Chapter 8

Mobile Measurement of Greenhouse Gas Emissions (GHG)

Introduction

In many cities of India, shared auto-rickshaws are the predominant mode of intermediate transportation. Auto-rickshaws are three-wheelers used for passenger transport, often classified as Intermediate Public Transport (IPT). Auto-rickshaws have popularity because they provide affordable and convenient mobility for last-mile connectivity. As per the National Sample Survey Office [1], the auto-rickshaws are the most preferred mode of transport in urban and rural India after busses.
The Indian Ministry of Road Transport Highways [2] reported that around half a million auto-rickshaws are registered annually. In Telangana, where the capital city of Hyderabad is located, registered auto-rickshaws are 435,507 as of March 2020 [3]. The greenhouse gas emissions in India consist of 70% CO_2 and 30% non-CO_2 (methane, nitrous oxide, F-gas) emissions [4]. Also, these rickshaws contribute around 10% of India's carbon dioxide (CO_2) emissions [5]. To compute the impact of these auto-rickshaws on urban and rural air quality and greenhouse gas levels, it is necessary to quantify vehicular emissions. Measurement of vehicle exhaust emissions on the road is crucial for successful air pollution management in the transportation industry. In this work, a portable emission measurement system (PEMS) was used to measure CO_2 and CO for three-wheeler auto-rickshaws in urban and rural traffic scenarios under real-world driving circumstances. The study's findings may be utilized to understand better the emission variables associated with on-road transportation in a particular city or area. Existing policymakers may find the identified emission factors helpful in implementing a traffic control system.

Experimental Methodology

The detailed research methodology adopted in this study to capture the emission trends under real-world driving conditions from diesel auto-rickshaws for urban and rural traffic scenarios is shown in Figure 8-1.

1: Study area

Sangareddy is a town and the administrative headquarters of the Sangareddy district in Telangana, India, with a population of 72,344 people distributed over 13.70 square kilometers. Its population density is 5300 persons per sq. km. The data was collected over a 14-kilometer-long test route in Sangareddy town, including feeder, rural, and urban routes with varying traffic levels. As illustrated in Figure 8-2, the study stretch has geometric components such as mid-block openings, uncontrolled junctions, and signalized intersections, with no steep slope, as shown in Figure 8-2.

2: Calculation of emission factor

The measured emission concentration recorded in % volume from the gas analyzer was converted into grams per second (g/s) by assuming a constant exhaust flow rate. The calculation of emission rate in g/s is shown in Equation 1.

$$Erc = C * Fv * p \qquad (1)$$

Erc : Emission rate of pollutant C in g/s
C : Instantaneous concertation of pollutant C in % volume
Fv : Exhaust flow rate in L/sec
P : Density of the pollutant in g/L

The exhaust flow rate from the auto-rickshaw was calculated based on the engine size and the average engine speed (rpm), as shown in Equation 2.

$$Fv = E * R/2 \qquad (2)$$

E : Engine size in liters
R : Engine speed in revolution per second (rps) The average engine speed is assumed to be 2500 rpm for the auto-rickshaws.

3: Data Analysis

The speed and emission data on urban and rural roads were checked with a normality test. The data do not follow the normal distribution ($p < 0.05$). Further, a Wilcoxon signed-rank test was conducted pairwise between speed and emission data on urban and rural roads. The results showed a significant difference in emissions between the two road types at a 5% significance level. Based on the above finding, separate models were developed for urban and rural roads. The relationship between the average emission rates of CO_2 and CO with speed for urban and rural traffic conditions is discussed in this section. Firstly, the data was divided into a bin of 5 kmph such that the bin includes all the speed values observed during the entire data collection. The curve fitting is performed using the statistical package of social science (SPSS) software by considering the emission rates as the dependent variable and speed as the independent variable.

Figure 8-1 The detailed experimental methodology adopted in this study captures the emission trend

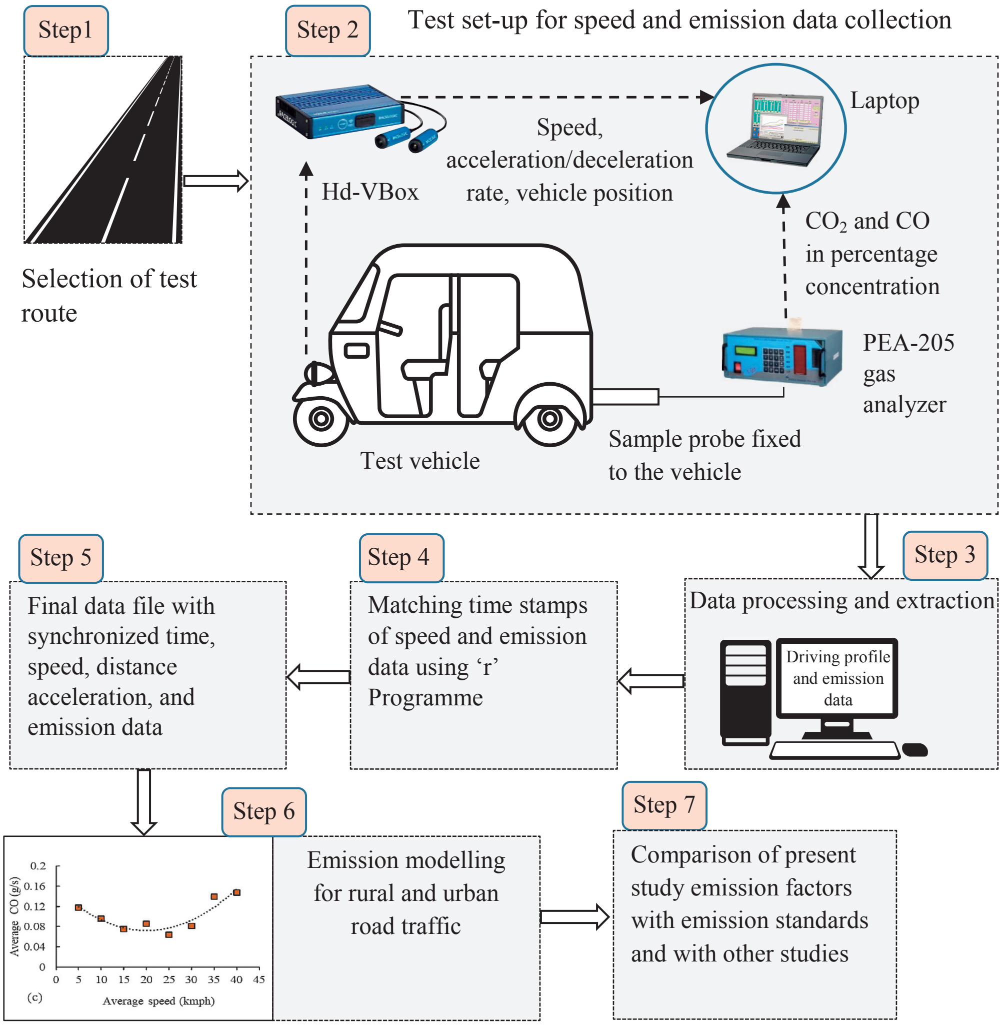
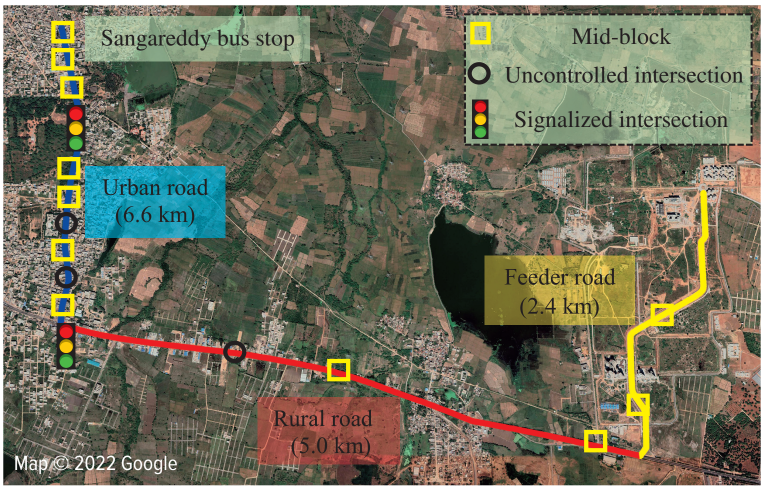


Figure 8-2 Study area (Google Earth view)



Experimental Results

The data was fitted with quadratic polynomial function and validated by obtaining the various goodness of fit. Since the graphical fits are highly subjective, numerical fit with the goodness of fit statistics is preferred. All the plots of the emission rates concerning speed for urban and rural traffic conditions followed a second-order polynomial fit shown in Equation 3; the same is depicted in Figure 8-3.

$$y = constant + v_1 x + v_2 x^2 \qquad (3)$$

Where, y : the average CO_2 emission in (g/s)
x : the speed in kmph
v_1 and v_2 : the coefficients.

The emission factors are high at very low speeds of 5 to 10 kmph. The emission factors in urban traffic are approximately 1.2 times higher than in rural traffic. The average emission factors of CO_2 were found to be around 5% higher in urban traffic than in rural traffic for a speed range of 5–10 kmph and a speed range of 40–45 kmph, respectively, Figure 8-3 (a) and (b)). The average CO emission factors were found to be approximately 30% higher in urban traffic than in rural traffic for a speed of 5, 20, and 30 kmph, respectively (Figure 8-3 (c) and (d)). The average emission factors of CO were found to be 7% higher in urban traffic than rural traffic for a speed (25 and 35 kmph) and approximately 12% higher in urban traffic than rural traffic for a speed of 10–15 kmph (Figure 8-3 (c) and (d)). Also, the emissions factors for all the speed bands were considerably higher than prescribed emission standards (BS values), as shown in Figures 8-3. As seen in Table 8-1, emission factors obtained from our studies varied significantly from the emission factors given by ARAI (Automotive Research Association of India). The variation in emission factor values may be because ARAI emissions were obtained in a laboratory test using the standard Indian driving cycle (IDC). The variation in emissions may also depend on vehicle age, vehicle maintenance, vehicle kilometers traveled, etc. Thus, the studies which use the laboratory-based emission factor to estimate emission inventories may underestimate the total emissions of CO from diesel auto-rickshaw.

Comparison with emission standards

The emission factors values obtained from our study were found to be 5.28 and 4.73 times higher than prescribed BS-III and BS-IV emission standards, as shown in Table 8-1.

Conclusions

The emission from auto-rickshaws in urban areas is a severe problem

Figure 8-3 Emission rates as a speed function for urban and rural traffic

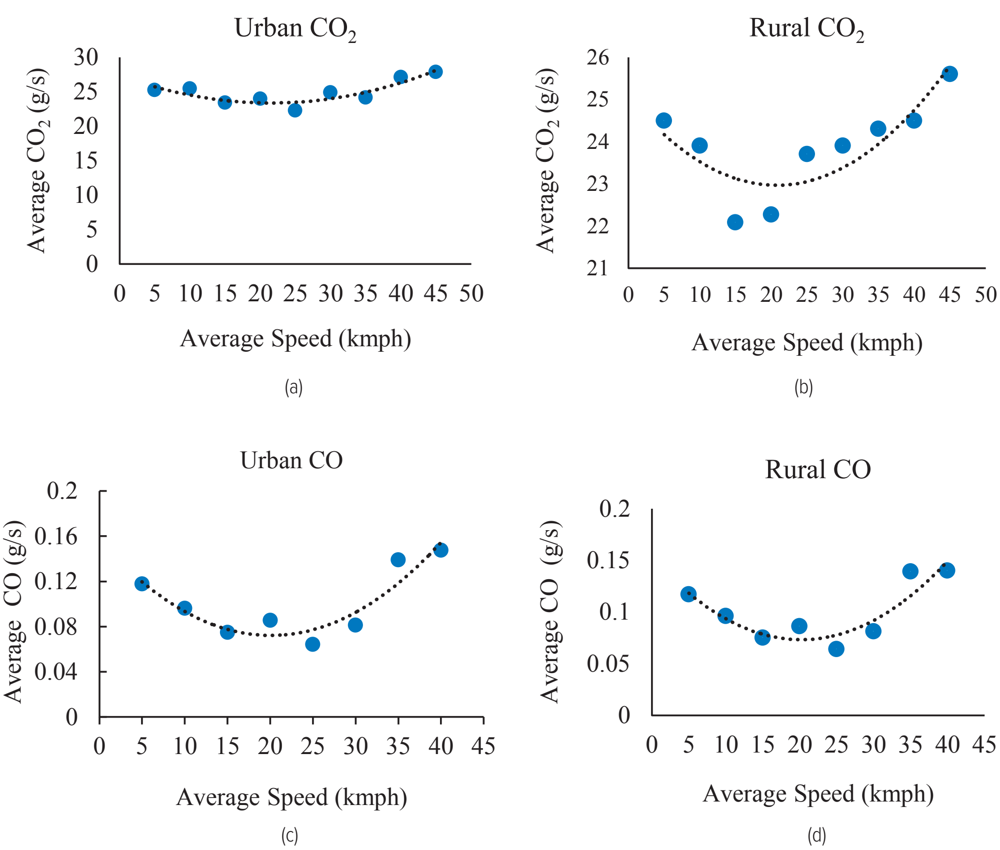


Table 8-1 Comparison of the real-world emission factors with emission standards.

Diesel	Emission standard	CO	BS values
3-w	BS - Ⅲ (2010)	*2.6	0.50
3-w	BS - Ⅳ (2016)	*1.8	0.38

*indicates the results obtained from this study

that researchers have not received adequate attention to. The present study quantified the emissions from diesel auto-rickshaws for urban and rural traffic conditions. Unlike laboratory tests, the real-world tests conducted in this study measure the emissions in real-time; thus, typical driving conditions were captured for Indian urban and rural roads. The result shows that the CO emission from the diesel auto-rickshaws is significantly higher than prescribed emission standards (BS values). Also, the emission rate for urban traffic conditions is slightly higher than in rural traffic. The findings from the study may be helpful to the local policymakers in implementing a proper traffic management system, therefore improving the city's air quality.

Real-world emission and policy implementation

The emission standards prescribed by the Automotive Research Association of India (ARAI) are based on laboratory testing of the vehicles, and there has been limited prominence on real-world emissions monitoring. Thus, it is crucial to verify emission control system performance and durability, not just in laboratory certification tests of new engines but also in the real-world driving conditions, which will be needed for emissions standard formulations. Finally, a combination of the policy decision, including congestion pricing, encouraging public transport services, and carpooling, would be necessary to reduce emissions drastically. Introducing e-rickshaw in urban traffic with proper charging infrastructure could be a possible replacement for fossil fuel-based auto rickshaws to improve the city's air quality.

References

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