air pollution is widespread in urban areas where vehicles are the major contributors and in a few other areas with a high concentration of industries and thermal power plants. Vehicular emissions are of particular concern since these are ground level sources and thus have the maximum impact on the general population. Also, vehicles contribute significantly to the total air pollution load in many urban areas.

Air pollution in Pune city is an issue of very great concern today. In typical urban environment, air has other substance which in excess of certain proportions could be harmful to human health or vegetation. This could be called air pollution. The quality of air we breathe has deteriorated to a very large extent due to toxic substance like sulphur dioxide(SO$_2$), nitrogen oxide(NOx), carbon monoxide(CO) and particulate matter from many sources like industry, automobiles, power plants, air conditioning equipment etc. However, it is estimated that more than 60% of the air pollution is caused by automobile emissions.

Vehicular Pollution:

It is worth mentioning here that vehicular exhaust are obnoxious and occur at ground level. Vehicular pollution sources are not homogenous, as there is a complete range of technological mix. The mix could be in terms of fuel used – gasoline or diesel or natural gas; or engine type – 2-stroke or 4-stroke and/or a combination of these.

Emissions from Gasoline Vehicles:

Gasoline-powered engines are of two types: 4-stroke and 2-stroke. The exhaust emissions from gasoline-run vehicles consist of CO, HC, NOx, SO$_2$, and partial oxides of aldehydes, besides particulate matters including lead salts. The incomplete combustion of gasoline due to an imbalance in the air-fuel ratio leads to emissions of CO and HC especially from 2-stroke engines. The Nox, however, are formed due to high combustion temperature and availability of oxygen and nitrogen in the combustion chamber, whereas aldehydes result from the partial oxidation of HC. In cities, majority of the pollution is emitted by vehicles consuming gasoline − especially 2 and 3-wheelers, having predominantly 2-stroke engine. The 2-stroke 2- and 3-wheelers require 2 T oil for lubrication of engine, which is carried out through either premixing mode or oil injection system. In either case it is a total loss system, as the oil is burnt along with the fuel. Since the burning quality of mineral based lubricating oil is very poor vis-à-vis gasoline, major fraction of it that enters the engine either remains unburned or burns only partially. This unburned and partially burned oil comes through the exhaust and is responsible for smoke and SPM emission. The studies indicate that 2-stroke engine's exhaust contains almost

15-25% of unburned fuel (Pundir, 2001). In actual practice, the 2-stroke vehicles require 2% concentration of 2 T oil i.e., 20 ml in a litre of petrol and even a modest 1% increase of oil, may lead to 15% increase in SPM besides visible smoke (CPCB, 1999).

Emissions from Diesel Vehicles:

As diesel engines breathe only air, blow by gases from the crankcase (consisting primarily of air and HC) are rather low. Due to its low volatility, evaporative emissions from the fuel tank can also be ignored. The low concentration of CO and un-burnt HC in the diesel exhaust are compensated by high concentration of NOx. Diesel engines also emit smoke particles and oxygenated HC, including aldehydes and odour-producing compounds having high nuisance value. Smoke from diesel engines comes in three different hues – white smoke emitted during cold start idling and at low loads; blue smoke from the burning of lubricating oil and additives; and black smoke, a product of incomplete combustion. Black smoke, the most obvious type of vehicular air pollution, consists of irregular shaped agglomerated fine soot/particulates, the formation of which depends on injector nozzle parameter and type of combustion chamber (direct or indirect injection). Black smoke is a particular problem with diesel engines that are not well tuned, which is often the case in the developing world.

Materials and MethodLiterature

A detailed study was carried out to collect baseline information related to various work done on the subject, methodology used and what were their observations. It includes review of books, journal, website, and magazines to understand the present status of work on traffic related air pollution and air quality and their relation. This step provided framework and basic knowledge for further research.

Site Selection

Two locations Swargate Junction and Karve Road were selected for the analysis of vehicle traffic. The selection site was based on factors like traffic density, pollution status and traffic congestion.

Data Collection

Secondary data was collected from RTO(Regional Transport office), MPCB(Maharashtra Pollution Control Board), PMC, ARAI.

Data Analysis

Vehicle count was taken from data and analyze to obtained percentage of vehicles. Total registered vehicle data was taken from data and analyze to obtained present vehicles. Air Quality is taken and analyze. Statistical methods were used for analyzing data.

$$r = \frac{\sum dxdy}{\sqrt{\sum dx^2 dy^2}}$$

| Value of "r"	Degree of Correlation
$^+_-$ 0.7 to 1	High
$^+0.3$ to $^+_-0.7$	Moderate
0 to $^+_-0.3$	Low

Result and Discussions
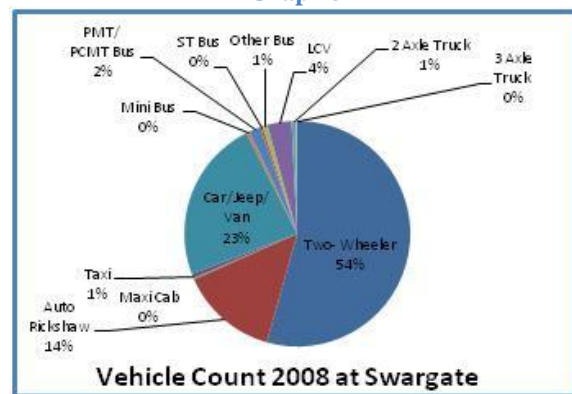
Graph 1

Source: RTO, Pune
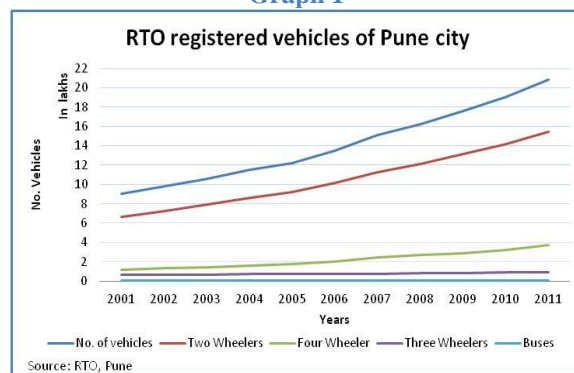
As seen during study Pune's vehicular population going on increasing at faster rate this is due to urbanization of Pune city. City is expanding at faster rate because of industrialization Pune is emerging as IT park city it provides a source of employment and also Pune is major corridor of education which attracts the people from other state migrating to urban areas. Another reason decreasing cost of vehicles (at affordable rate), different companies are also coming with vehicle loans

Graph 2

RTO registered Vehicles of Pune

Source: RTO, Pune
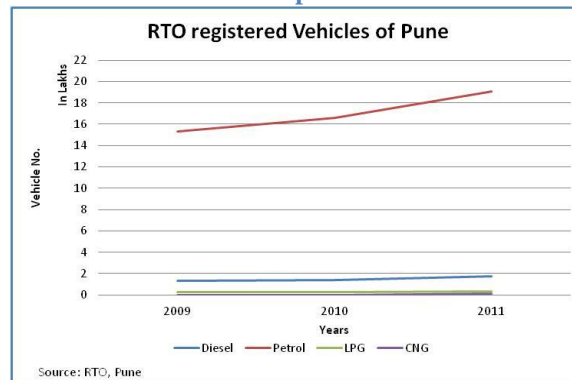
Graph 1 and Graph 2 shows trend of vehicular population. Two wheelers accounted 74% of total vehicular population while three wheelers 3% and 17% vehicle load is of four wheelers. Graph 4 shows RTO registered vehicles according to fuel category. This shows petrol vehicles contribute 91%. This is due to decreasing cost of vehicles(at affordable rate), different companies are also coming with vehicle loans, due to rapid increase in urbanization in Pune it is emerging as a IT Park also which is providing a large employment and Pune is major corridor of Education which attracting people migrating to Pune.
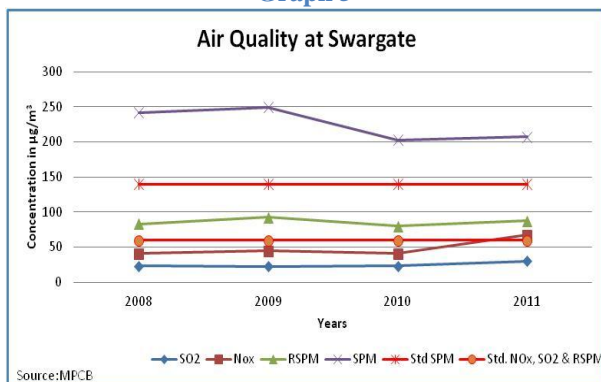
Graph 3

Vehicle Count 2008 at Swargate

Graph 4

Vehicle Count 2008 at Nal Stop
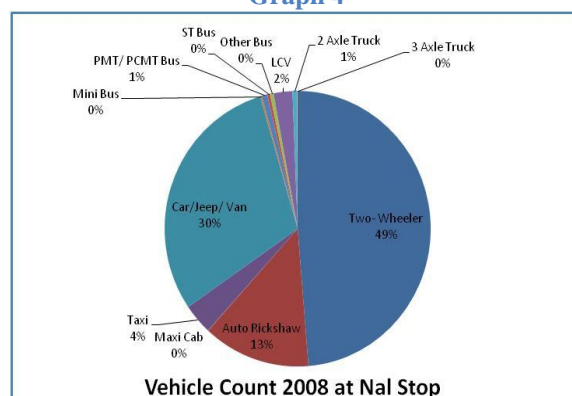
From traffic density Graph 3 and Graph 4 it is observed that at selected locations two wheelers count is around 50%, Auto rickshaw is around 14%, 4Wheelers is 23-30%, buses 1-3% . The numbers of vehicles registered in 2008 were 16, 22,675. While in year 2011 reached to 20, 88,093. The number of two wheelers has gained increase of 45% from 2008 to 2011.
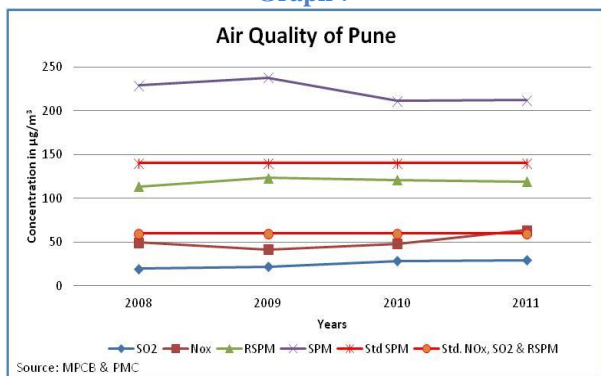
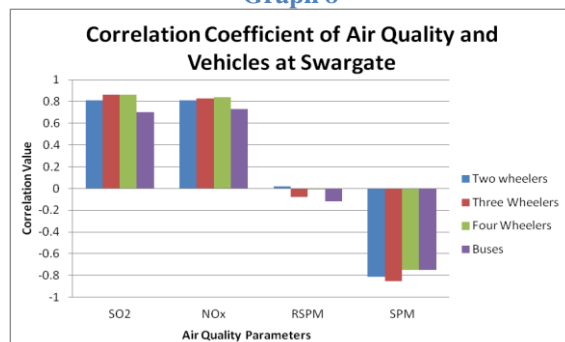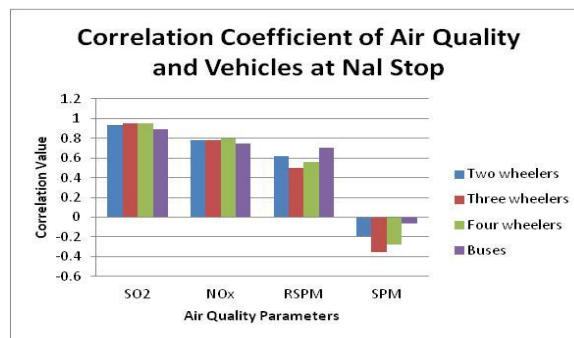**Graph 5**

Graph 6
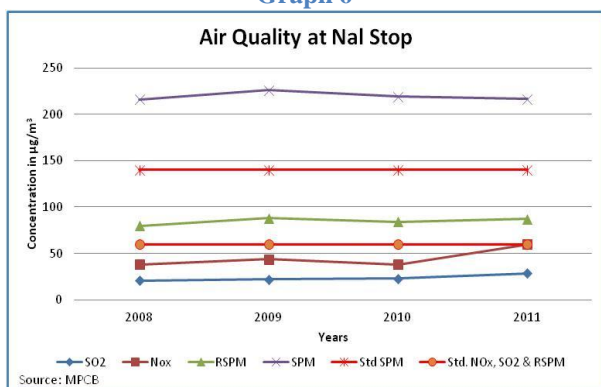
Graph 7

Air Quality of Swargate, Nal Stop and Pune was showed in Graph 5,6 and 7 shows that SPM and RSPM concentration levels at all the location are above the standard limit given by National Ambient Air Monitoring Standards (NAAQS) given by CPCB. NOx concentrations in 2011 were above limit given by NAAQS. SO_2 concentration levels were observed to be within the limits.
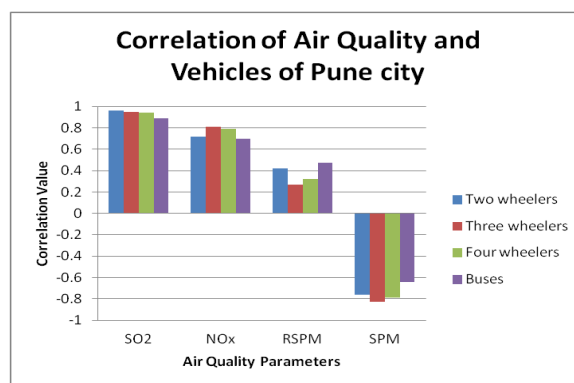
Graph 8

Graph 9

Graph 10

Air Quality and vehicles at Swargate, Nal Stop and Pune was taken under study, statistical analysis was done. The analysis shows in Graph 8,9 &10 that the level of concentration of Suspended Particulate Matter (SPM) at all the locations SPM correlation values observed and it shows low degree of correlation (0.0 to $\pm$ 0.3) at Nal Stop range from -0.05 to -0.34. And high degree of correlation observed at Swargate & Pune. Maximum correlation observed with two wheelers. Table 5 shows correlation values at Swargate, Table 6 & 7 shows correlation values at Nal Stop & Pune respectively. Air quality SPM concentrations was observed to be more than 200μg/m^3 which is high compared to the standard reading (140μg/m^3) given by National Ambient Air Quality Standards (NAAQS) CPCB. Study shows that at Swargate site SPM concentrations range observed between 203μg/m^3 to 250μg/m^3, Nal Stop between 216μg/m^3 to 226μg/m^3, Pune between 211μg/m^3 to 238μg/m^3, maximum concentration of SPM observed in year 2009 at all the locations. This shows that there were external factors acting on it. Improved fuel quality, vehicle design can reduce the effect of SPM on environment. PM 10 emission inventory shows that there was 30.32 kg/km is released in 2011 from vehicles. Petrol vehicles are contributing 69% of total emission.

RSPM was observed to be a low degree of correlation (0 to $\pm$0.3) at Swargate and Pune. However at Nal stop RSPM shows moderate degree of correlation ($\pm$0.3 to $\pm$ 0.7) with vehicles which shows a positive value maximum correlation found with bus. Level of concentration of Respirable Suspended Particulate Matter (RSPM) was observed to be more than 80 μg/m3 which is high compared to standard level (60 μg/m^3) given by NAAQS by CPCB at all the locations. At Swargate RSPM concentration range between 80μg/m^3 to 92μg/m^3, at Nal Stop concentrations range was 80μg/m^3 to 88μg/m^3. Analysis shows that at Pune its ranging from 113μg/m^3 to 123μg/m^3. Which clearly indicates that all concentrations were above the standard level (60μg/m^3) given by NAAQS by CPCB, maximum concentration of RSPM is observed in 2009. RSPM has a very less correlation with vehicles. Air quality data shows RSPM level is above the standard level. It clearly signifies that external factors are leading to emission of RSPM than vehicles viz. road dust, construction activities, and industries. Among vehicles buses are contributing more amount of RSPM emission. However at Nal stop RSPM shows a strong correlation that may be because of more traffic congestion.

Correlation between NOx and vehicles also observed to be high degree of correlation which has range from 0.70 to 0.84. Maximum correlation found with three wheelers and four wheelers. NOx concentrations range observed between 40μg/m^3 to 68μg/m^3, At Swargate concentrations range were 41μg/m^3 to 68μg/m^3, at Nal Stop 38μg/m^3 to 68μg/m^3, Pune range was between 42μg/m^3 to 64μg/m^3 maximum concentration were

observed in 2011 at all the location and it was also above the standard level given by NAAQS. NOx Study shows that increasing vehicles contributes to increase in NOx emission. From emission inventory estimated that in 2011 NOx emission by vehicles was 824 kg/km released and petrol vehicles contributing 89%. Study also shows that petrol vehicles are major polluting than any other fuel. Air quality also shows that NOx concentrations were above the standard level in 2011

Analysis shows that correlation between SO_2 and all vehicles (two wheeler, four wheeler, three wheeler and bus) observed high degree of correlation range from 0.7 to 1.0 correlation(r). Maximum correlation with SO_2 and vehicle was found to be with three wheelers and four wheelers. In air quality SO_2 concentrations were observed to be in range of 22μg/m^3 to 30μg/m^3, SO_2 concentrations were found below standard level (60μg/m^3) given by NAAQS. At Swargate concentrations of SO_2 observed between 22μg/m^3 to 30μg/m^3, at Nal Stop it was between 21μg/m^3 to 29μg/m^3, Pune shows SO_2 concentrations between 20μg/m^3 to 30μg/m^3. This show as vehicles going on increasing there is increase in SO_2 concentrations. Vehicles are one of the major sources of SO_2 emission because of sulphur content in fuel, improper combustion. It is also observed that among the vehicle fuels petrol contributes more SO_2 emission than other, but others are also present in fair quantity as number of petrol based vehicle was more. But the air quality shows the concentrations of SO_2 is well below standard limits that may be because of the dispersion of gas in atmosphere.
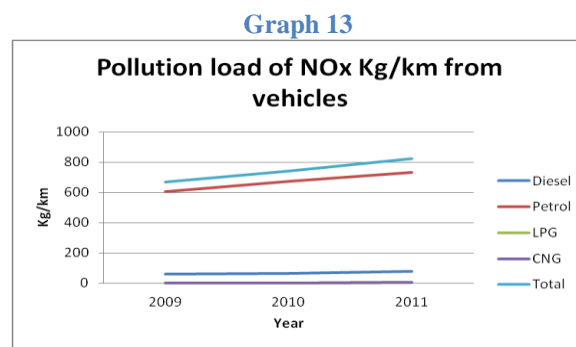
Graph 11
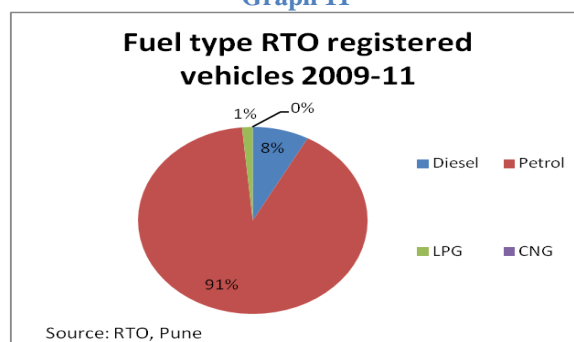
Graph 8 shows the fuel type segregation of Pune city (Source: RTO, Pune). It is observed that in 2009 and 2010 petrol vehicle contributed 91% vehicle growth while diesel contributes 8% and LPG 1%. In 2011 petrol vehicles contributes 89%, diesel 8%, LPG 2% and CNG 1%.

Graph 12
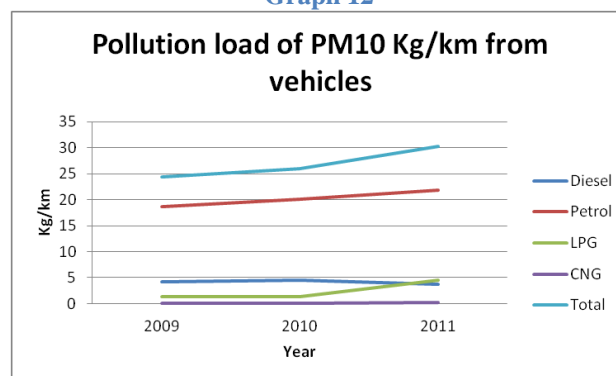
Graph 12 shows estimated pollution load of Particulate Matter (PM 10) emission from different vehicles in Pune City on the fuel basis total estimated emission 30.33 Kg/km in 2011. Petrol vehicles contribution was 69%, diesel vehicle 19% and LPG 12% from 2009 to 2011.

Graph 13

Graph 13 shows a NOx emission of from different vehicles on the fuel basis the maximum emission from petrol vehicles estimated that 91% from 2009 to 2011. In 2011 estimated emission from petrol vehicles observed 89%

Conclusions:

1. At Swargate & Nal Stop vehicles increased was calculated and compared with air quality it was observed that Air quality concentrations at Swargate was more than Nal stop, Although there were more vehicles at Nal Stop than Swargate that could be due to more traffic congestion, more public vehicles and more traffic signals at Swargate than Nal Stop.

2. Correlation studies showed as vehicles increased there was increase in SO_2 and NOx levels. In 2011 it was observed that NOx concentrations were above standard level while SO_2 concentrations were within standard level. At Swargate correlation between SO_2 and vehicles shows maximum correlation with three wheelers and four wheelers i.e. 0.86, with two wheelers it was 0.81 and with bus it was 0.7. At Nal stop correlation was more than Swargate, maximum correlation with four wheelers and three wheeler that was 0.95, two wheeler 0.92 and bus 0.89. It shows that four wheeler and three wheelers have more impact on the SO_2.

3. NOx concentration and correlation with vehicles showed that at Swargate correlation was more than that of at Nal Stop, maximum correlation was found with four wheelers i.e. 0.84 & 0.8 at Swargate and Nal Stop respectively. It shows that four wheeler and three wheelers have more impact on the SO_2 and NOx. NOx emission inventory shows vehicle contributes 94.63% of emissions than any other sources. (Source: Emission inventory report, ARAI)

4. At Nal Stop it was seen that correlation between RSPM and vehicles have maximum with buses i.e. 0.7 followed by 0.62 for two wheelers, 0.56 for four wheelers and 0.5 for three wheelers which indicates that buses were have more impact on RSPM. This could be due to diesel fuel, improper combustion which leads to release of RSPM. PM10 emission inventory shows 53% emission from vehicles combustion of fuel without considering road side dust than any other sources.(Source: Emission inventory report, ARAI)

5. There is dramatic growth in personal vehicles which pushing load on road network and causing traffic congestion and road accidents. Personal vehicles are contributing 90% of total vehicles registered. The average occupancy of two wheelers is 1 and four wheelers is 1.3. Pune has narrow roads in core parts of the city. Due to this fact and lack of public transport, personal mobility using a bike. The same is reflected in exponential vehicle growth and high two wheeler numbers.

6. It is observed that petrol vehicles are contributing more pollution that any other fuel vehicles. And there are 91% petrol vehicle registered from 2009 to 2011 while diesel vehicles were 8%.

7. It is observed that there was increase in CNG vehicles in 2010 to 2011 from 445 to 12858 vehicles. This also increased pollution load from 5 gm/km to 188 gm/km PM10 emission and from 268 gm/km to 6550 gm/km NOx emission.

8. Vehicles have been identified as the major source of air pollutants in metropolitan cities. The reasons for high rates of vehicle emissions include poor fuel quality, high vehicular density, the large number of old vehicles, inadequate I&M system, poor vehicle design, fuel adulteration, improper traffic management, and inadequate mass transport systems.

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ANNEXURE:

National Ambient Air Quality Standards:

Pollutants	Time-weighted Average	Concentration in ambient air		
		Industrial Areas	Residential, Rural & other areas	Sensitive Areas
Sulphur Dioxide (SO$_2$)	Annual Average	80 μg/m^3	60 μg/m^3	15 μg/m^3
	24 hours	120 μg/m^3	80 μg/m^3	30 μg/m^3
Oxides of Nitrogen (NOx)	Annual Average	80 μg/m^3	60 μg/m^3	15 μg/m^3
	24 hours	120 μg/m^3	80 μg/m^3	30 μg/m^3
Suspended Particulate Matter(SPM)	Annual Average	360 μg/m^3	140 μg/m^3	70 μg/m^3
	24 hours	500 μg/m^3	200 μg/m^3	100 μg/m^3
Respirable Particulate Matter(RPM)	Annual Average	120 μg/m^3	60 μg/m^3	50 μg/m^3
	24 hours	150 μg/m^3	100 μg/m^3	75 μg/m^3

Emission Inventory by ARAI

Emission Inventory			
	2006-2010	PM	Nox
2-Wheeler	Scooter 4S	0.015	0.25
	Motorcycle	0.013	0.5
Autorikshaw	3-Wheeler CNG 4S	0.015	0.5
	3-Wheeler Petrol 2S	0.012	0.2
	3-Wheeler LPG 2S	0.13	0.04
	3-Wheeler Diesel	0.091	0.51
4-Wheeler	4-Wheeler-Petrol	0.002	0.09
	4-Wheeler-Diesel	0.015	0.28
	4-Wheeler-LPG	0.002	0.2
	4-Wheeler-CNG	0.006	0.74
	LCVs 4wheeler GC	0.475	2.12
Trucks and MAV	Large Trucks+MAV	0.42	8.63
BUS	Buses-Diesel	0.3	6.53
	Buses-CNG	0	6.21
Source: Emission Inventory analysis, ARAI			