Impact of Control Measures on Vehicular Emissions - A Case Study

Prashant Gargava

Central Pollution Control Board, Parivesh Bhawan, East Arjun Nagar, Delhi - 110 032, India

(Telephone no.: +91-11-2226122; fax no.: +91-11-2217079)

(E-mail: cpcb@alpha.nic.in)

ABSTRACT

The paper presents a case study, on the assessment of likely impacts of various vehicular pollution prevention and control measures, for the capital city of Delhi. The measures include phasing out of 15-year old commercial vehicles; phasing out of leaded petrol; use of CNG as alternate fuel for buses, taxis and three wheelers; and retrofitting of catalytic converters in two and three wheelers. The major pollutants emitted through vehicular sources viz. carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NOx), particulate matter (PM) and lead (Pb) have been considered. The emissions of these pollutants are calculated using number of registered vehicles, average vehicle utilization and corresponding emission factors for different categories of vehicles. A total quantity of about 2945 T/day of the four pollutants (excluding PM) is expected to be emitted, wherein CO (1450.0 T/day) has the maximum contribution of about 49% of the total pollution load. NOx, HC and Pb follow this with daily emissions of 1038.0 T, 458.0 T and 0.85 T respectively. In addition, 134.0 T/day of PM is emitted from heavy-duty diesel driven vehicles. Two wheelers are the major source for HC emissions (39.0%) followed by three wheelers (22.6%), heavy-duty vehicles (19.4%) and passenger cars (17.5%). NOx is emitted mainly from the heavy-duty diesel driven vehicles (almost 95% of the total emissions). These vehicles, along with passenger cars, also account for major share of CO emissions. Cars followed by two and three wheelers are the main sources for Pb emissions. The study reveals that phasing out of leaded petrol should reduce the Pb emissions by 85%. Phasing out of 15-year old commercial vehicles is another good step taken for reducing vehicular emissions in Delhi. This will have sizable reduction in PM and NOx emissions, while retrofitting of catalytic converters in two and three wheelers will have significant reduction in HC emissions. Use of CNG as alternate fuel for buses, taxis and three wheelers appears to be one of the most promising options capable of reducing HC emissions by about 32%. This will also reduce emissions of PM and CO by about 16% and 14% respectively.

1.0 INTRODUCTION

In this age of rapid industrialisation, one of the biggest problems being faced by us is the issue of clean air. Among the various sources contributing to air pollution, the automobile industry has emerged as the largest source of urban air pollution in the developing countries.

Because of their versatility, flexibility and low initial cost, motorized road vehicles overwhelmingly dominate the markets for passenger and freight transport throughout the world. In developing countries, economic growth has triggered a boom in the number and use of motor vehicles. Although much more can and should be done to encourage a balanced mix of transport modes-including non-motorized transport in small-scale applications and rail in high-volume corridors-motorized road vehicles will retain their overwhelming dominance of the transport sector for the foreseeable future.

Owing to their rapidly increasing numbers and limited use of emission control technologies, motor vehicles are emerging as the largest source of urban air pollution, particularity, in megacities. Air pollution levels in megacities such as Bangkok, Cairo, Delhi and Mexico City exceed those in any city in the industrialized countries and contribute to the public health problem (*1*).

Although the vehicular population in Indian metropolitan cities is much less compared to that in developed countries, yet ill-maintained vehicles, outdated engine designs, defective road networks, erratic driving patterns and congestion due to mixed & slow moving traffic are all adding to the air pollution problem. The unprecedented rise in the vehicular population and the resulting problems are challenging tasks. Without timely and effective measures to mitigate the adverse impacts of motor vehicle use, the living environment in the cities will continue to deteriorate and become increasingly unbearable.

Realizing the gravity of the problem various Government Agencies in India have taken/initiated various steps to check vehicular pollution and manage growth of motorized transport for maximum benefit with minimum adverse impact on environment and society. The main components of initiatives include technical measures involving vehicles and fuels, transport demand management and infrastructure & public transport improvements. The focus, in the present paper, is on technical measures only as the other two options, though should go hand–in–hand with the first one, need to be addressed separately.

The paper presents, as a case study, the assessment of likely impacts of various vehicular pollution prevention and control measures, on emissions in the capital city of Delhi. The various scenarios and control options considered in the study are:

i) business as usual;
ii) phasing out of 15-year old commercial vehicles;
iii) phasing out of leaded petrol;
iv) use of CNG as alternate fuel for buses, taxis and three wheelers; and
v) retrofitting of catalytic converters in two and three wheelers

2.0 VEHICLE DEMOGRAPHY

There has been a steady increase in the size and proportion of the urban population in India. The impact of macro-economic policies adopted in 1991, with new industrialisation and trade liberalisation is expected to accelerate the pace of growth of urban population. Unfortunately, there has not been proportional growth in the basic civic services including transport. Urban transport is most expensive infrastructure to be put in place and also to operate and maintain. The direct consequence of this is the increase in personalized vehicles in all the cities.

The total number of vehicles in India has increased from 0.3 million in 1950 to 21.3 million in 1991. About one fifth of the vehicular population in India is concentrated in the major metropolitan cities. The automotive industry in India is presently growing at a rate of 20-30% and it is estimated that the vehicular population would cross 30 million by the turn of the century (*2*).

In Delhi, registered population of vehicles was 0.18 million in 1971, which has risen to 3.2 million by 1996 registering a growth by almost 15 times. There has been steep increase after 1985. The growth of vehicles is depicted in Fig. 1, which indicates that during 1991-96 there was an increase of about 45% in the vehicle population (*3*). Passenger cars have registered maximum increase of about 52% followed by 43% of increase in two-wheelers. The lions share, in the number of vehicles, is of two-wheelers, which are about 66% of the total vehicles (Fig. 2). To estimate the vehicle population for the year 2001, which is the base year for the study, annual growth rate of 10% is used.

3.0 EMISSIONS

The major pollutants emitted through vehicular sources are carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NOx), particulate matter (PM), lead (Pb) and sulphur dioxide (SO_2). The ambient air quality measurements in Delhi indicate that the suspended particulate matter (SPM) and respirable particulate matter (RPM) are most critical pollutants in Delhi, exceeding with the prescribed limits at almost all the monitoring locations and times. However, their concentrations are high even in residential and industrial sources. This essentially implies that many other reasons/sources, including the high background levels and re-suspension of roadside dust, could contribute to their higher levels. However, heavy-duty diesel driven vehicles will emit significant quantity of PM. The levels of CO and NOx have been found to be high in high traffic zones. The levels of Pb were also high, particularly, prior to the use of unleaded gasoline. The SO_2 concentrations are well below the permissible levels. Though the HC are not being monitored regularly, vehicles are the prime source of their emissions. As such, five pollutants viz. (i) CO; (ii) HC; (iii) NOx; (iv) Pb and (v) PM have been considered in the study. With regard to PM emissions, only heavy-duty diesel driven vehicles have been considered.

The emissions are calculated using number of registered vehicles, average vehicle utilization and corresponding emission factors for different categories of vehicles. The average vehicle utilization (Km/day/vehicle) for two wheeler, three wheeler, car, taxi and heavy duty vehicle is taken as 13.5, 120.0, 27.0, 85.0 and 186.0 respectively (*4*). The emission factors for Indian vehicles, provided in Table 1, have been used (*5*).

The estimated emissions of CO, HC, NOx, Pb and PM for different scenarios for the year 2001are depicted in Fig. 3 through Fig. 7 and also discussed in the following sections:

3.1 Scenario 1: Business as Usual

Scenario 1 refers to the 'business as usual scenario', wherein projection of emissions due to vehicular activities are made for the year 2001 without considering any of the pollution prevention and control options. However, varied emission factors corresponding to the year of manufacture of the vehicles have been taken into account while estimating the emissions. The emission estimates for HC, NOx, Pb and CO are provided in Table 2. A total quantity of about 2945 T/day of these four pollutants is expected to be emitted, wherein CO (1450.0 T/day) has the maximum contribution of about 49% of the total pollution load. NOx, HC and Pb follow this with daily emissions of 1037.8 T, 458.1 T and 0.85 T respectively. PM emissions from heavy-duty diesel driven vehicles are about 134.0 T/day.

Two wheelers are the major source for HC emissions followed by three wheelers, heavy-duty vehicles and passenger cars. NOx is emitted mainly from the heavy-duty diesel driven vehicles (almost 95% of the total emissions). These vehicles, along with passenger cars, also account for major share of CO emissions. Cars followed by two and three wheelers are the main culprits for Pb emissions. It may be pertinent to mention here that the Pb emissions, in this case, are estimated assuming if the leaded gasoline would have continued to be in use.

3.2 Scenario 2: Phasing Out 15-Year Old Commercial Vehicles

The continued plying of old vehicles with poor engine design, which are not only grossly fuel inefficient but high polluters, is another factor for the deteriorating air quality. In contrast to the developed countries where the turnover period of vehicles is 6-8 years, in India it is about 20 years. Thus, despite the introduction of newer cleaner vehicles with improved engine design, emissions arising from the older vehicles are still substantial and significant. The magnitude increase in the total vehicular population has also offset the benefits in terms of reduced per capita emission load due to the introduction of tighter emission norms (*2*).

The 15-year old commercial vehicles viz. buses, goods vehicles, three wheelers and taxis are being phased out since December 31, 1998. Hence, emissions in this case are calculated based on the understanding that all the commercial vehicles manufactured before 1986 had stopped operating in Delhi in 2001 (*6*).

Phasing out of 15-year old commercial vehicles will have considerable reduction in NOx emissions (34.7%) and PM emissions (31.5%). The step is also expected to reduce CO and HC emissions by 17% and 13% respectively.

3.3 Scenario 3: Phasing Out Leaded Petrol

Based on the initiatives taken by Central Pollution Control Board, only unleaded petrol is being supplied for all the vehicles in Delhi since September 1998. This has resulted into removal of Pb, a lethal pollutant, from vehicular exhaust. The apprehension that the unleaded petrol would adversely affect the engines and increase the emission of benzene have also been allayed. Necessary steps are being taken to reduce the benzene and aromatic content in the petrol (*6*).

The estimates indicate that use of unleaded petrol should reduce the Pb emissions drastically from 0.85 T/day to 0.1248 T/day, which are almost 85% less than the emissions generated in case of use of leaded petrol.

3.4 Scenario 4: Use of CNG as Alternate Fuel for Buses, Cars, Taxis and Three Wheelers

Natural gas, which is 85-99% methane, has many desirable qualities as a fuel for spark-ignition engines. Clean burning, cheap and abundant in many parts of the world, it already plays a significant role as a motor fuel in Argentina, Italy, Canada, New Zealand, Russia and the United States. There are over one million natural gas vehicles (NGVs) in operation worldwide; Argentina and Italy account for more than 50% of the global fleet. Most of the NGVs in operation worldwide are retrofits, converted from gasoline vehicles. CNG fueled vehicles emit no Pb and produce fewer NOx, CO and HC emissions than gasoline fueled vehicles (*1*).

The Government of India has also taken up the use of CNG, an Eco-friendly fuel, for use of diesel/petrol driven vehicles. The existing fleet of city buses is being replaced with buses having dedicated CNG engines. In addition, many of the three wheelers and taxis plying in Delhi have now been using CNG.

Indian Institute of Petroleum, Dehardun has also developed a kit, which could be utilized for use of CNG in three wheelers. Besides, it also has know-how for operation of cars and buses on CNG. The economics of switching over to CNG fuel will depend upon the cost of retrofitting of CNG kits or dedicated CNG engines and price and efficiency of CNG vis-a-vis gasoline and diesel (*2*). However, the cost-benefit analysis of various options is beyond the scope of this study.

It is assumed that CNG would reduce emissions of HC, CO and NOx from three wheelers by 63%, 71% and 20% respectively (*7* assumed to be 71%, 72% and 17% less as compared to diesel driven buses (*8*). Use of CNG as an alternate fuel appears to be an attractive option with reduction in HC (about 32%), PM (about 16%), CO (about 14%) and NOx (about 11%).

3.5 Scenario 5: Use of Catalytic Converters in Two and Three Wheelers

The catalytic converter is one of the most effective emission control devices available. The catalytic converter processes exhaust to remove pollutants, achieving considerably lower emissions than is possible with in-cylinder techniques. The Indian automotive industry has been developing catalytic converters with their two-stroke engines in association with world's leading catalytic converter manufactures, to meet the 2000 emission norms. Present indications are that the catalytic converter can help to achieve the 2000 norms with durability ranging from 25000 km to 35000 km. However, with higher 'engine out' emissions catalyst conversion efficiency and durability would decrease. Indian Oil Corporation and Associated Cement Company have also developed a novel catalytic converter technology for two-stroke engine application. These catalytic converters could be even considered for retrofitment on existing population of two-stroke engine (*9*). The retrofitting of catalytic converters in two and three-wheelers is expected to reduce CO and HC by 45% and 40% respectively (*10*).

The retrofitting of catalytic converters will have significant impact on HC and CO registering reduction by 25.0% and 13.0% respectively. But two-way converters will not reduce NOx emissions.

4.0 CONCLUSIONS

Following conclusions could be drawn from the study:

(i) Phasing out of leaded petrol has been a good initiative, which is expected to reduce the Pb emissions by 85%.

(ii) Phasing out of 15-year old commercial vehicles is another good step taken for controlling vehicular emissions in Delhi. This will have sizable reduction in NOx and PM emissions.

(iii) Use of CNG as alternate fuel for buses, taxis and three wheelers appears to be an effective option capable of reducing HC emissions by about 32%. This will also reduce PM and CO emissions by 16% and 14% respectively.

(iv) Retrofitting of catalytic converters in two and three wheelers will have significant reduction in emissions of HC.

(v) As all the pollutants can not be controlled using only one of these measures, implementation of all the above options will yield good results.

5.0 LIMITATIONS

The number of vehicles registered in Delhi has been used in the study, as the data on vehicles moving in and out of Delhi from neighbouring towns as well as the vehicles plying in Delhi but registered elsewhere were not available. The emissions from vehicles would increase with the age of vehicles but in the absence of adequate information on actual emissions from old vehicles, the emission estimates were based on the emission factors corresponding to the year of manufacture of the vehicles. With regard to PM, emissions factors are available only for heavy-duty diesel-driven vehicles.

ACKNOWLEDGEMENT

The author is thankful to all those who helped, directly or indirectly, for conducting this study.

REFERENCE

1. Faiz A. et al. (1996) *Air Pollution from Motor Vehicles.* The World Bank, Washington D.C.
2. Chandini T. (1998) *Control of Vehicular Pollution in India: Some Recent Initiatives.* Workshop on Integrated Approach to Vehicular Pollution in Delhi, New Delhi.
3. Ministry of Surface Transport. (1996) *Motor Transport Statistics of India 1996.* Ministry of Surface Transport, Government of India, New Delhi.
4. Das Aditi et al. (1997) *The Automotive Air Pollution Perspective and Potential Abatement Measures*. Indian Journal of Transport Management.
5. Datta S.A. and Sengupta B. (1998*) Air Quality Goals for Delhi - Options to Meet them by Year 2005*. Workshop on Integrated Approach to Vehicular Pollution in Delhi, Delhi.
6. Central Pollution Control Board. (1999) *PARIVESH*, Newsletter. Vol. 6 (i), Delhi.
7. Sharma Rajeev (1999) *Compressed Natural Gas (CNG) - An alternate transport fuel.* Seminar proceedings, Fuel & oil conservation, alternative fuels and pollution control in heavy-duty commercial vehicles, Association of state Road Transport Undertaking & Petroleum Conservation Research Association.
8. Gandhi K. K. and Sharma J. (1998) *Alternative fuels: Approach for pollution reduction in Delhi.* Workshop on Integrated Approach to Vehicular Pollution in Delhi, Delhi.
9. Malhotra R.C. et al. (1998) *Novel Design of Catalytic Converter for Pollution Control from 2/3 Wheelers*. Workshop on Integrated Approach to Vehicular Pollution in Delhi, Delhi.
10. Association of Indian Automobile Manufacturers (1998). *Retrofitment of catalytic converters on in-use vehicles and use of ULP in non-catalytic converter fitted vehicles,* Workshop on Integrated Approach to Vehicular Pollution in Delhi, Delhi.

TABLE 1 Emission Factors for Different Vehicles

Type of Vehicle	Year	Emission Factors (gm/km)				
		CO	PM	HC	NOx	Lead
Car, Jeep and Taxi	Upto 1991	25.00	-	05.00	02.00	0.030
	91-94	19.80	-	02.73	02.00	0.030
	94-95	19.80	-	02.73	02.00	0.008
	95-2000	06.45	-	01.14	01.14	0.0003
	2000-2005	03.16	-	00.56	00.56	0.0003
Two-wheelers	Upto 1991	08.30	-	05.18	00.10	0.008
	91-94	06.49	-	04.50	00.10	0.008
	94-96	06.49	-	04.50	00.10	0.002
	96-2000	05.00	-	04.32	00.10	0.002
	2000-2005	02.40	-	02.40	00.10	0.0002
Three-wheelers	Upto 91	12.00	-	07.00	00.26	0.019
	91-94	12.00	-	07.00	00.26	0.019
	94-96	12.00	-	07.00	00.26	0.005
	96-2000	08.10	-	06.48	00.26	0.005
	2000-2005	04.80	-	02.40	00.26	0.0004
Buses and	Upto 91	12.70	3.0	02.10	21.0	-
Goods	91-96	12.70	3.0	02.10	21.0	-

TABLE 2 Emission Estimates for Scenario 1

S. No.	Vehicle Type	Vehicle Population	Average Vehicle Utilization (Km/day/vehicle)	Total Vehicular Movement (Km/day)
1	Two wheeler	28,04,180	13.5	3,78,56,430
2	Three wheeler	1,27,240	120.0	1,52,68,800
3	Car	10,20,820	27.0	2,75,62,140
4	Taxi	22,000	85.0	18,70,000
5	Bus + goods vehicle	2,59,840	186.0	4,83,30,240

S. No.	Vehicle Type	Total Emissions (t/day)				
		CO	PM	HC	NO_X	Pb
1	Two wheeler	254.1	-	178.8	3.7	0.194
2	Three wheeler	160.5	-	103.8	3.9	0.192
3	Car	441.2	-	80.5	44.8	0.432
4	Taxi	30.8	-	5.7	3.0	0.030
5	Bus + goods vehicle	563.4	134.0	89.3	983.3	-
	Total	1450.0	134.0	458.1	1037.8	0.848

LIST OF FIGURES

Figure 1 Growth of vehicles in Delhi

Figure 2 Vehicle population in Delhi

Figure 3 Estimated CO emission for different scenarios

Figure 4 Estimated HC emission for different scenarios

Figure 5 Estimated NOx emission for different scenarios

Figure 6 Estimated Pb emission for different scenarios

Figure 7 Estimated PM emission for different scenarios

LIST OF TABLES

Table 1 Emission Factors for Different Vehicles

Table 2 Emission Estimates for Scenario 1

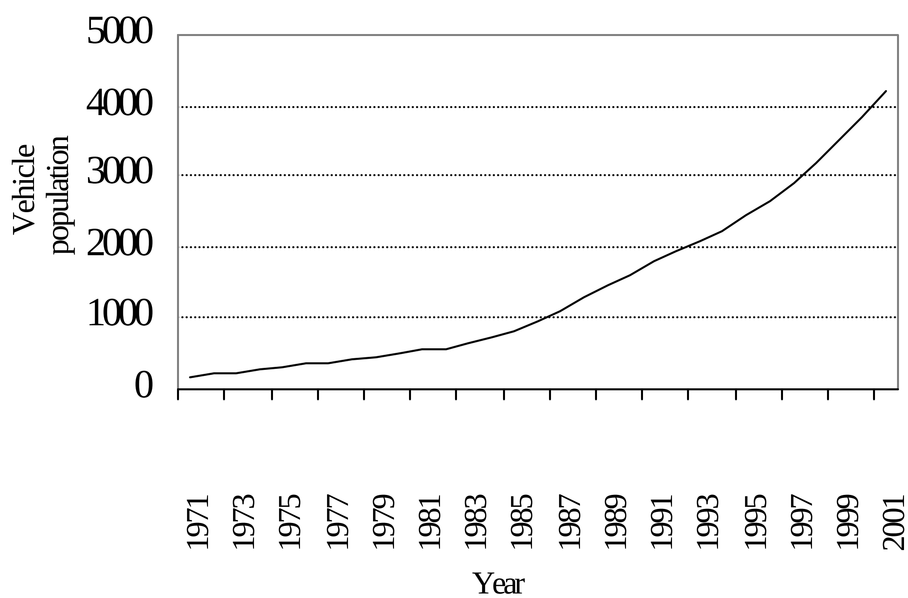

Figure 1 Growth of vehicles in Delhi

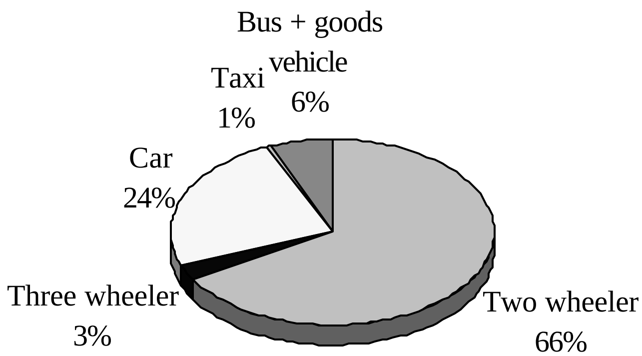

Figure 2 Vehicle population in Dellhi

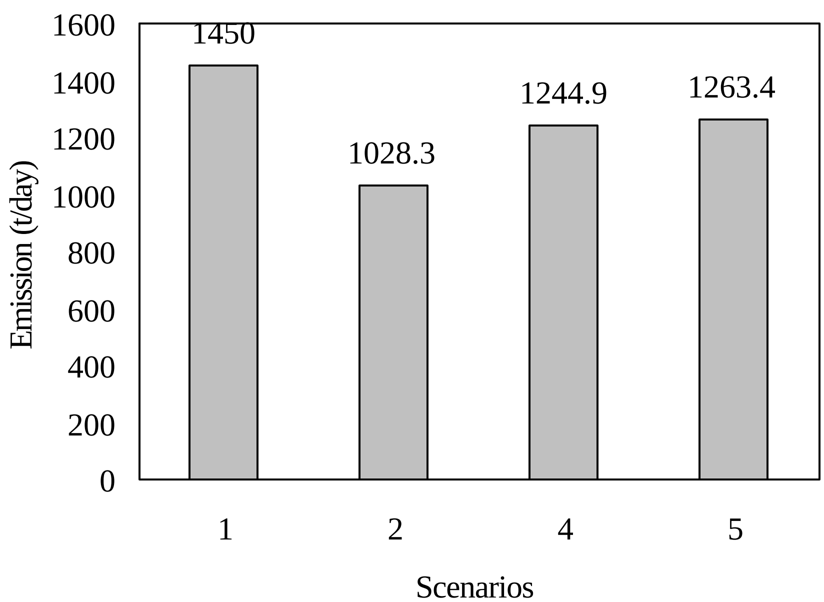

Figure 3 Estimated CO emission for different scenarios

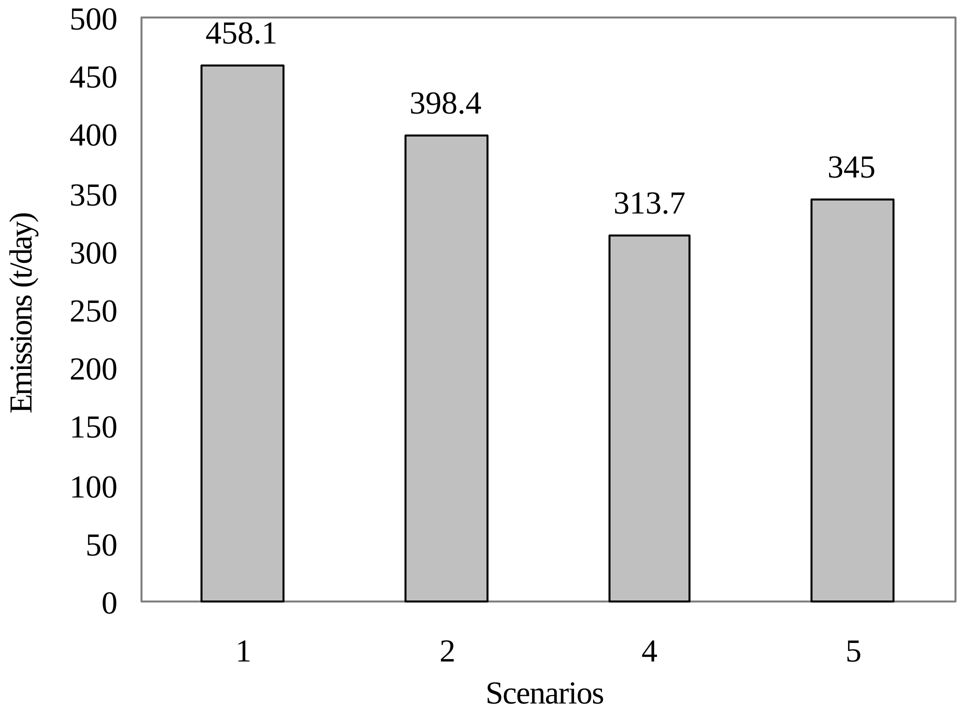

Figure 4 Estimated HC emission for different scenarios

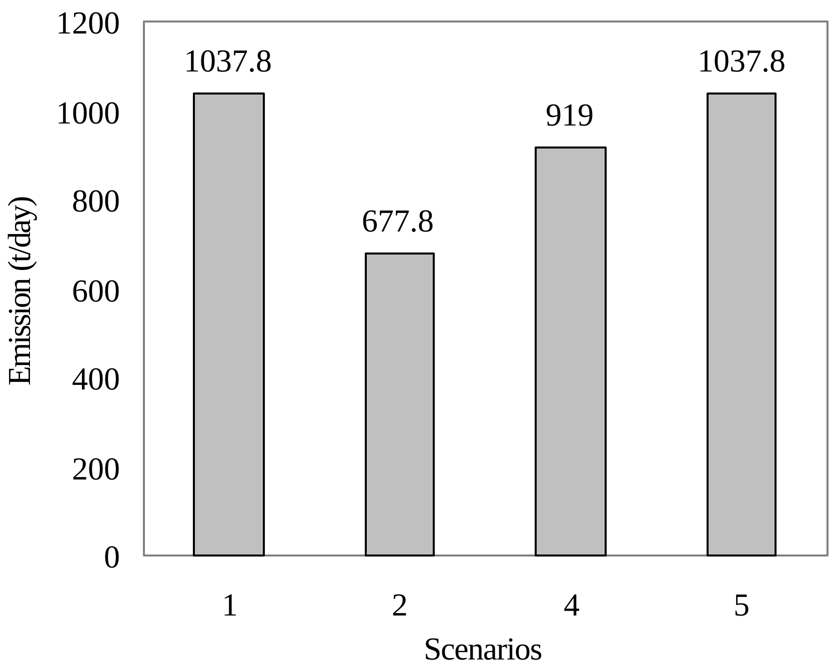

Figure 5 Estimated NOx emission for different scenarios

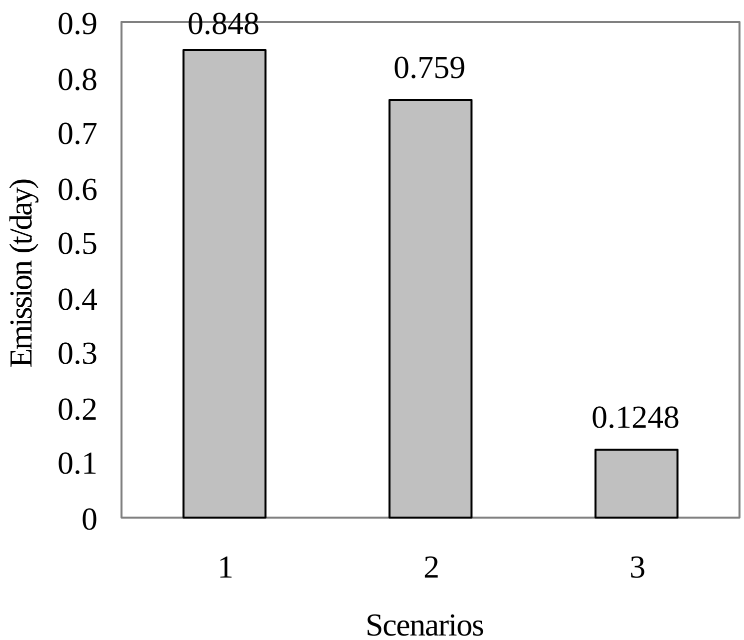

Figure 6 Estimated Pb emission for different scenarios

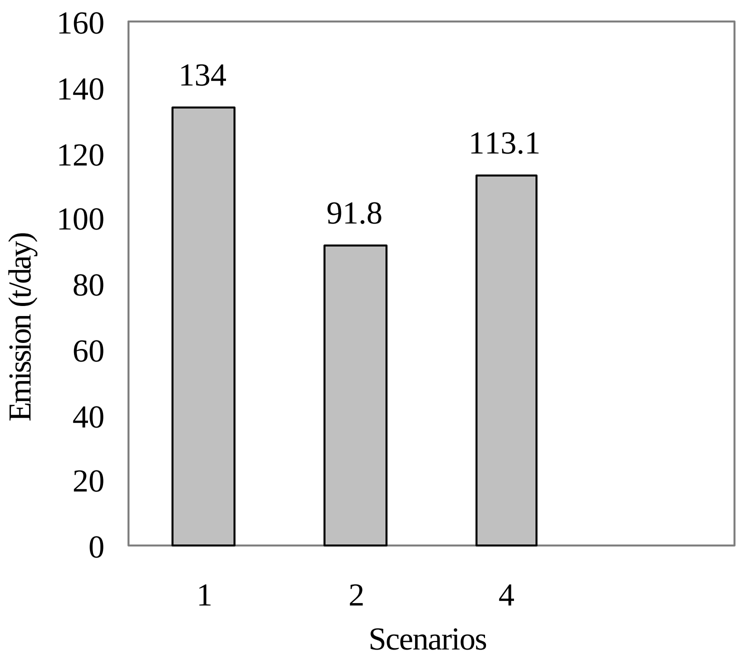

Figure 7 Estimated PM emission for different scenarios