

Estimation of Idle Emissions from the On-Road Vehicles in Dhaka

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Abstract

Vehicle emission is a major source of air pollution in Dhaka. Old fleet, lack of maintenance, improper traffic and parking management, overloading, fuel adulteration etc. are responsible for high emissions from the vehicle sector. In this study, vehicle emissions have been measured on-road in Dhaka using an Automotive Gas Analyzer and Smoke Opacity Meter to determine the existing vehicle emission scenario in the city. Concentrations of carbon monoxide (CO) and hydrocarbons (HC) in the emissions from CNG/gasoline vehicles, and opacity of the emissions from diesel vehicles were measured. The results were compared with the corresponding national limit values. It was found that all types of CNG vehicles performed very well with more than 80% satisfying the corresponding limit values. Private cars ranked at the top in performance among the CNG/gasoline vehicles. Diesel vehicles were found as the worst polluters in the vehicle sector; emissions from about 75% of the diesel vehicles had opacity more than 65 HSU, the national limit value for emissions from diesel vehicles. Motor cycles were also highly polluting; 60% of the motor cycles emitted CO and HC concentrations higher than the respective national emission limit values.

Keywords: Air Pollution; Vehicle; Emission; Opacity; Idle Emission Test.

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1. Introduction

Air pollution has become a serious concern for public health in many urban areas of Bangladesh [1,2]. Annual averages of fine particulate matter (PM_{2.5}) concentrations in the air of Dhaka during 2013 to 2014 were found about six times greater than the standards for PM_{2.5} in Bangladesh [3]. Higher pollution scenarios usually happen in dry season (November - April), which poses great threat to the human health in the country. About 92000 early deaths from the exposure to air pollution throughout the country of

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Bangladesh in 2010 were calculated [4], out of which about 13100 deaths were estimated in Dhaka alone.

Vehicle emission is one of the major sources of air pollution in the city [5]. Irregular maintenance, inadequate enforcement, improper traffic and parking systems, overloading, etc. are responsible for high emissions from vehicles in the city. The growth of vehicles in Dhaka is also high. Statistics from the Bangladesh Road Transport Authority (BRTA) show that the number of vehicles in Dhaka has increased by about 67% in the last eight years [6]. However, in spite of this surge in vehicle numbers in the city overall contribution of this sector to air pollution has decreased for some control measures being taken and implemented by the Government of Bangladesh. The emission standards for new and in-use vehicles were set in 2005. Two-stroke three-wheeled baby taxis which were one of the main contributors to the air pollution of Dhaka were driven out from the city from the 1st January 2003. It was estimated that $PM_{2.5}$ concentration in Dhaka was decreased by about 41% as a result of this removal of those two-stroke baby-taxis [7]. The introduction of cleaner fuel compressed natural gas (CNG) to vehicle sector in early 90s and its massive usage from early 20s also helped reduce particulate emissions from the vehicle sector in Dhaka. The reforms in the vehicle sector have accordingly altered the source contributions to $PM_{2.5}$ concentrations in the city. Latest apportionment study conducted with the data from 2010-2012 under the Clean Air and Sustainable Environment (CASE) project of the Department of Environment (DoE) attributed about 58% of fine particulate matter concentration in Dhaka to the brick manufacturing industries, 10.4% to vehicles and 15.3% to dust sources [8], whereas the previous apportionment study found 22.0, 36.0 and 24.5 % contributions from these sources respectively [9].

CASE project conducted vehicle emission testing with an aim to assess the existing emission scenario of the in-use vehicles in Dhaka. Idle carbon monoxide (CO) and hydrocarbons (HC) from the gasoline/CNG vehicles and free acceleration smoke opacity of diesel vehicles were measured. Overall 1317 vehicles were tested at 08 hotspots in the city, out of which 815 were CNG/gasoline vehicles and 502 were diesel vehicles. This work is first of its kind in Bangladesh and bears high importance in understanding and managing the vehicle emissions in the country.

2. Experimental

2.1. Emission testing sites

Vehicle emission testing was carried out in 08 different hot-spots of Dhaka City from 2011 to 2015; the spots were chosen in different routes of the city so that vehicles plying to all directions could be tested. The spots were Abdullahpur (Uttara), Joar Shahara (Airport Road), Police Staff College (Mirpur – 14), Taltala (Agargaon), Darussalam (Mirpur), Sobhanbagh (Dhanmondi), Manik Mia Avenue (Tejgaon), and Notun Bazar (Badda) (Fig. 1).



Fig. 2. Instrument for vehicle emission testing.

2.3. Vehicle emission limit values

The emissions standards of different types of vehicles were revised and notified in 2005 by the Government of Bangladesh (gazette SRO# 220-Law/2005). Emission standards of different categories in-use vehicles are provided in Tables 1-2.

Table 1. Emission standards for petrol and CNG driven vehicles registered before September 1, 2004.

Vehicle Type	Test	CO (% v)	HC (ppm)
4-wheeled petrol	Idle Speed	4.5	1,200
All CNG vehicles	Idle Speed	3.0	-
Petrol driven 2-Stroke engine 2 and 3-wheelers	Idle Speed	7.0	12,000
Petrol driven 4-Stroke 2 and 3-wheelers	Idle Speed	7.0	3,000

Note: Idle Speed RPM to be specified by the manufacturer.

Table 2. Emission standards for vehicles registered after September 1, 2004.

Vehicle Type	Test	CO (% v)	HC (ppm)	Lambda (λ)	Smoke Opacity
4-wheeled petrol and CNG vehicles	Idle Speed	1.0	1200	-	-
	No load, 2500-3000 RPM	0.5	300	1.0 ± 0.03	-
Petrol driven 4-Stroke 2 and 3-wheelers	Idle Speed	4.5	1200	-	-
CNG driven 3-wheelers	Idle Speed	3.0	-	-	-
Naturally aspirated diesel vehicles	Free acceleration	-	-	-	65 HSU or 2.5 m^{-1}
Turbo-charged diesel vehicles	Free acceleration	-	-	-	72 HSU or 3.0 m^{-1}

Note: Idle speed RPM to be specified by the vehicle manufacturer.

2.4. Classification of vehicles

Vehicles with great varieties in their fuel-use, capacity, size and weight, manufacturing years, etc. ply on the roads. Because of heavy traffic movement and absence of legal documents (in many cases) with the drivers, it was fairly impossible to collect all the information of the vehicles for a proper classification. With this drawback, the vehicles were primarily classified, for this study, by their fuel use, (1) CNG/gasoline vehicles and (2) Diesel vehicles. Table-3 shows detailed classification and name/type of the vehicles under each class.

Table 3. Classification of the vehicles tested.

Category	Local names of vehicles	Number of vehicle tested
CNG/Octane		
Auto Rickshaw	Auto Rickshaw	144
Bus	Bus, Minibus	67
Car	Private car, human hauler, jeep, laguna, microbus, taxi	243
Light Duty Vehicle	Pickup, minivan, mini truck, mini covered van, delivery van, mini delivery van	118
Motor Cycle	Motor Cycle	243
Diesel		
Bus	Bus, Minibus	158
Truck	Covered Van (heavy duty), Concrete Mixtures, Lorries, Trucks	141
Light Duty Vehicle	Delivery van, human hauler, jeep, leguna, mini truck, maxi, microbus, mini covered/delivery van, pick up, rider	203

2.5. Vehicle number and growth

Steady economic growth and ongoing urbanization in recent years in the county have instigated vehicle numbers to grow fast in the urban areas. It is estimated that the number of vehicles registered in Dhaka alone up to June 2018 is 1.67 times high of the number in 2010. Table 4 shows the number of different types of vehicles registered in Dhaka up to June 2018 [9].

The statistics reveal that the Light Duty Vehicles (LDV) have increased greatly (183%) within the period from 2010 to 2018; human hauler, jeep, leguna, mini truck, maxi, microbus, mini-van, pick up, rider, etc. are within the category of LDV. The increase in Auto Rickshaws, buses and cars were moderate, all of these categories have increased by about 50%. Truck numbers have doubled in the last 8 years; a portion of new heavy duty trucks runs on CNG.

Table 4. Number and increase of different category vehicles registered in Dhaka up to 2010 and up to 2018.

Vehicle category	Registered up to 2010	Registered up to June 2018	% increase
Auto Rickshaw	7664	11467	50.0
Bus	26273	39375	50.0
Car	268829	399808	49.0
LDV	39989	112220	183.0
Truck	26922	56784	111.0
Total	369677	619654	67.6

2.6. Data correction

For a 4-stroke petrol engine, sum of CO% and CO₂% should be 15 or higher and for CNG engine it should be 12 or higher. When the sum of these two gases for an individual test was less, exhaust gas dilution was suspected and the observed CO and HC concentrations were corrected. Similarly, for a 2-stroke petrol engine CO% + CO₂% should be 10 or higher and the concentration of CO and HC were corrected when the sum was less than 10. In all cases corrections were done as per the following equations (Eq.1 to 6),

(a) For 4-S Petrol Engine:

$$CO_{\text{corr}} = CO_{\text{meas}}(\%) \times \frac{15}{[CO\% + CO_2\%]_{\text{meas}}} \% \quad (1)$$

$$HC_{\text{corr}} = HC_{\text{meas}}(\text{ppm}) \times \frac{15}{[CO\% + CO_2\%]_{\text{meas}}} \text{ppm} \quad (2)$$

(b) For 2-S Petrol Engines:

$$CO_{\text{corr}} = CO_{\text{meas}}(\%) \times \frac{10}{[CO\% + CO_2\%]_{\text{meas}}} \% \quad (3)$$

$$HC_{\text{corr}} = HC_{\text{meas}}(\text{ppm}) \times \frac{10}{[CO\% + CO_2\%]_{\text{meas}}} \text{ppm} \quad (4)$$

(c) For 4-S CNG Engines:

$$CO_{\text{corr}} = CO_{\text{meas}}(\%) \times \frac{12}{[CO\% + CO_2\%]_{\text{meas}}} \% \quad (5)$$

$$HC_{\text{corr}} = HC_{\text{meas}}(\text{ppm}) \times \frac{12}{[CO\% + CO_2\%]_{\text{meas}}} \text{ppm} \quad (6)$$

Where CO_{corr} and HC_{corr} are corrected concentration of CO and HC

3. Results and Discussion

3.1. Overview of vehicle performance

The vehicle emission measurements were mainly Dhaka centric as 40% of the vehicles in the country are registered in Dhaka alone, and also for a great portion of populations in the city lives under a threat of increased level of air pollution to which vehicle sector is a big contributor. The emission testing results were compared with the corresponding limit values – the vehicles were tagged with “Passed” when the emission results satisfied the respective limit values and with “Failed” when the results were over the limit values. Table 5 gives an overview of the performance of different category vehicles. The result shows that the auto rickshaws and cars performed very well in respect to the standards set by the Government; 92.3% of the auto rickshaws and 87.8% of the cars could meet the national standards. However, CNG driven bus and light duty vehicles with success rates of 74.5 and 76.7 % respectively should have done further better in consideration of using the cleaner fuel. The performances of motor cycles were found very pale; its performance rate was only 22.2%.

On the other hand, diesel vehicles irrespective of the category performed very poorly. About 84% of the diesel buses and minibuses were found emitting smokes with opacity more than the limit value, while 69% trucks and 58.6% LDVs were unsuccessful in meeting the national limit values (Table 5).

Table 5. Overview of the performances of different category vehicles.

Category	CNG/Octane Vehicles		Category	Diesel Vehicles	
	Number of vehicles tested	% of vehicles passed		Number of vehicles tested	% of vehicles passed
Auto Rickshaw	144	92.3	Bus	158	16.0
Bus	67	74.5	LDV	203	41.4
Car	243	87.8	Truck	141	31.0
LDV	118	76.7	–	–	–
Motor Cycle	243	22.2	–	–	–

3.2. Analyses of vehicle emission data

3.2.1. Idle CO emissions from CNG/Octane vehicles

i. Among the CNG/octane vehicles auto rickshaws were the most effective in meeting the CO regulatory limits. About 83% and 86.0% of them exited emissions with CO concentrations less than 0.3 and 0.6 % (v) respectively (Fig. 3), and about 95.0% of the auto rickshaws emitted CO concentrations less than 2.0 % (v). The existing limit value of CO concentrations for this category vehicle is 3.0 % (v).

- ii. About 70% of the cars emitted CO concentrations less than 0.3 % (v); 77% of them passed the existing limit value of 1 % (v) (Fig. 3).
- iii. Buses performed little better than LDVs with respect to CO emissions – while 77% of the buses emitted CO concentration less than 1% (v), only 63% of LDVs did the same. 82% of the buses contrasted to only 70% of the LDVs exited CO concentrations below 2%(v) (Fig. 3).

Table 6 shows a ranking of the CNG/octane vehicles in terms of their CO emission.

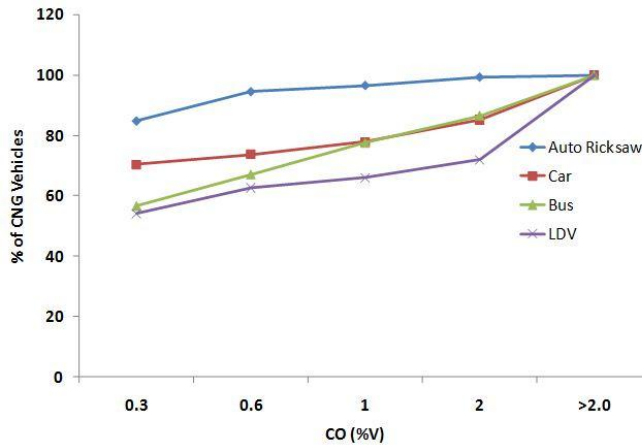


Fig. 3. Cumulative distributions of CNG vehicles for CO emissions.

Table 6. Ranking of CNG/Octane driven vehicles in respect to CO emissions.

Vehicle Category	% of vehicle with CO emission (%v)			Rank
	≤0.6	≤1.0	≤2.0	
Auto rickshaw	94.5	96.5	99.3	1 st
Car	73.7	77.8	85.2	2 nd
Bus	67.2	77.6	86.5	3 rd
LDV	62.7	66.1	72.0	4 th

3.2.2. *Idle HC emissions from CNG/octane vehicles*

- i. There is no national limit value for HC emissions from the on-road CNG three wheeled auto rickshaws; nevertheless, HC concentrations from this type of vehicles were recorded and analyzed to assess their performances. Fig. 4 shows the HC emitting potentials of different category CNG vehicles. It is found that 50.6% of auto rickshaws exited HC concentration ≤ 500 ppm and 72% of these vehicles emitted HC at ≤1500 ppm. The result (Fig. 4) shows the CNG auto rickshaws were not so promising in HC emissions although those were very miser in CO emissions (Fig. 3).
- ii. About 43.2% of buses exited HC concentrations at ≤500 ppm and 87.0% of them emitted HC at ≤1500 ppm. All of the CNG driven buses emitted HC within 3000 ppm (Fig. 4).

iii. Cars and LDVs showed comparatively good results in HC emissions. About 74.3% of cars and 70.5% of LDVs emitted HC concentrations less than 500 ppm, and about 97.5% of these vehicles emitted HC at ≤ 1500 ppm.

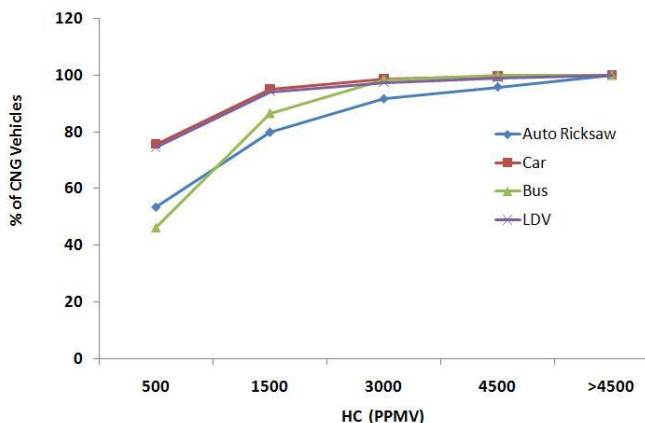


Fig. 4. Cumulative distributions of CNG vehicles for HC emissions.

Table 7. Ranking of CNG/Octane vehicles in respect to HC emissions.

Vehicle Category	% of vehicle with HC emission (ppm)				Rank
	≤ 500	≤ 1200	≤ 3000	≤ 4500	
Auto rickshaw	53.5	71.3	91.7	95.8	4 th
Car	75.7	90.5	98.8	99.6	1 st
Bus	46.3	80.6	98.5	100	3 rd
LDV	74.6	88.6	97.5	99.2	2 nd

3.2.3. Idle CO and HC emissions from motor cycles

i. Motorcycles were found as the worst polluters in the CNG/octane vehicle category. Fig. 5a shows that only 40% of the motorcycles exited emissions with CO concentrations $\leq 4.5\%$ (v), the existing limit value for motor cycle emission. About 36.5% of these vehicles emitted CO concentrations greater than 7.0% (v), which may be considered very high emission.

ii. Motor cycles were also found high HC emitters among the CNG/octane category. It was found that only 37% of the motorcycles emitted HC at ≤ 1500 ppm, and about 58.8% emitted HC at ≤ 3000 ppm (fig. 5b). The figure also shows that about 24% of the motorcycles emitted HC greater than 5000 ppm that may be considered very high.

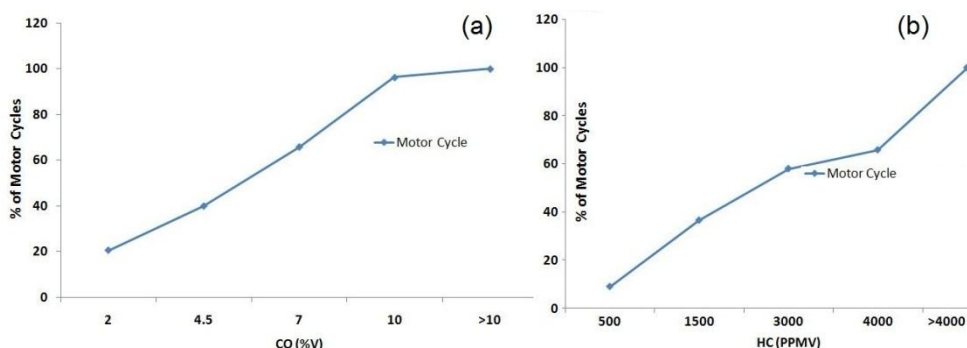


Fig. 5. Cumulative distributions of motor cycles for (a) CO and (b) HC emissions.

3.2.4. Comparative positions of CNG/Octane vehicles with respect to Idle CO at 1%v and idle HC at 1200 ppm

Irrespective of the manufacturing year, the vehicles were sorted according to their performances in simultaneously emitting CO within 1%(v) and HC within 1200 ppm concentrations which are the existing limit values for the CNG/gasoline vehicles registered after 01 September 2004. It is found that the cars ranked at the top with 71.6% meeting those limit values simultaneously, while the auto rickshaws stood at the second place with 68% compliance. LDVs and Buses performed very closely with 59.1 and 59.6 % compliance respectively.

3.2.5. Analysis of smoke emissions from diesel vehicles

- i. Buses were found to be the highest polluters among the diesel vehicles. This category includes heavy duty buses which are mainly district bound vehicles, and mini buses which ply within the city. Most of the minibuses in Dhaka city are converted to the CNG system, but a fraction of them are still running on diesel. It is seen from the data analysis that only 18% of the buses could meet the national limit value of 65 HSU opacity. More than 70% buses emitted smoke with opacity greater than 85 HSU. Fig. 6 shows cumulative distribution of different category diesel vehicles with respect to their smoke opacity.
- ii. Trucks followed nearly the same status as buses did. Only 24.6% of the trucks could satisfy existing limit value of 65 HSU, and about 65% of trucks emitted smoke with opacity greater than 85 HSU (Fig. 6). As heavy duty trucks and buses are allowed entering the Dhaka City after 10.00 pm, large number of those vehicles waiting outskirts of the city from the evening rush in to the city at 10:00 pm, stimulating ambient air pollution in the city.
- iii. Among the diesel vehicles LDVs performed little better compared to buses and trucks (Fig. 6). 40.9% of LDVs could satisfy limit value of 65 HSU and about 50% of them had smoke opacity greater than 85 HSU

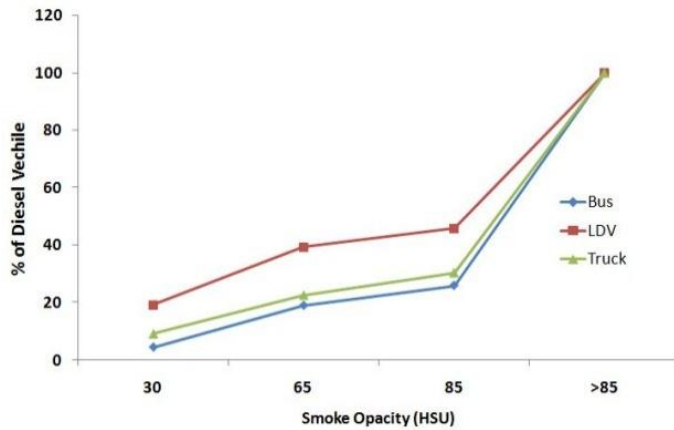


Fig. 6. Cumulative distributions of diesel vehicles for smoke opacity.

4. Conclusion

On-road vehicle emission testing was carried out on 815 CNG/gasoline and 502 diesel vehicles in 08 hot-spots of Dhaka from 2012 to 2015. Idle measurement of carbon monoxide (CO) and hydrocarbons (HC) in the emissions from CNG/gasoline vehicles, and opacity of the emissions from diesel vehicles were conducted. The results showed that all types of CNG vehicles performed very well with more than 80% satisfying the corresponding limit values. Private cars ranked at the top in performance among the CNG/gasoline vehicles. Contrasted to the performance of the CNG vehicles all types of diesel vehicles were found highly polluting; emissions from about 75% of the diesel vehicles had opacity more than 65 HSU, the national emission limit value for the diesel vehicles. Motor cycles were also highly polluting; 60% of the motor cycles were found unsuccessful in satisfying the corresponding limit value. Further analyses of the emission monitoring data resulted the following findings,

- (a) About 75% of the CNG vehicles emitted $\text{CO} \leq 1\%(\text{v})$ concentration and about 88% of the vehicles emitted $\text{CO} \leq 3\%(\text{v})$ concentrations. HC emissions from these vehicles were also promising – about 85% of CNG vehicles emitted $\text{HC} \leq 1200\text{ppm}$ concentrations.
- (b) Only 40% of the motorcycles could meet the CO emission standard of $4.5\%(\text{v})$; about 35% of the motorcycles emitted CO concentrations more than $7\%(\text{v})$. The scenario for HC emission from motorcycle was about the same; only 30% of motorcycles satisfied the limit value of 1200ppm.
- (c) Only 23% of diesel buses and trucks could meet the limit value of 65 HSU opacity and about 67% of them had emissions with opacity >85 HSU.

Appendices

Appendix A: Guidelines for measurement of CO and HC emissions from spark ignition engine vehicles (Idle test)

The idle CO and HC emission inspection tests were completed in the following phases:

- i. Test equipment set up
- ii. Vehicle Preparation
- iii. Execution of idle test

(i) *Test preparation and equipment setup*

(a) A NDIR gas analyzer for measurement of concentration of CO and HC as hexane shall be used. In addition, CO₂ will also be measured for correction of measured CO and HC for any leakage or air into the exhaust system. The exhaust gas analyzer shall have capability to measure Lambda for testing of vehicles equipped with 3-way catalytic converters.

(b) Follow instructions provided by the manufacturers of analyzers for operation of the gas analyzers.

(c) Analyzers should be calibrated daily at the beginning of work but no more than 4 hours before use. Each time the instrument is moved or transferred to new location, perform a span and zero calibration using calibration gas. Follow the instructions in the user manual of the analyzers.

(d) Ensure any filters in the sampling line are clean.

(e) Ensure that there are no leaks in the sampling line. Carry out leak test on analyzer if there is provision.

(f) Ensure that the sampling handling line and probe are free from contaminants by carrying out periodic hang up test. HC reading should drop to 20 ppm or less within 5 minutes when the probe is removed from the exhaust. If it takes more than 5 minutes for HC reading to drop to 20 ppm or less, then replace the probe with a new one.

(g) Purge the system after measurements on each vehicle as per the manufacturer's instructions.

(h) If the analyzer has provision to key in vehicle data such as registration no., make, date or test, etc., then feed in the information.

(ii) *Vehicle preparations*

Prior to conducting the test, following items must be completed,

(a) Vehicles should have been warmed up by operation for 10 km or 15 minutes before emission measurement.

(b) If the vehicle is equipped with a manual transmission, the transmission must be placed in neutral gear and clutch must be released. If the vehicle is equipped with an automatic transmission, the transmission must be placed in the park position, if available, or otherwise in the neutral position.

(c) Vehicle wheels or the vehicle must be restrained to prevent from moving during testing.

(d) Vehicle accessories such as air conditioning, fan, radio, etc., should be turned off.

(e) The vehicle should be inspected for exhaust leaks. Severe leaks in the system may cause air to enter into the exhaust stream, which may give erroneously low test results.

(f) Ensure that manual choke control has been returned to rest position.

(g) Where the vehicle is equipped with an exhaust system having multiple outlets, either these shall be joined to a common pipe or the CO, CO₂ and HC content from each of them shall be measured and the result of the test would be reached by taking arithmetical average of these concentrations for each pollutants.

(iii) Execution of idle test

- (a) Ensure vehicle is prepared as discussed above.
- (b) If an engine RPM tachometer is available, note engine idle speed.
- (c) Insert analyzer probe into vehicle tail pipe at least 300 mm. Use an exhaust pipe extension if necessary.
- (d) Allow the exhaust emissions measurement reading to stabilize for approximately 1 minute.
- (e) Record or print out results. Note any abnormalities.
- (f) For vehicle equipped with a catalytic converter and where an engine RPM tachometer is available, an additional test is to be carried out with the engine idle speed held constant at approximately 2000 RPM.

References

1. A. Salam, T. Hossain, M. N. A. Siddique, and A. M. S Alam, Air Qual. Atmos. Health **1**, 101 (2008). <https://doi.org/10.1007/s11869-008-0017-8>
2. B. A. Begum and P.K. Hopke, Aerosol Air Qual. Res. **19**, 118 (2019). <https://doi.org/10.4209/aaqr.2017.12.0604>
3. M. M. Rana, N. Sulaiman, B. Sivertsen, M. F. Khan, and S. Nasrin, Environ. Sci. Pollut. Res. **23**, 17393 (2016). <https://doi.org/10.1007/s11356-016-6950-4>
4. J. Leliveld, J. S. Evans, M. Fnais, D. Giannadaki, and A. Pozzer, Nature **525**, 367 (2015). <https://doi.org/10.1038/nature15371>
5. A. K. Azad and T. Kitada, Atmos. Environ. **32**, 1991 (1998). [https://doi.org/10.1016/S1352-2310\(97\)00508-6](https://doi.org/10.1016/S1352-2310(97)00508-6)
6. Bangladesh Road Transport Authority (BRTA), Date of access 22/09/2019. www.brta.gov.bd
7. B. A. Begum, S. K. Biswas, and P.K. Hopke, J. Air Waste Manage. **56**, 85 (2006). <https://doi.org/10.1080/10473289.2006.10464430>
8. Clean Air and Sustainable Environment (CASE) Project, In: S-13-Source Apportionment-All Elements Report, Date of access 22/09/2019 <http://case.doe.gov.bd>
9. B. A. Begum, P. K. Hopke, and A. Markwitz, Atmos. Pollut. Res. **4**, 75 (2013). <https://doi.org/10.5094/APR.2013.008>