



Urban real-world driving traffic emissions during interruption and congestion



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ABSTRACT

On-road emissions from urban traffic during interrupted and congested flow conditions are too high as compared to free-flow condition and often influenced by accelerating and decelerating speed due to frequent stop-and-go. In this study, we measured emissions from passenger cars and auto-rickshaws during peak and off-peak hours and analyzed according to different mileages with the instantaneous speed and acceleration for interrupted and congested traffic conditions. It was found that during flow, several short-events lasting over fractions of a second each lead to a sharp increase in pollutant emissions, indicating episodic conditions. The emission levels are sensitive to frequency and intensity of acceleration and deceleration, in accordance with the traffic-flow patterns and speed, besides mileages. Further, congestion conditions occur during both peak and off-peak hours, but last for different durations. The results are important in the sense that instantaneous estimates of pollutant emissions are necessary for the assessment of air quality in urban centers and for an effective traffic management plan.

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Introduction

Passenger cars make up a major portion of traffic fleets on urban roads (Shukla and Alam, 2010). Rapid growth and expansion of urban centers increase traffic demand, which in most cities have exceeded the road capacities, and a major cause of frequent congestion events. Traffic congestion events are severe particularly the times when people by virtue of workplaces, schools and other commercial activities crowd in urban centers, causing excess transport demand. During such crowded times, interaction between vehicles and between vehicles and people increases, which reduces the overall speed of the traffic flow causing congestion (Gakenheimer, 2002). Vehicles, when encounter frequent stop-and-go, increase commuting time, fuel consumption and pollutant emissions. Pollutants emitted from vehicular exhausts – carbon monoxide (CO), hydrocarbon (HC), oxides of nitrogen (NO_x) and fine particulate matter (PM), are associated with vehicle types and fuels used. Besides, road traffic also contributes to greenhouse gases such as carbon dioxide (CO₂).

The share of passenger cars and auto-rickshaws on urban roads is high in developing countries; the numbers of trips in urban centers are also high in comparison to other personalized vehicles. For example, one auto-rickshaw in New Delhi travels on average 150 km daily (Reynolds et al., 2011). Auto-rickshaws are important hire-transport vehicles in most Asian cities. Auto-rickshaws with 2-stroke engines consume about 20% more fuel and emit more CO₂ emissions compared to 4-stroke engines (Reynolds et al., 2011). Ramachandra (2009) and Singh (2006) reported that annual utilization of cars and

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taxi is higher than two-wheelers, almost double, i.e. 12,600 km as compared with the 6300 km of two-wheelers, in India. Li (2011) found CO₂ emissions in gasoline passenger cars high as compared to other transport modes.

Vehicles in metropolises of India contribute about 70% of CO, 50% of HC and 30–40% of NO_x (CPCB, 2006). De Vlieger et al. (2000) demonstrated that during rush hours, fuel consumption increases by 10% and emissions of CO, HC and NO_x emitted from passenger cars increase by up to 20% compared to during non-rush hours. Emissions also vary with vehicle and road types. A few studies have analyzed environmental benefits of specific road geometry in terms of vehicle delay, number of stops and duration of stops (Guerrieri et al., 2015; Tollazzi et al., 2015). Road geometry and type also influence the number of acceleration/deceleration cycles and time spent in idling and therefore have significant impacts on fuel consumption and exhaust emissions (Pandian et al., 2009; Gokhale, 2012). Li et al. (2004) have studied signal timing model to reduce vehicle delays, fuel consumptions and emissions at traffic intersections. Further, several studies, which carried out on-board measurements of CO, HC, and NO_x, found that sharp accelerating peaks produce higher emissions and sometimes single sharp acceleration causes emissions higher than even an overall trip (Frey et al., 2001, 2003; Guensler, 1993; Bachman, 1998; De Haan and Keller, 2000).

Shukla and Alam (2010) studied the relationship of traffic and emissions by testing one light-duty-petrol-driven passenger car of 69,000 km mileage in a dynamic urban traffic condition in Delhi. They found high emissions during accelerations. Another study of Zhang et al. (2011) compared the work zone and rush-hour congestion with free-flow traffic and found high emissions during the transitional phase, when traffic-flow changed from free to congested condition. The study, however, used speed-acceleration profiles by car floating technique, which represents an average scenario of a limited number of vehicles on roads and may be underestimating actual emissions. Chen et al. (2007) carried out a study on nine heavy-duty diesel vehicles and reported that low speed with frequent acceleration and deceleration, particularly in congested conditions, are the main factors that aggravate vehicle emissions and cause high emissions of CO and HC. The emission levels depend heavily on traffic-flow characteristics, such as average flow speed, the frequency and intensity of vehicle acceleration and deceleration, the number of stops, and vehicle operating mode (Faiz et al., 1996). Episodic effects of emissions, caused by short-events, may be important consideration therefore for short-term near-road human exposure assessment (Zhai et al., 2008).

While most studies analyze emissions based on the chassis-dynamometer tests which reflect only a subset of real-world driving conditions, this study carried out the real-world on-road instantaneous measurements of speeds and exhaust emissions from light-duty-petrol-driven passenger cars and auto-rickshaws (a 3-wheeler passenger vehicle) with different mileages traveled in different traffic-flow patterns. Passenger cars and auto-rickshaws are the highly used road transport modes with the highest daily trips in urbanized cities compared to other transportation modes. The aim of this study, therefore, has been to evaluate the effect of different traffic-flow patterns and short-events on speed, acceleration, travel time and concomitant instantaneous pollutant emissions.

Experimental method

The study includes the real-world measurements of instantaneous speed, acceleration and tailpipe emissions of passenger cars and auto-rickshaws of different mileages on a highly trafficked urban road of Guwahati, one of the fastest growing cities in the North-East of India. A detailed traffic count was done on the road at two points of the test runs (Fig. 1a) during both peak hour (PH) and off-peak hour (OPH) with the help of videotapes. For traffic count, videotapes of 100 m stretch on the road were analyzed and speed and travel time of different category vehicles were estimated every 5 min over the same 100 m stretch. Robertson (1994) has also analyzed traffic data at 5 min intervals. Fig. 1b shows the section of road with a traffic scenario captured at camera point 1 during a peak hour. The stretch of the test run was 3.8 km long, double-lane (for two-way traffic) 16 m wide. It consists of a signalized intersection near camera point 2 and an unsignalized U-turn under the flyover near camera point 1. The measurements were carried out during different timings of the day, PH and OPH and on different working days of March 2014. The average traffic flow on the test route during OPH and PH was about 2590 ± 326 and 9368 ± 265 , respectively. In the traffic fleet, the average share of two and four-wheelers (2W and 4W) was 87%, followed by 9–10% of three-wheeler (3W) and 3–4% of buses. During OPH, the share of 4W and 2W was 52% and 28%, respectively, while during PH, it was 34%, and 53%, respectively. The average fleet speed during OPH and PH was 46.84 ± 8.83 km/h and 20.26 ± 3.64 km/h, respectively.

The free, interrupted, congested traffic-flow patterns were identified (defined based on traffic video analysis), the proportion of the time traffic spends in each pattern was estimated, and impacts of speed, acceleration in PH and OPH were evaluated, particularly, in interrupted flow condition. These data were utilized to determine various traffic characteristics such as, percentage share of vehicle types, traffic-flow patterns and percentage of the time traffic spends in different traffic-flow patterns. Traffic volume observed at the site during the week and weekend days had a major share of passenger cars and auto-rickshaws. Therefore, these two categories of vehicles, which are gasoline-powered with different mileages traveled, were selected for the study. Table 1 shows the vehicle specifications and mileages used for emission tests. The auto-rickshaws are of the same weight while the passenger cars vary slightly in weights, which however may not impact the emissions significantly because they are gasoline driven. A few studies have reported that vehicle weight is one of the characteristics that influence emissions mostly of PM and NO_x but in case of diesel driven vehicles rather than gasoline driven (Keller and Fulper, 2000; Durbin et al., 1998; Beydoun and Guldman, 2006).

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