Road Side Emission Testing Program

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Clean Air and Sustainable Environment Project
Department of Environment
Dhaka-1207

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Abbreviations and Acronyms

AR (P/O)	= Auto Rickshaw run on Petrol/Octane
AR (CNG)	= Auto Rickshaw run on CNG
AQ Cell	= Air Quality Cell
Bus (CNG)	= Bus run on CNG
Bus (D)	= Bus run on Diesel
C/Mic (P/O)	= Car/Microbus run on Petrol/Octane
C/Mic (CNG)	= Car/Microbus run on CNG
CNG	= Compressed Natural Gas
CO	= Carbon Monoxide
CO_2	= Carbon Dioxide
HC	= Hydrocarbon
HSU	= Hartridge Smoke Unit
HPMTMCV(CNG)	= Human Hauler/Pick up/Mini truck/Mini covered van run on CNG
HPMTMCV(D)	= Human Hauler/Pick up/Mini truck/Mini covered van run on Diesel
MB	= Motor Bike
MinB (CNG)	= Minibus run on CNG
MinB (D)	= Minibus run on Diesel
ppm	= Parts per million
%(v)	= Percent by volume
PAH	= Poly Aromatic Hydrocarbon
P/O	= Petrol/Octane
Ta (CNG)	= Taxicab run on CNG
TrCV (D)	= Truck/Covered Van run on Diesel
VOC	= Volatile Organic Compound

Executive summary

Air pollution is one of the serious concerns of public health in major cities of Bangladesh where vehicular emission is one of the largest sources of air pollution. Irregular maintenance of the vehicles, lacking of proper enforcement mechanisms, improper traffic and parking management reducing average traffic speed are responsible for high emission from the vehicles. In view of reducing contribution of air pollution from vehicular emission several policy initiatives including revision of emission standards in 2005 for new and in-use vehicles were undertaken by the Government. The current emission standard for new vehicles is equivalent to Euro-II for Petrol vehicles and Euro-I for diesel vehicles.

Road side emissions testing program has been conducted for collecting emission data to review and analyze the current status of the in-use vehicles emission levels and propose possible revision aligning with proposed Road Transport and Traffic Act (RTTA). The data analysis showed that more than 71.7% Petrol/CNG vehicles emit CO less than 1% and 93% vehicles emit HC less than 1200 ppm and mutually can meet 66% approximately. On the other hand 73.5% of diesel vehicles violate emission standard (65HSU). If we can meet the in-use emission standards through I/M program, in that case more than 20% CO emission and 5% HC emissions reduction from 4W-Petrol/CNG vehicles and 23% Black smoke emission (HSU) reduction from Diesel vehicles can achievable. Inspection/Maintenance (I/M) program has played an important role to reduce vehicle emissions. Generally, diesel engine is worse than gasoline vehicles, but it depends much on how well the vehicle is maintained. Therefore, some guiding principles those need to be considered while moving forward.

1. Introduction

Air pollution is one of the leading causes of mortality and morbidity in major cities of Bangladesh. Rapid economic growth, growing needs for goods and personal transportation have made Bangladesh one of the fastest growing in automobile sector and vehicular emission is also growing in parallel. In the last five years from 2005 the numbers of registered motor vehicles have been doubled whereas the road space remains almost the same (Figure-1). Irregular maintenance of the vehicles, fuel/lube oil adulteration, over loading, lacking of enforcement mechanisms, improper traffic and parking management are responsible for high emission from the vehicles.

Gradual stringent standard is needed to ensure minimum pollution from the mobile sector. It is essential for developing effective strategies to improve urban air quality by controlling the vehicles with excessive emissions systematically and cost-effectively. Therefore, Clean Air and Sustainable Environment (CASE) Project) has taken massive initiatives of vehicle emission testing in four cities i.e. Dhaka, Chittagong Cox's Bazar and Rajshahi from 14 March 2011 to 27 December 2011. The enforcement of current standards a crucial part of environmental regulation – remains weak. Consequently, revisions of the 1997 ECR are needed in order to introduce stricter standards and an amendment of the 1995 ECA is required in order to enforce "the polluter pays" principle for vehicular emissions. A sum of about 781 vehicles has been tested within this period (Table-1). Result of this study will certainly give valuable information to design a realistic plan for emission reduction strategy and to revise the current vehicular emission standards.

2. Objectives

2.1 General objective:

To improve the air quality at major cities of Bangladesh by reducing vehicle exhaust emissions, and reduce the consumption of petroleum-based fuels through the proper maintenance of vehicles. These goals are part of the national vision embodied in the Environment Conservation Act and are especially relevant to international concerns over global climate change.

2.2 Specific objectives:

1) To assess the emission characteristics of in-use vehicle fleet in different cities;
2) To revise the vehicle emission standards;
3) To determine percent of emission reduction by compliance emission standards;
4) To make sense of regular Inspection & maintenance of vehicles among the owners;
5) To raise public awareness against the mobile air pollution.

3. Methodology and Techniques

In the road side emission testing program, idle CO and HC emissions are measured by gas analyzer for Petrol & CNG vehicles. Carbon dioxide (CO_2) and Air Fuel Ratio (AFR) was also measured to check the dilution of the exhaust gas by the presence of air in the exhaust system or during sampling. On the other hand, the parameter measured from diesel engine vehicles was the smoke emission (smoke opacity) under free/snap acceleration test and finally converted to HSU.

Smoke opacity meter measurement principle on light turbidity procedure and Exhaust gas analyzer measurement principle on non-dispersive infrared (NDIR). The emission inspection test is completed in the following phases: a) Test equipment set-up b) Vehicles are in warmed condition c) Execution test and d) Reporting of result.

4. Overall scenario of emission characteristics in different cities

Dhaka and Chittagong have enough infrastructures for CNG fuelling whereas Cox's Bazar and Rajshahi is out of CNG network. Most of the light duty vehicles in Dhaka and Chittagong run on CNG while the local vehicles in Cox's Bazar and Rajshahi usually use petrol/octane or diesel. Trucks, in all places, were found to use diesel. Engine condition of heavy duty vehicles (minibus, bus, trucks, etc) seemed to be at the worst because of aging, lack of maintenance, driving pattern, overload etc. Good number of old minibuses using diesel are still seen plying on streets in Dhaka city. Trucks are rare in

Dhaka city during daytime due to bar on their access. But this type of barrier is not present in Chittagong, Cox's Bazar and Rajshahi. Most of the trucks tested under this program were found very old and high emitters of black smoke. Motorbikes usually use petrol/octane as fuel and not in good condition on the point of emitting emissions. Approximately more than 90% Passenger Car/ Taxi/ Microbus/Van /Jeep/Pick-up are operated by CNG. It is also observed that most of Maxi and Human haulers are run by CNG and pollute les. However, few years before these kind of vehicles run by Diesel fuel and more than 90% vehicles emitted higher than 80 HSU.

It couldn't collect manufacturing year of a big portion of vehicles for the absence of valid documents with the drivers. However, a snap of age distribution of vehicles that could be managed is provided in Table 2. For taking emission data, we face some problem due to considerable amount of exhaust pipe is either broken or in the middle of vehicles where testing probe/sensor can not be reached.

5. Road Side Emission Data Analysis and Result

Analysis of Petrol/CNG vehicular Emissions:

Idle CO Emissions:

i) About 71.7% of the petrol and CNG cars, taxis and other light duty vehicles gave idle CO emissions ≤ 1.0 % and 66% vehicles ≤0.5% (Figure.2). Post 2004 vehicles as a group were observed to give generally lower CO than the older vehicles although the correlation coefficient between the CO emissions and vehicle registration year was very poor and it is $R^2 = 0.001$ (Figure-03)

ii) The 4-stroke petrol auto-rickshaws and Motor Cycles were high emitters of CO as about 36% gave CO below 4.5% and 24% below 3.0% (Figure.4). Though at the survey time it has found some new motor cycles failed to meet the standards but the correlation between the CO emissions and vehicle registration year obtained through linear regression of the data was very poor with correlation coefficient, $R^2 = 0.003$ (Figure-5).

iii) The CNG powered auto-rickshaws are very low emitters of CO. Almost 94% tested in this program had CO less than 0.5 % and 95.5% equal

to or lower than 1.0%. However if we calculate the on the base of present standards what is 3%vol for CO then it showed 100% equal to or lower than the limit (Figure-6). However, some of these vehicles when tested were operating on petrol and were found to be very high emitters of CO.

Idle HC Emissions:

i) About 76% cars/taxis and light duty vehicles had idle HC emissions ≤ 600 PPM, more than 85% vehicles ≤ 800 PPM and more than 93% vehicles ≤ 1200 PPM (Fig-7). Again, there was very poor correlation between the vehicle registration year and idle HC emissions, the correlation coefficient R^2 being 0.00.

ii) 4-stroke engine petrol auto-rickshaws and Motor cycle gave higher idle HC compared to cars. About 71% of these had HC more than 1200 PPM and 41% more than 3000 PPM. Most of these vehicles were operating quite rich.

iii) CNG operated three wheelers as expected gave low HC emissions, 52 % falling below 600 PPM and 68% below 1200 PPM.

About 65% of CNG/Petrol 4-wheel vehicles below both 1%CO (vol) and 1200 PPM HC and 58% vehicles below 0.5% CO (vol) and HC (1000 PPM) emission level. About 63% of CNG/Petrol 4-wheel vehicles below both 1% CO (vol) and 1000 PPM HC regardless vehicles model years.

In-use vehicle emissions standard for 4-wheeler Petrol/CNG vehicles is divided in two categories: before and after 2004 year of registration. The average of CO% after 2004 year of registration is 0.86 and for HC is 400 ppm. On the other hand, the average of CO% before 2004 year of registration is 1.1% (vol) and for HC is 427 PPM. In addition, only 2.3 % difference between post 2004 vehicles (67.3%) and all year vehicles (65%) that can meet the emission standards.

Among the all Petrol/CNG vehicles, the average percentage of CO and HC of Taxi is the lowest and motor cycle is the highest emission emitter (Figure-08 & 09).

Analysis of Diesel Smoke Emissions:

Free acceleration smoke from the different diesel vehicle types are given in Table-2 and are discussed below:

(1) Of all the heavy-duty vehicles, double-decker buses gave the lowest smoke emissions but the number of this kind of vehicle is plying very few than previous.

(2) Only 27% diesel vehicles gave free acceleration smoke lower than 65 SHU and Smoke emission levels of 80 HSU were met by only 28% of diesel vehicles (Figure-10).

(3) Trucks and Oil tankers diesel vehicles are seen to be the worst polluters; only 16% of the oil tankers and 20% of the trucks tested had smoke ≤ 65 HSU.

(4) When all the diesel vehicles tested were considered together, smoke levels of 65, 75 and 80 HSU were met by 27, 27.5 and 28% vehicles, respectively. (Figure-11)

6. Percent of emission reduction by compliance emission standards

On the base of current Road side emission testing data, the following result has found (Calculation procedure is showed as annex-1)

Percentage reduction of CO emission from Petrol /CNG 4 Wheel Cars = 20 % (When Standard = 1.0% vol)

Percentage reduction of HC emission from all Petrol 3/ 4 Wheel Cars =5 % (When Standard = 1200 ppm)

Percentage reduction of HC emission from all 4-S Motor cycle =17 % (When Standard = 3000 ppm)

Percentage reduction of CO emission from Petrol 2/3 Wheel Vehicle = 32.6% (When Standard = 4.5% vol)

Percentage reduction of CO emission from CNG 3 Wheel Vehicle = 0% (When Standard = 3.0% vol)

Percentage reduction of CO emission from CNG 3 Wheel Vehicle = 1.0% (When Standard = 0.5% vol)

Percentage reduction of Black smoke emission (HSU) from Diesel vehicles = 23% (When Standard = 65 HSU)

7. Fuel quality

Introduction of non-leaded gasoline and CNG as a fuel for automobiles, impose ban on the import 2-stroke three wheeler auto rickshaw are very much helpful to improve air quality in Bangladesh. Study showed that gaseous pollutants are not so trouble unlike PM in metropolitan city and these particulate matters are mostly carbonations along with that are responsible for mainly Brick kiln & Diesel vehicles. On the other hand, sulfur in fuel is also responsible for PM and what's more hinders efficient functioning and durability of emission control devices viz. Catalytic convertor. It should be mentioned here that the new vehicle emissions standard for petrol engine is equivalent to Euro-ii standards where sulfur level in fuel below 500ppm. In addition, fuel quality monitoring activities should be enhanced for checking adulteration of fuel/lube oil.

Therefore, it is suggested that vehicle emission standards and fuel quality standards should go hand in hand with tightening of the new vehicle emission standards so that the benefits of the advanced emission control technology adopted in the new vehicles are not lost through poor fuel quality. As CNG is more environmental friendly fuel so it should be switching to CNG vehicles especially in exchange of Diesel vehicles which is responsible for PM producing. It is not only saves our environment also save our money. Therefore, it is suggesting establishing more number of CNG stations in others city where CNG is accessible.

8. Develop framework for compliance and enforcement

Vehicle emission regulations enforcement program is one of the primary components of a vehicle emission control strategy. People expect to protect them and their society from air pollution. Regarding this, though Bangladesh government set up VES however, it is not enough to adopt laws; legislation must be effectively enforced.

Revisions of the 1997 ECR are needed in order to introduce stricter standards and an amendment of the 1995 ECA is required in order to enforce "the polluter pays" principle for vehicular emissions. The vehicles, which do not pass the test in first instance, need not be penalized straight away. Instead, they may be given a timeframe by the enforcement agency for meeting the emission norms after necessary maintenance. If the vehicle has satisfactorily passed the emission test, the enforcement agency may give them a sticker / certificate for a defined period of one year for the light duty vehicles and 6 months for the heavy duty vehicles.

The following general principles govern the application of the Act:

- Compliance with the Act and its regulations is mandatory.
- Enforcement officers throughout Bangladesh will apply the Act in a manner that is fair, predictable and consistent. They will use rules, sanctions and processes securely founded in law.
- Enforcement officers will administer the Act with an emphasis on prevention of damage to the environment.
- Enforcement officers will examine every suspected violation of which they have knowledge, and will take action consistent with this Compliance and Enforcement Policy.
- Enforcement officers will encourage the reporting of suspected violations of the Act.
- Enforcement officers are individuals with that designation under the *Environmental Conservation Act, 1995*.
- At the time that the DG, DoE designates a qualified individual to be an enforcement officer under ECA 1995, to specify limits power that the enforcement officer may exercise.

9. Conclusion and Recommendation

For the CNG auto rickshaw has no HC standards as most HC would be methane. However, on the point of global warming and the Ozone (O_3) precursor, idle HC standards might be considered at upcoming revision. In addition, CO standards for CNG vehicles and HC standards for 4-wheler Petrol/CNG should be more stringent. More than 23% of black smoke from Diesel vehicles, 20% of CO from 4 wheel vehicles and 32% reduction of HC emission from Petrol 2/3 Wheel Vehicles could be reduced through meeting the emission standards. As only 2.3 % difference between post 2004 4-wheel Petrol/CNG vehicles (67.3) and all year vehicles (65%) that can meet the emission standards and also correlation coefficient between emissions and vehicle years was very poor. So the standards could be same for all 4-wheel Petrol/CNG vehicles. Among the all Petrol/CNG vehicles, the average percentage of CO and HC, Motor cycle is the highest emission emitter and it is about 5 times than others.

The emission standards for diesel vehicles were phased in three stages over a period of time. The reasons are that vehicle owners and mechanics time to meet the new requirements. However, the survey data showed that there is no improvement of diesel vehicles emissions and more than 73% diesel vehicles violet the emission standards (65 HSU). Therefore, strict enforcement is essential for maintained at acceptable low level emissions especially motor cycle and diesel vehicles in the urban areas. In this regard, AQ Cell staff should be trained up through this ongoing Road side emission testing program and this program should be continue through the right way that tackle air quality and increase public awareness of air pollution issues. In use vehicle emission standard, part D what is standard for diesel vehicles should be merge part F due to the time frame already expired.

Road side emission testing experiences offer the following recommendations regard to pollution control from the vehicle sector:

- Massive awareness program on Vehicular Emissions Standard, maintenance of vehicles and emission impact on health to be undertaken very soon all over the country.

- In-use vehicle emissions standards should be revised and strict enforcement is essential for maintained the emissions standards.

- Old diesel minibuses, buses and trucks to be dumped.

- Adequate infrastructure to be built in major cities for the emission testing or checking.

- All vehicles should be tested both at port of entrance and at places of registration.

- Adequate infrastructure for maintenance of vehicles to be developed

- AQ Cell staff should be trained up through this ongoing Road side emission testing program. Practice of QA/QC should be adopted for

  increasing reliability of tests and minimizing false passes. More realistic system based on dynamometer tests is to be developed in the long run.

- Establish more number of CNG stations in others city where CNG is accessible.

- Sulfur level in petrol fuel should below 500ppm for matching the new vehicle emissions standard which is equivalent to Euro-ii standards.

- Campaigns like “No Pollution Week/Pollution month” should be taken up by the city corporation with DoE to increase awareness for I&M.

10. Annex

Annex-1:

Percentage reduction of CO emission from Petrol /CNG 4- Wheel Cars

CO Range		% of Vehicle
0.0	0.5	66.5
0.5	1.0	4.7
1.0	1.5	4.2
1.5	2.0	2.8
2.0	2.5	3.3
2.5	3.0	4.2
3.0	3.5	4.2
3.5	4.0	2.4
4.0	4.5	3.3
4.5	5.0	0.9
5.0	5.5	0.9
5.5	6.0	1.4
6.0	6.5	0.0
6.5	7.0	0.5
7.0	7.5	0.0
> 7.5		0.5

Weighted average of CO concentration = $\sum(CO)_i.N_i/\sum N_i$

Where $(CO)_i$ = mean value of CO concentration in the ith range above std%CO

Ni = Percent vehicles giving more than std% CO emission in the ith range.

Ni= 28.8%

Weight average CO of failed vehicles = 90.45/28.8=3.14

Percentage reduction of CO emission from Petrol /CNG 4 Wheel Cars= (3.14-1.0)*28.8/3.14 = 20 % (When Standard = 1.0% vol)

11. Figure

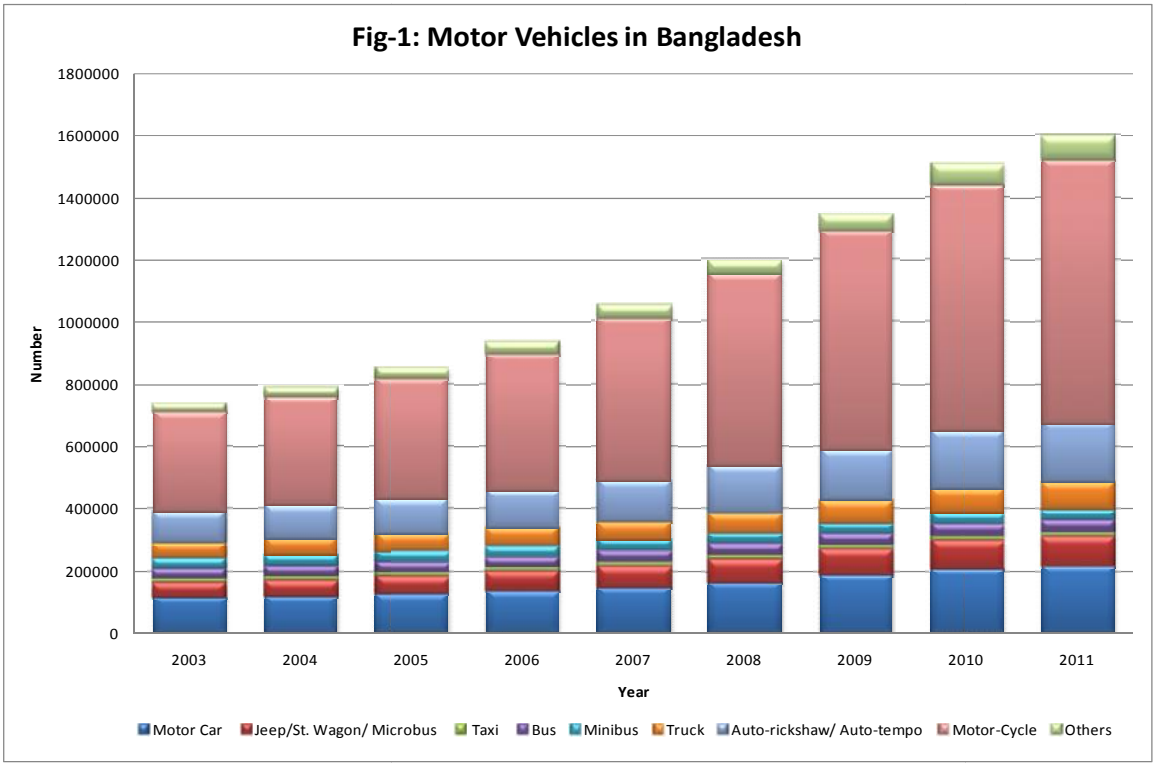
Fig-1: Motor Vehicles in Bangladesh
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
Number
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year
Motor Car
Jeep/St. Wagon/ Microbus
Taxi
Bus
Minibus
Truck
Auto-rickshaw/ Auto-tempo
Motor-Cycle
Others

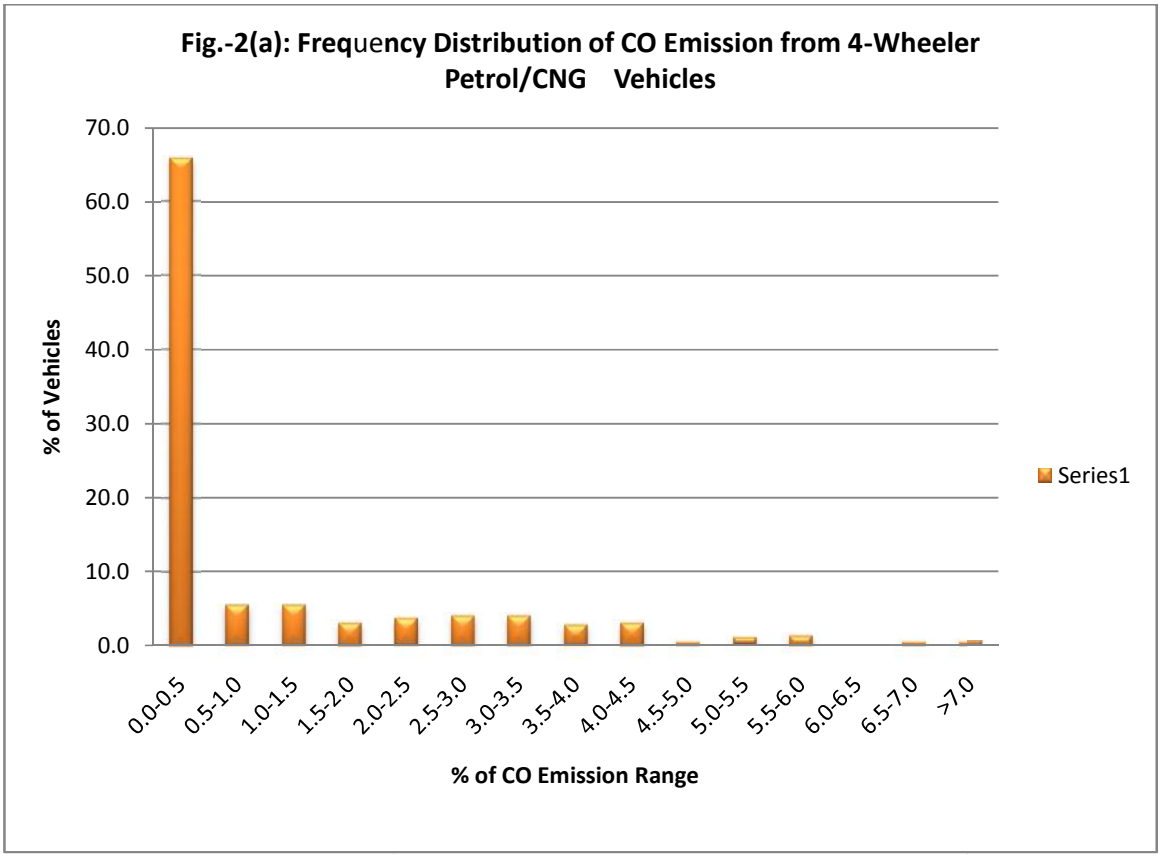
Fig.-2(a): Frequency Distribution of CO Emission from 4-Wheeler Petrol/CNG Vehicles
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
% of Vehicles
0.0-0.5
0.5-1.0
1.0-1.5
1.5-2.0
2.0-2.5
2.5-3.0
3.0-3.5
3.5-4.0
4.0-4.5
4.5-5.0
5.0-5.5
5.5-6.0
6.0-6.5
6.5-7.0
>7.0
% of CO Emission Range
Series1

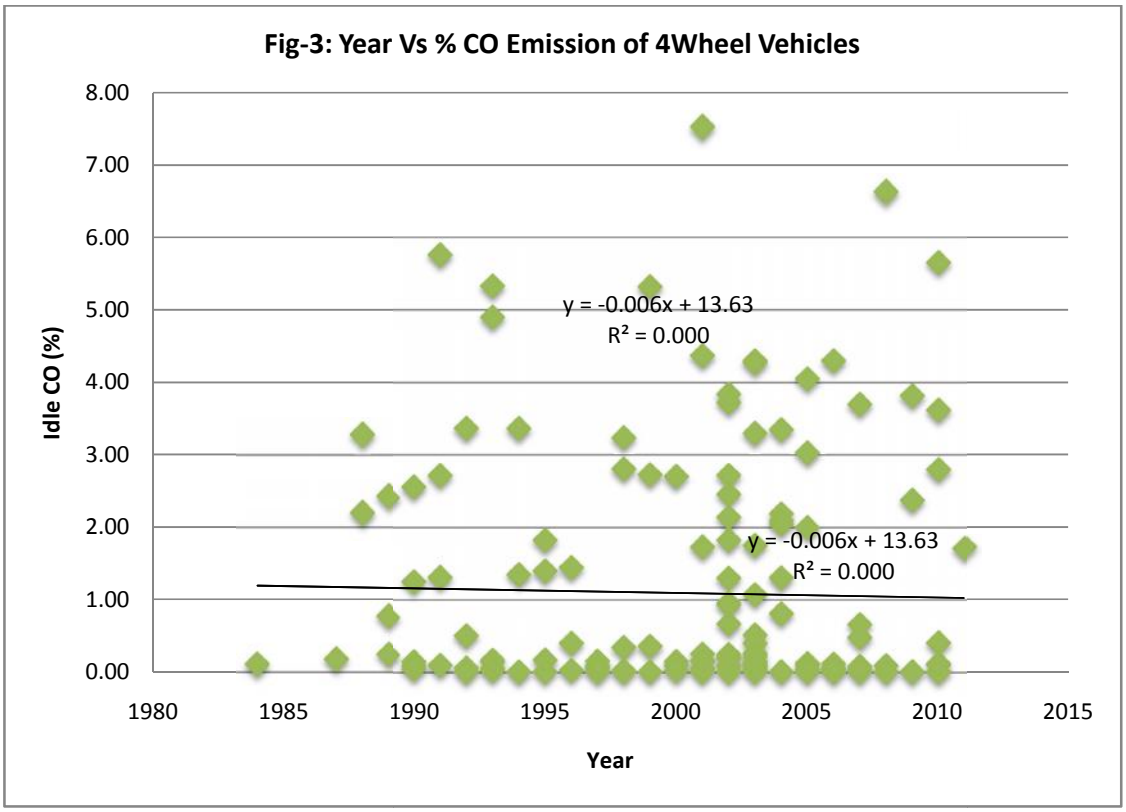
Fig-3: Year Vs % CO Emission of 4Wheel Vehicles
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Idle CO (%)
y = -0.006x + 13.63
R² = 0.000
y = -0.006x + 13.63
R² = 0.000
1980
1985
1990
1995
2000
2005
2010
2015
Year

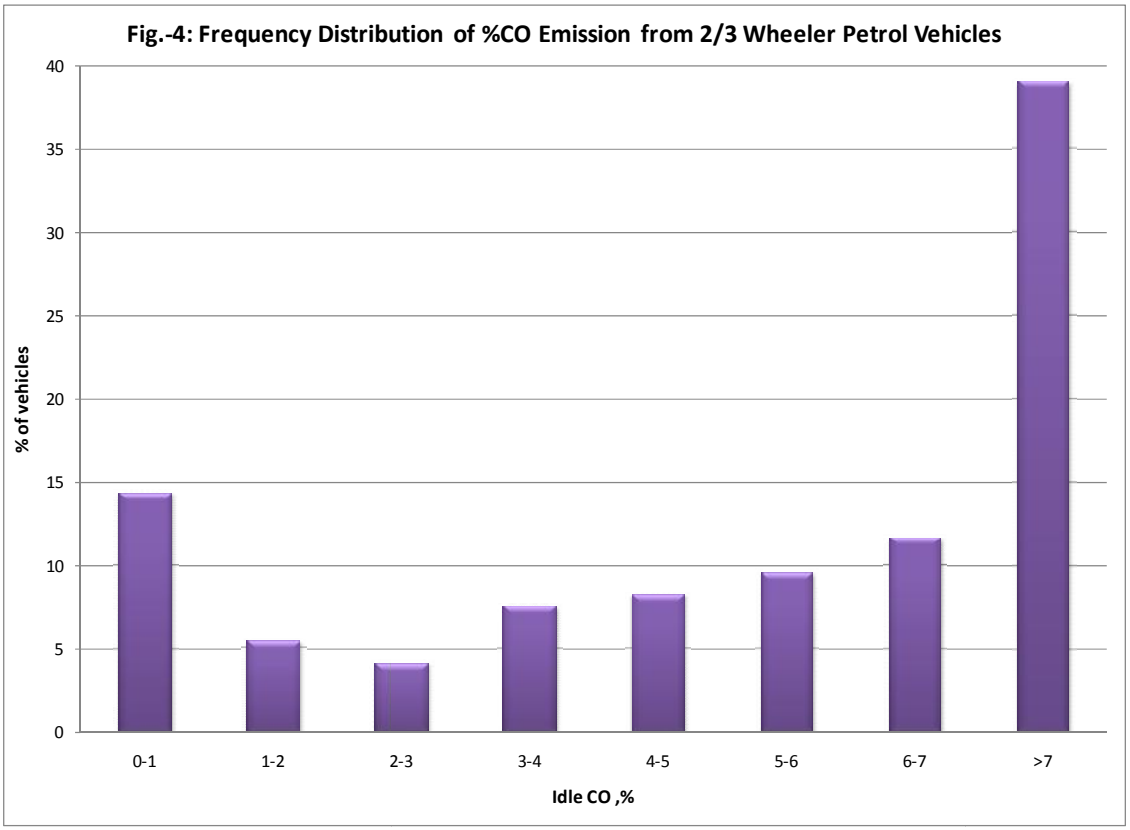
Fig.-4: Frequency Distribution of %CO Emission from 2/3 Wheeler Petrol Vehicles
40
35
30
25
20
15
10
5
0
% of vehicles
0-1
1-2
2-3
3-4
4-5
5-6
6-7
>7
Idle CO ,%

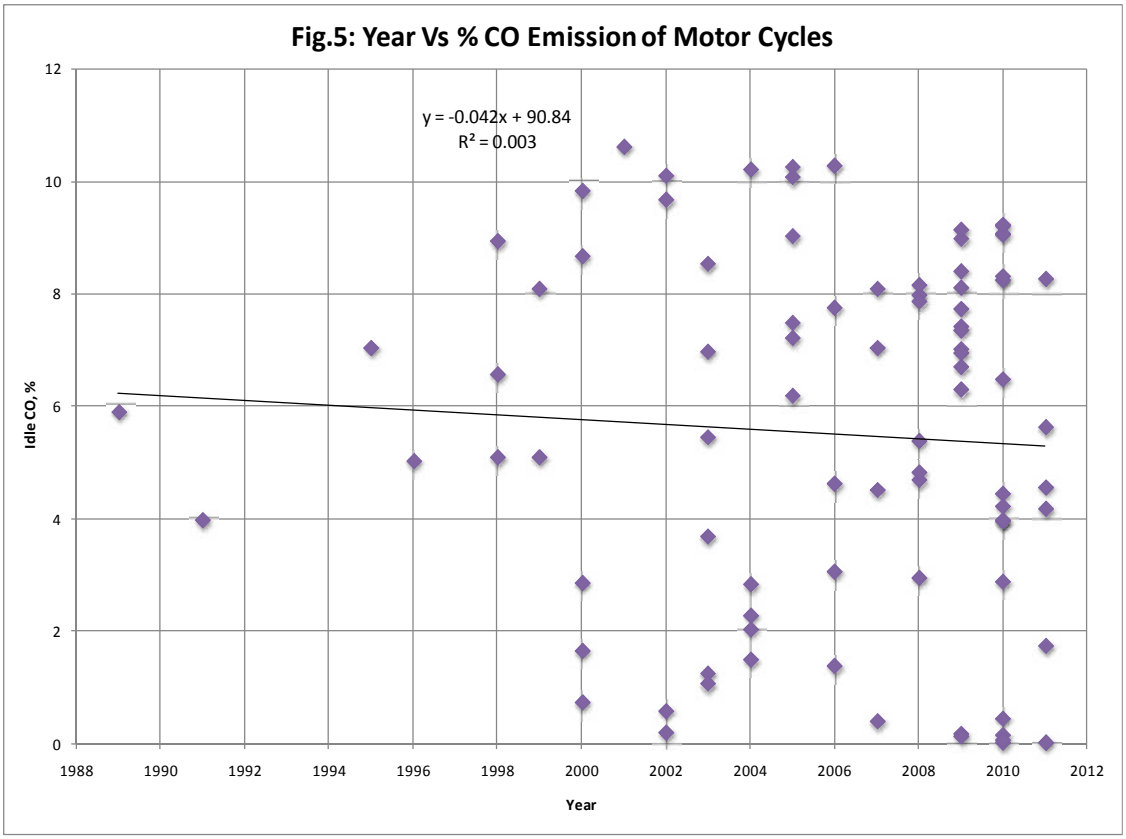
Fig.5: Year Vs % CO Emission of Motor Cycles
y = -0.042x + 90.84
R² = 0.003
Idle CO, %
Year
0
2
4
6
8
10
12
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

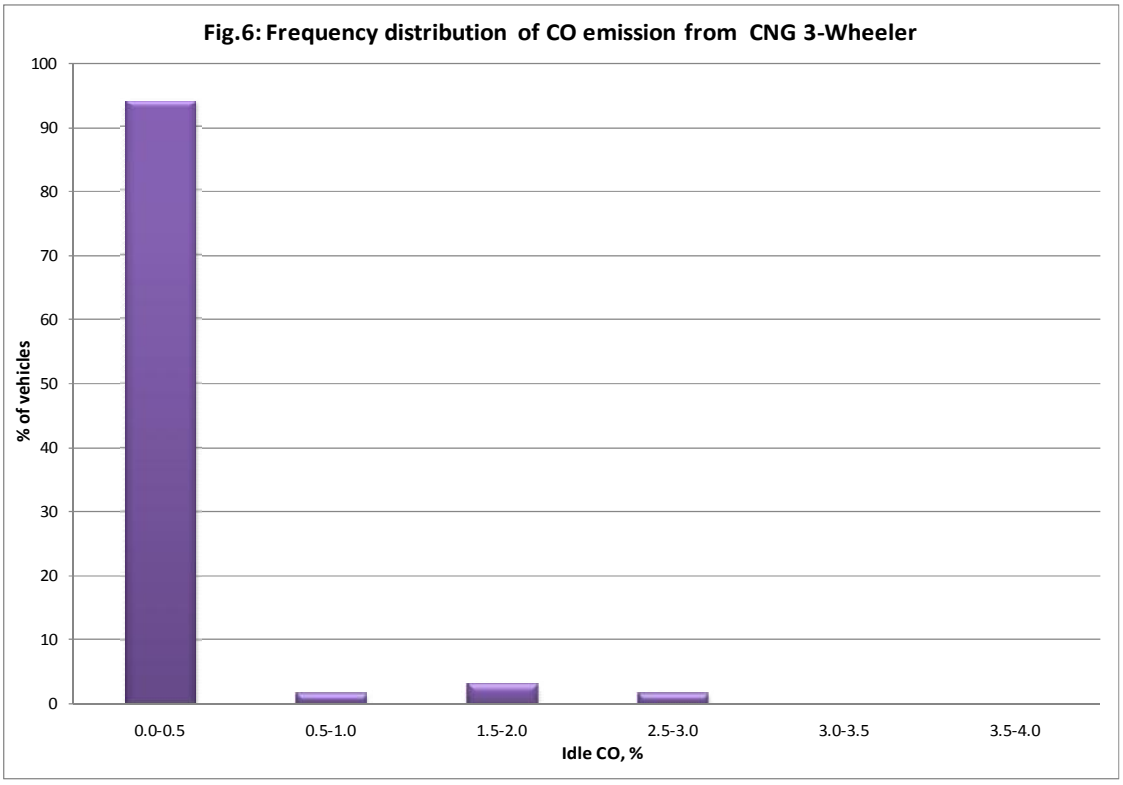
Fig.6: Frequency distribution of CO emission from CNG 3-Wheeler
% of vehicles
Idle CO, %
0
10
20
30
40
50
60
70
80
90
100
0.0-0.5
0.5-1.0
1.5-2.0
2.5-3.0
3.0-3.5
3.5-4.0

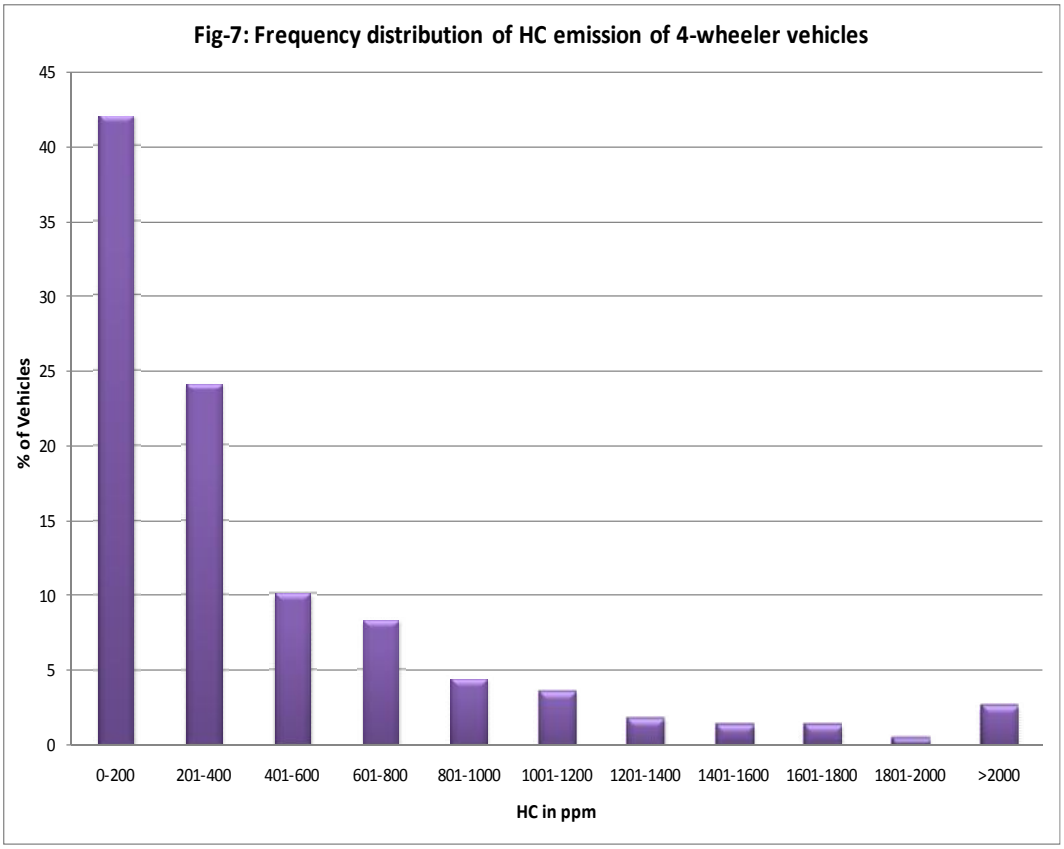
Fig-7: Frequency distribution of HC emission of 4-wheeler vehicles
45
40
35
30
25
20
15
10
5
0
% of Vehicles
0-200
201-400
401-600
601-800
801-1000
1001-1200
1201-1400
1401-1600
1601-1800
1801-2000
>2000
HC in ppm

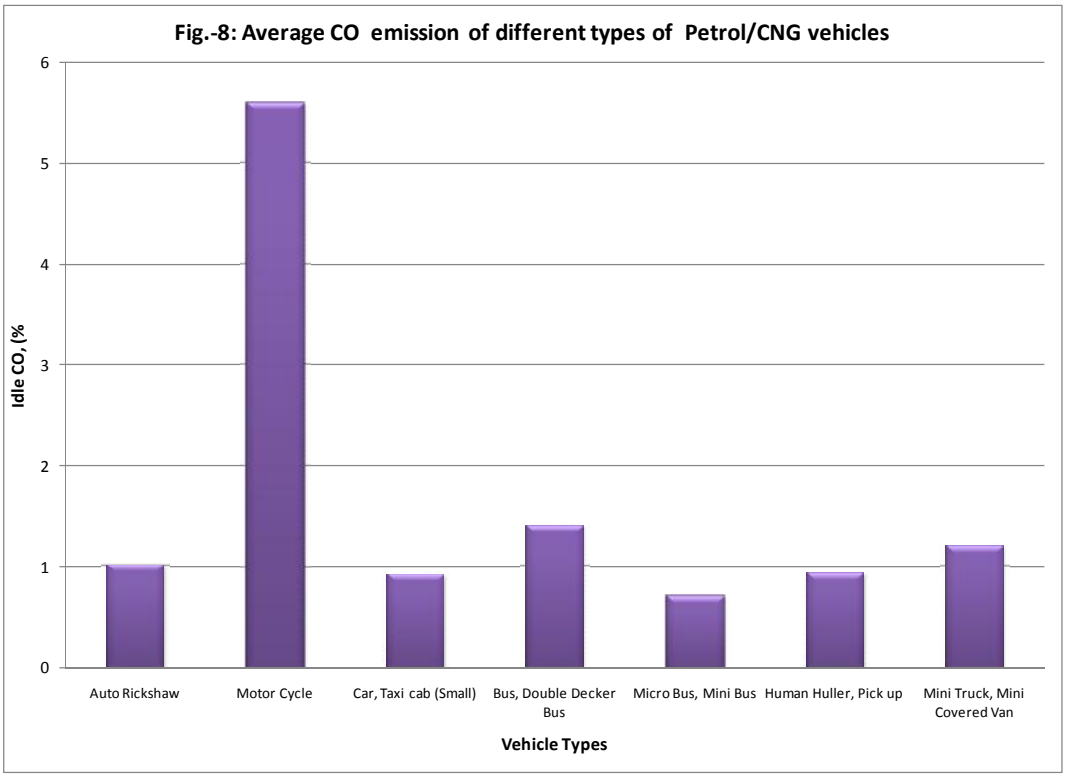
Fig.-8: Average CO emission of different types of Petrol/CNG vehicles
6
5
4
3
2
1
0
Idle CO, (%
Auto Rickshaw
Motor Cycle
Car, Taxi cab (Small)
Bus, Double Decker Bus
Micro Bus, Mini Bus
Human Huller, Pick up
Mini Truck, Mini Covered Van
Vehicle Types

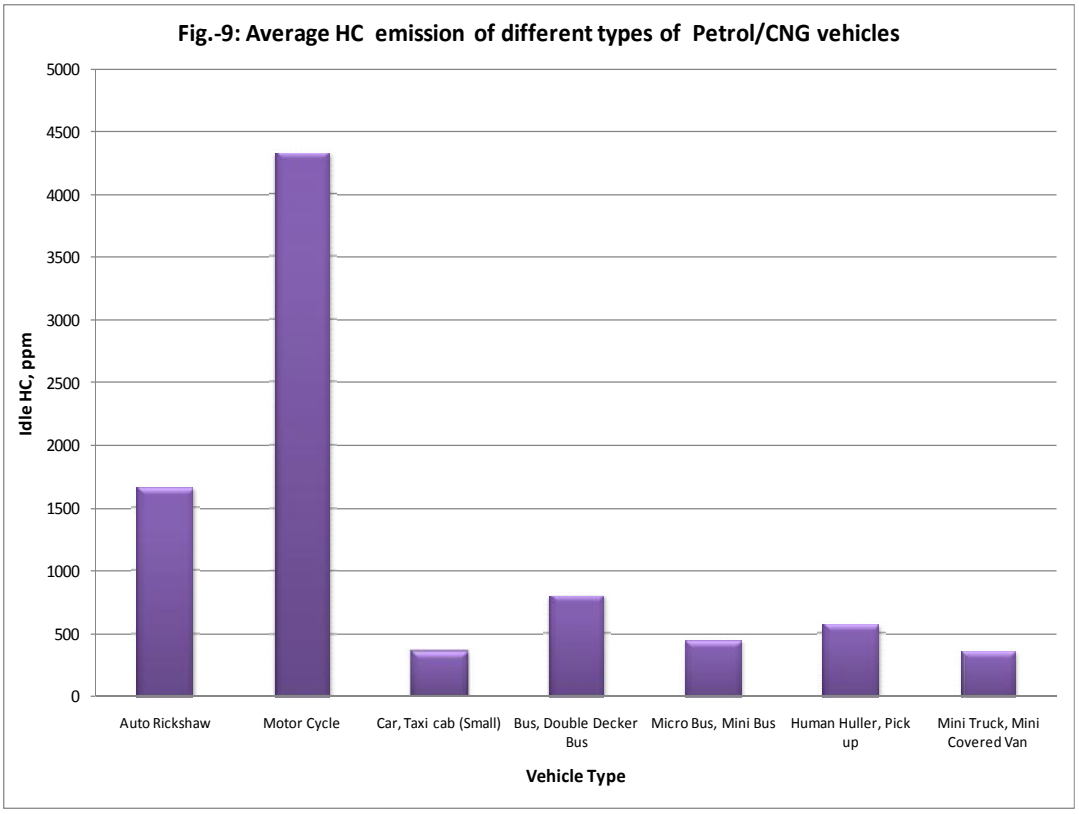
Fig.-9: Average HC emission of different types of Petrol/CNG vehicles
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Idle HC, ppm
Auto Rickshaw
Motor Cycle
Car, Taxi cab (Small)
Bus, Double Decker Bus
Micro Bus, Mini Bus
Human Huller, Pick up
Mini Truck, Mini Covered Van
Vehicle Type

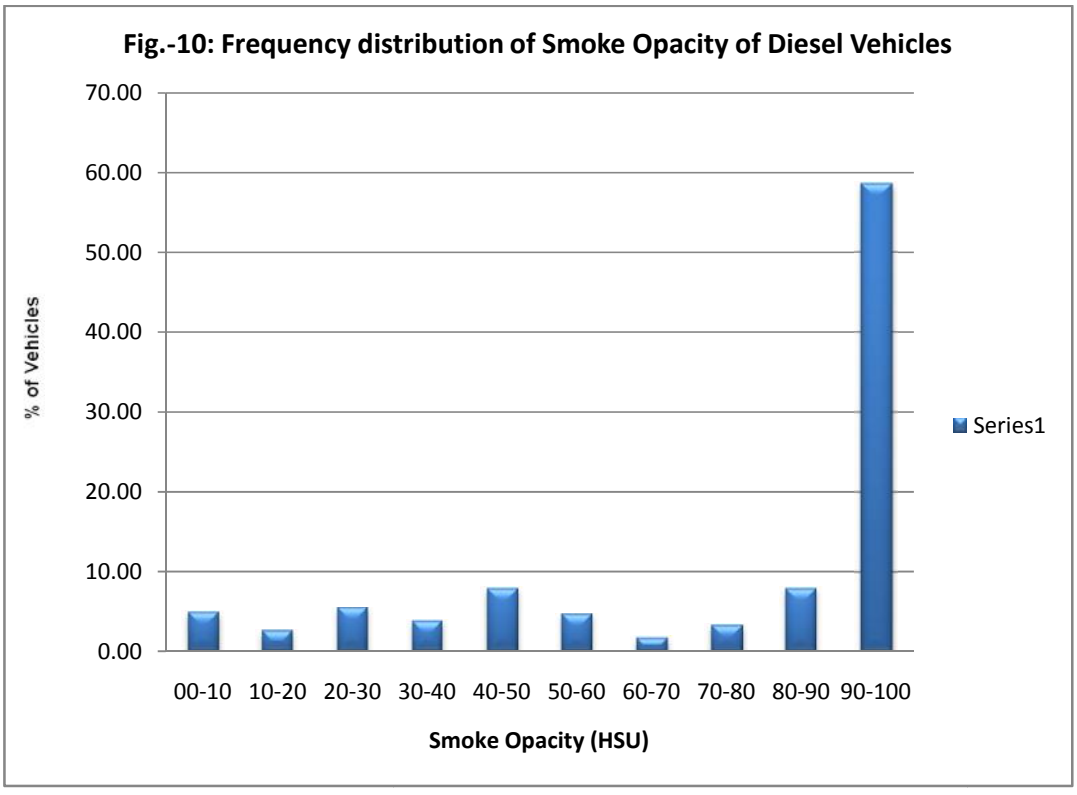
Fig.-10: Frequency distribution of Smoke Opacity of Diesel Vehicles
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
% of Vehicles
00-10
10-20
20-30
30-40
40-50
50-60
60-70
70-80
80-90
90-100
Smoke Opacity (HSU)
Series1

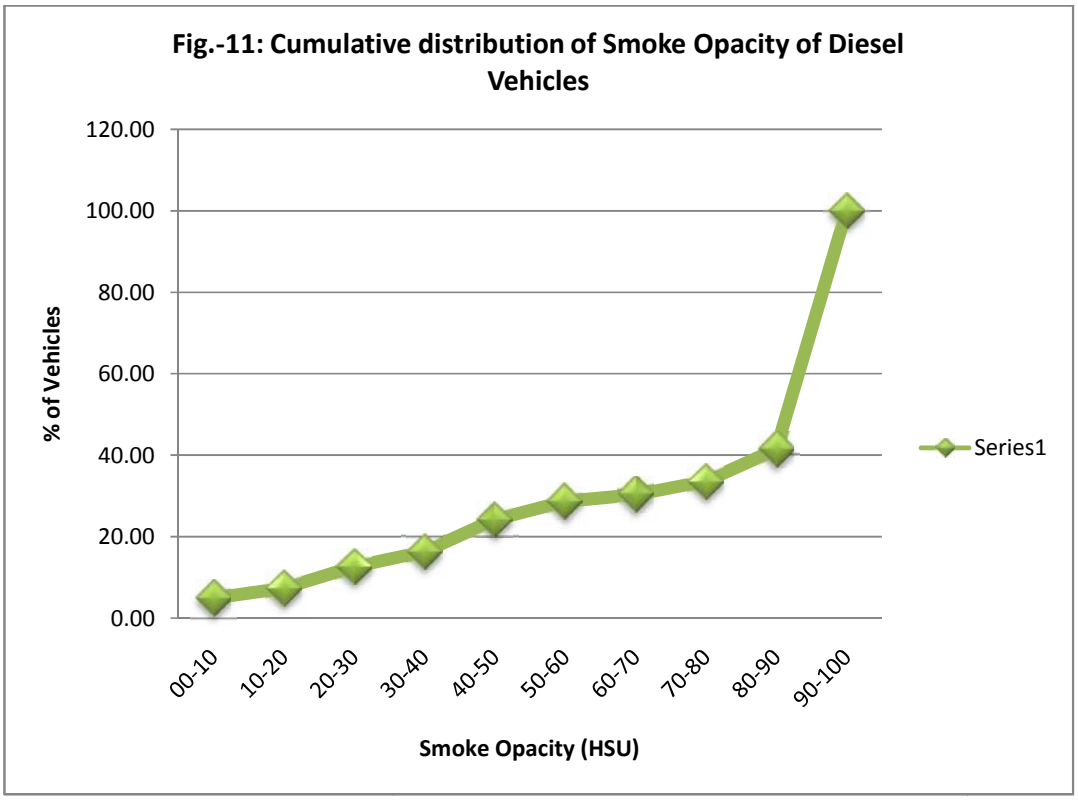
Fig.-11: Cumulative distribution of Smoke Opacity of Diesel Vehicles
120.00
100.00
80.00
60.00
40.00
20.00
0.00
% of Vehicles
00-10
10-20
20-30
30-40
40-50
50-60
60-70
70-80
80-90
90-100
Smoke Opacity (HSU)
Series1

12. Table

Vehicle Type	Number of vehicles tested
Petrol vehicles (Idle CO & HC emissions measured)	
Passenger Car/ Taxi	13
Bus/Mini Bus/Microbus	6
Van /Jeep/Pick-up	1
Auto-rickshaw	13
Motorcycle	154
Total Petrol vehicles	187
CNG vehicles (Idle CO & HC emissions measured)	
Passenger Car/ Taxi	82
Bus/Mini Bus/Microbus	79
Van /Jeep/Pick-up	74
Auto-rickshaw	93
Total CNG vehicles	328
Diesel vehicles (Free acceleration smoke opacity measured)	
Bus and Mini bus	109
Truck	77
Light and medium duty vehicles	80
Total Diesel vehicles	266
Total vehicles	781

Table -1: Category-wise number of tested Petrol/CNG/Diesel vehicles

Petrol/CNG Vehicle	≤1990	1991-1995	1996-2000	2001-2005	2006-2011	Blank*
Passenger Car/ Taxi (95 nos.)	8	13	6	28	13	16
Bus/Microbus/Van /Jeep/Pick-up (160 nos.)	5	11	19	52	25	48
Auto-rickshaw (106 nos.)	0	0	0	57	10	39
Motorcycle (154 nos.)	5	2	12	26	68	41

Table-2: Age distribution of tested Petrol/CNG Vehicles

Diesel Vehicle	≤1990	1991-1995	1996-2000	2001-2005	2006-2011	Blank*
Double Decker bus/bus/ mini bus (109 nos.)	2	2	8	30	11	56
Truck (77 nos.)	14	1	4	6	11	41
Light/medium duty vehicles (80 nos.)	1	9	5	9	33	23

Table-3: Age distribution of tested Diesel Vehicles