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Characteristics of Exhaust and Non-Exhaust Emissions from Urban Roads – A Case Study in Delhi City

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Abstract

This paper presents the characteristics of exhaust and non-exhaust emissions measured at selected roads in Delhi city. The real-world exhaust emissions were measured in car using AVL Digest 1000 analyser. The silt load measurements were carried out as per EPA AP-42 methodology. Results indicated that the real-world exhaust emissions were higher in high-density roads (0.09 g/s), and low in low-density roads (0.03 g/s). Silt load measurements results indicated significant deposition of dust on high-density roads (44 g/m^2 -day) when compared to low-density road (3 g/m^2-day). The present results indicated that there is a need to manage both exhaust and non-exhaust emissions from urban roads.

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Keywords: Exhaust Emissions; Non-exhaust Emissions; Nitric Oxide (NO); Resuspendable Road Dust; Urban Road Emissions;

1. Introduction

Urban areas are prone to degradation of air quality due to significant contributions from industries, transport sectors, open burning, domestic burning, secondary particulates and resuspension of road dust. The air pollution due to industries can be managed by implementation of strategies such as local air quality management for industrial clusters and positioning of industrial clusters in outskirts of the city. Among the air pollutants in urban areas like Delhi, particulate pollution is a major concern as some of the severe health problems such as respiratory disease,

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cardiovascular disease, lung cancer, stroke etc., are associated with it. A World Health Organization (WHO) study estimated that there were 3.7 million deaths in 2012 from urban and rural sources worldwide out of which approximately 88% of the premature deaths occurred in developing countries (World Health Organization, 2014). The particulate pollution may also lead to transboundary health effects and global climate change.

In the present scenario of urban air pollution, road transport is one of the major contributors of global emissions. Pollution from road transport can be classified into exhaust and non-exhaust emissions. Motor vehicles running on different fuels such as diesel, petrol or gasoline, CNG, and biogas are the source for exhaust emissions. Whereas for non-exhaust emissions, tire wear, brake wear, and resuspendable road dust are some of the sources. Primary pollutants from vehicular emissions consists of particulate matter (PM2.5 & PM10), nitrogen oxides (NOx), sulfur oxides (SOx), carbon dioxide (CO2), carbon monoxide (CO) and hydrocarbons (HC) (Gurjar et al., 2010; Jaikumar, Shiva Nagendra, & Sivanandan, 2017; Johnson, 2016; Kuppili, Kumar, & Kim, 2015). Meanwhile, the non-exhaust emissions such as resuspension of road dust are contributing eminently to the PM concentrations in ambient air. The attenuation of road dust is one of the significant research problems being worked on, by the air quality researchers in the recent years. It is also a challenging research problem for researchers working in the field of sustainable transportation as vehicles are the major contributors for resuspension of road dust causing high pollution exposure to heavy metals and other carcinogenic compounds.

Management of pollution from transport sectors is complex, particularly in developing countries having heterogenous traffic. Management of air quality in cities is a very complex process involving monitoring, analysis, source identification, modelling, health exposure assessment, implementation of emission control strategies, and policy intervention. The regulatory bodies are successful to some extent in managing the exhaust emissions from vehicles, whereas the non-exhaust emissions related to the transport sector is not being managed effectively in developing nations like India. In this t paper the characteristics of exhaust and non-exhaust emissions in Delhi city has been presented.

Nomenclature

CO	Carbon Monoxide
LDV	Low Density Vehicle
NO_x	Oxides of Nitrogen
NO	Nitric Oxide
PM	Particulate Matter
SO_x	Oxides of Sulphur
MOES	Ministry of Earth Science

2. Material and Methodology

2.1. Study area

City of Delhi is considered as one of the extremely polluted cities in the world due to its high vehicular and industrial emissions (Nagpure, Sharma, & Gurjar, 2013). Over the past 10 years the average count of vehicle registration in Delhi is nearly 0.42 million vehicles/year and is growing at a rate of 5.8% (Ministry of Road and Transport). Vehicular population in Delhi city is increasing exponentially day by day. The study area was divided into three categories based on vehicular density, namely: (a) Low density road; (b) Medium density road; and (c) High density road. The different category of roads are shown in the Figure 1. Study areas for exhaust and non-exhaust emission measurements were selected based on the observed traffic characteristics and density during weekends and weekdays. JNU road and Qutub institutional area were identified as low-density traffic road because these areas were found to be residential apartment and the presence of institutional area nearby. IIT Delhi main road and JNU main road were identified as medium density road as a moderated traffic density was observed during morning and evening peak traffic hours. Munirka, Mahipalpur road is categorized as heavy density road in Delhi, as it connects the major business centres. Thus, Qutub Institutional road, IIT Delhi main road and Munirka roads were identified for low, medium and high-density roads respectively to collect resuspension dust emissions. Simultaneously, NO emissions were measured for the test car while traveling on these roads.

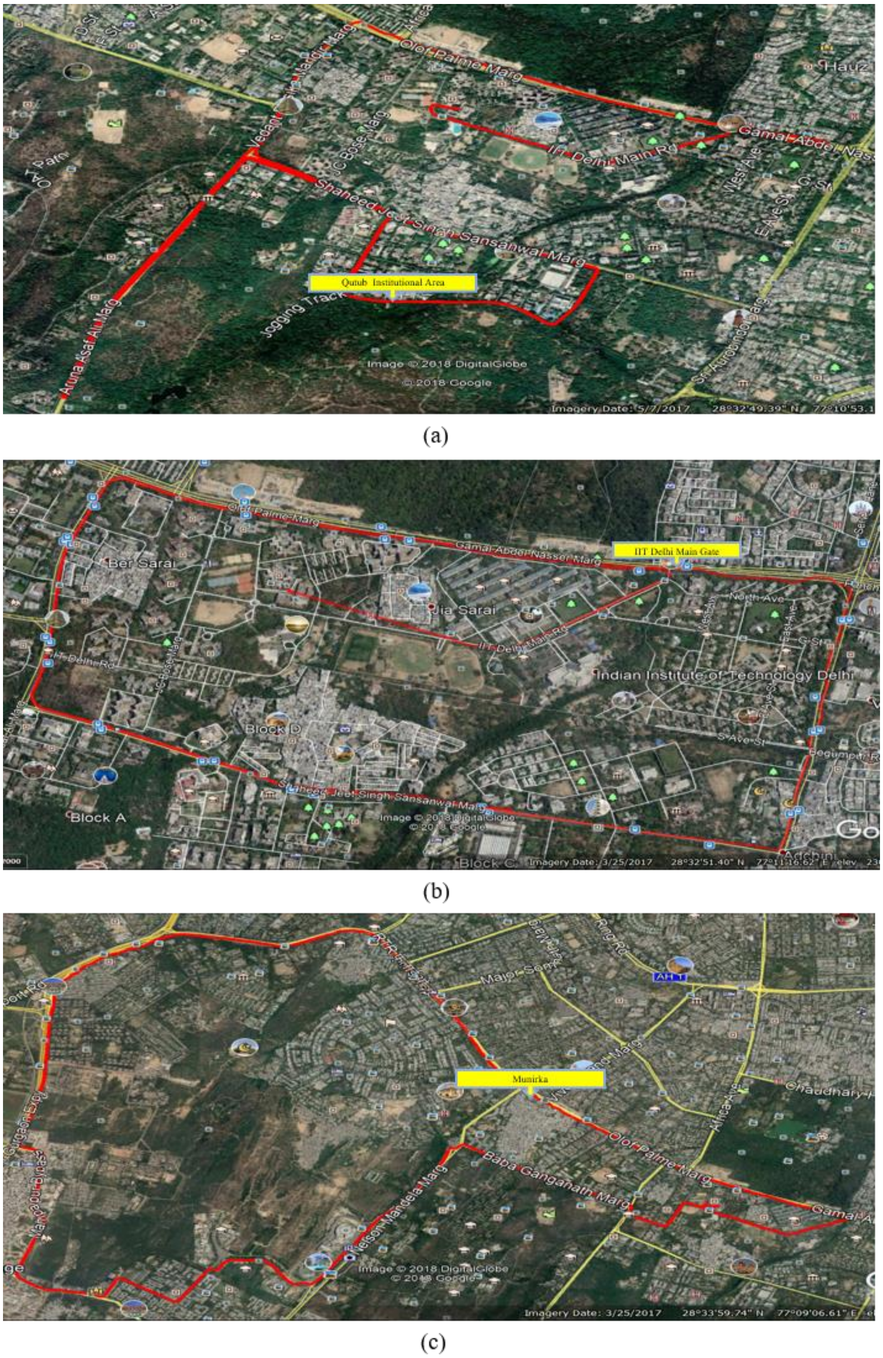

Figure 1.Route map of the study areas from exhaust and non-exhaust emissions in the city of Delhi

2.2. Data Collection

2.2.1. Exhaust Emissions

The AVL DITEST 1000 was used in this study to perform vehicular emission tests. This instrument can analyse CO, CO2 and O2 in volume percentage and HC, NO in ppm from the vehicle exhaust. For the purpose of this study only NO emissions from cars were measured and projected. The DITEST 1000 is handy and portable instrument, which can be easily installed to any vehicles. The complete set of AVL DITEST 1000 is shown in Figure 2. The instrument is having four connections typically (i) a power cable connected to backup power supply using external battery (UPS); (ii) an engine data link connected to the OBD data port; (iii) an emissions sampling probe inserted into the tailpipe; and (iv) a USB connection between AVL and computer for data observation and recording. The instrument requires approximately 2 minutes time to warmup including HC residue test and leak test.

Figure 2. (a) AVL Ditest 1000 instrument (b) OBD data port (c) Bluetooth device and (d) USB device

2.2.2. Non-exhaust Emissions

To study the characteristics of the resupendable road dust, samples will be collected from specified location following US-EPA AP-42 sample collection methodology. Figure 3 show the accessories used for the study. In order to collect the samples, a suitable area of 4 to 9 sq.m is marked out on the road surface such that a minimum of 500 to 600 grams of dust is accumulated within a span of 24 hours. The marked-out area is cleaned by sweeping to remove the coarser particles from the surface and an air blower is used to clean the finer dust particles from the voids on the surface. The pavement is exposed to normal traffic flow so that the dust gets accumulated on it due to the movement of vehicles, wind action and other factors contributing towards it.

After 24 hours the deposited dust samples will be collected using a vacuum cleaner. The collected sample is further sieved using IS sieve pans and the sample passing through 75micron sieve and collecting in a pan is weighed and the silt load (g/area/day) is estimated from equation 1. Further, $PM_{2.5}$ and PM_{10} emission concentrations were calculated from equation 2.

$$Silt\ Load\ (\frac{g}{day*m^2}) = \frac{(Sample\ passing\ through\ 75micron\ sieve)}{Area\ of\ pavement\ under\ consideration} \quad (1)$$

$$E = k * (sL)0.91 * (W)1.02 \quad (2)$$

E=PM emission factor units matching units of k
k=particle size multiplier, PM2.5 - 0.15 g/VKT, PM10 - 0.62 g/VKT
sL=silt loading - g/m2
W=Average weight (tons) of vehicles on the road

Figure 3. Accessories for road dust collection (a) vacuum cleaner (b) blower (c) Sieve and sieve shaker

3. Results and Discussion

3.1. Traffic Volume

During the exhaust emission measurement, a camera was installed at sampling locations to record the road trip which can help to carry out an investigation of counting vehicles for the same study.

Minimum number of vehicles were counted near to Qutub institutional area, for which the location was marked as low-density area. However, a moderate traffic density was observed around the IIT campus. Maximum traffic density was observed in Munirka-Mahipalpur road, for which the places were marked as heavy density roads. Number of 4W and LDV vehicles were found to be maximum in the present study. The traffic density for different category roads during morning (M), afternoon (A) and evening (E) is presented in Figure 4.

At low-density area, number of 4W vehicles were found to be maximum of 350±100 followed by LDVs (200±70), 3Ws (150±30), 2Ws (90±50) and HDV (25±5). During evening period traffic density was found to be maximum (Eg: 4W:350±100) followed by 300±100 and 250±50 during morning and afternoon hours, respectively. This could be due to business and school closure times. During the data collection, a maximum traffic density of >500±150 to >600±150 4Ws alone were observed in Munirka-Mahipalpur road, respectively. However, the traffic density was not constant at sampling locations, as it changes day by day and season to season. It was found that, maximum traffic dense area for the present study was Munirka-Mahipalpur followed by IIT Delhi main road and Qutub Institutional area.

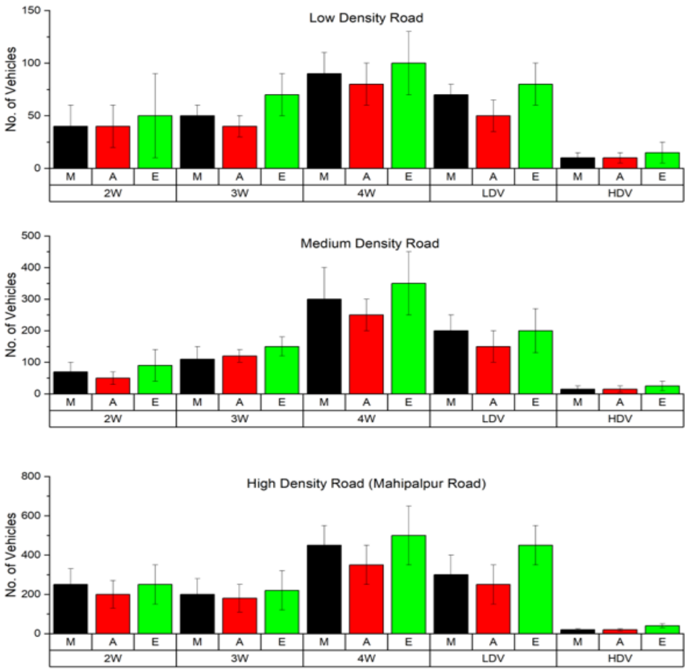

Figure 4.Road traffic density based on type of vehicle and duration of the day

3.2. Exhaust emissions

Real-time exhaust emission measurements were made for 4W. Figure 5 shows the variation of concentration and speed profile w.r.t. time. It was observed that the vehicle speed for 4W was found to be in the range of 10 – 70 kmph in all the three roads. However, the average speed of 4W was higher in low-density road which was measured at 34 kmph. Whereas, 4W on medium and high-density roads clocked 31.1 and 28 kmph respectively.

For low-density roads, NO emissions were ranging from 0.01-0.1 %vol, respectively. A similar trend of slightly varying pollutant concentration profile was observed with 4W vehicle in medium density roads. However, the speed profile was found to be different at medium and high-density roads due to more traffic congestion. For 4Ws at high-density roads, pollutant concentrations were varying from 0.005-0.06 %vol for NO.

At maximum speed, NO concentration was found to be maximum, which can be attributed to high engine temperatures. NO is usually formed at temperatures >1000 °C during fuel combustion inside the engine, whose emission concentration increase w.r.t. increase in engine temperature. During acceleration high volumes of fuel is injected into the engine combustion chamber, where under the presence of oxygen fuel is ignited instantly to achieve the necessary speed the vehicle driver is aiming to achieve. During this process the car engine temperature is measured to reach nearly 1200 °C, thus releasing high concentrations of NO (Flynn Et Al., 1999; L. & MICHAEL S. GRABOSKI;, 2000).

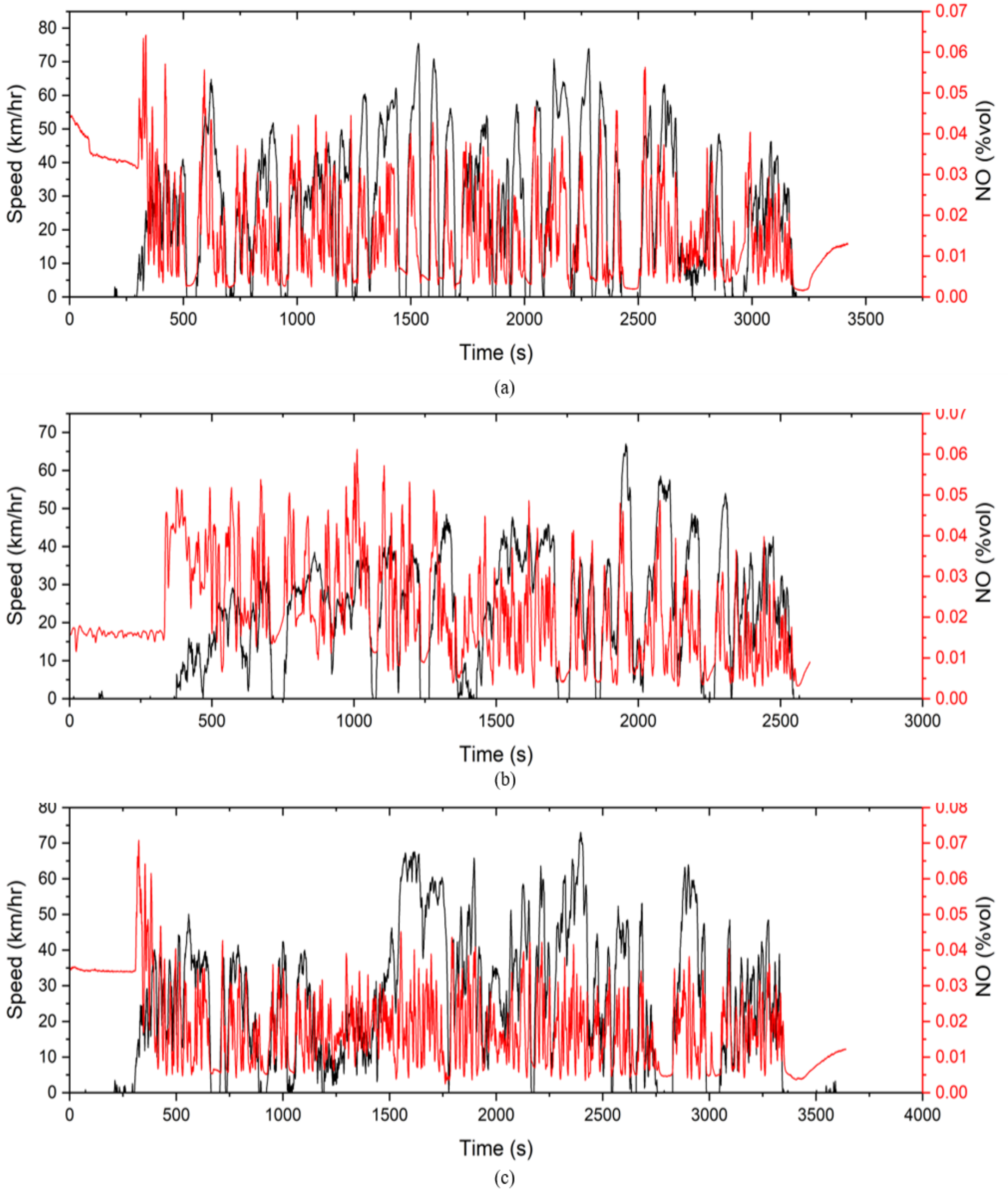

Figure 5.Speed and NO(%vol) concentration variation w.r.t. time (a) low-density (b) medium-density and (c) high-density roads

3.3. Non-exhaust Emissions

Silt load measurements were carried out at three different locations in Delhi, and the details are presented in Table 1 and Figure 6.

Table 1. Concentration of silt load, PM2.5 and PM10 at measuring locations in Delhi city

Road	Silt Loading (g/m^2.day)	PM2.5 Emission (g/VKm)	PM10 Emission (g/VKm)
IIT Main Gate	25	7.55	31.20
Qutub Institutional area	3	0.54	2.22
Munirka	44	12.40	51.25

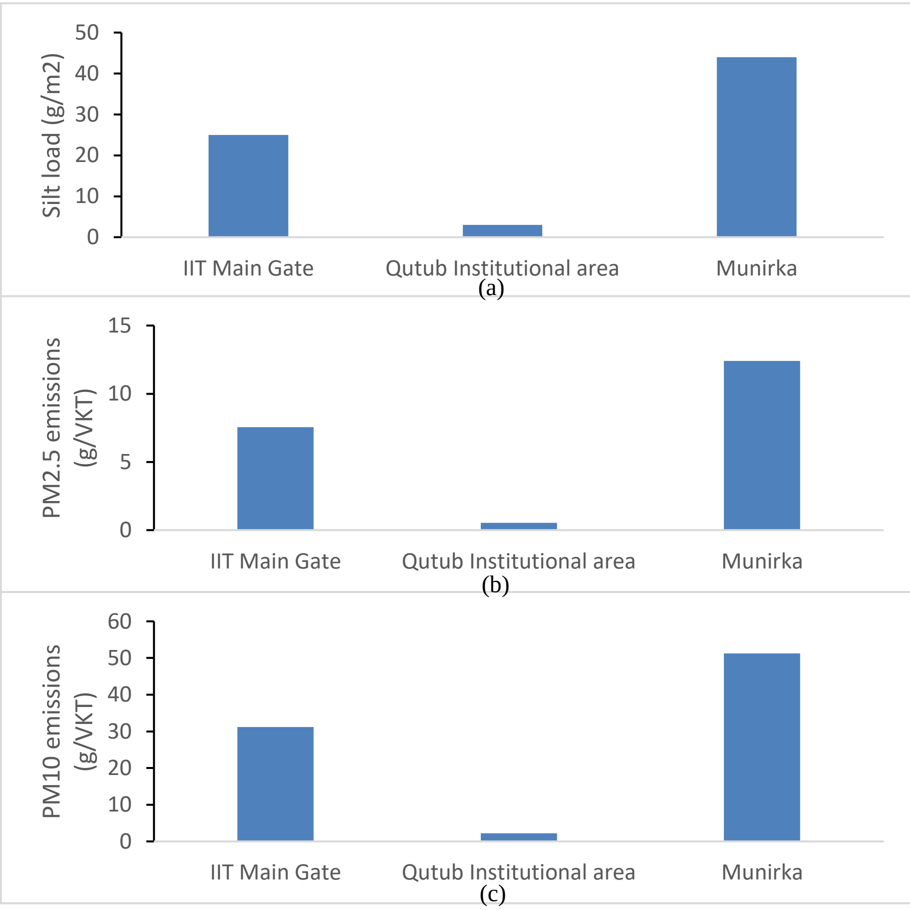

Figure 6.(a) Silt load (g/day.m2) (b) PM2.5 emissions (g/VKT) (c) PM10 emissions (g/VKT) at seven monitoring locations in Delhi

Results indicated that highest amount of silt load was observed at high-density road (44 g/m2.day) followed by medium-density (25 g/m2.day) and low-density (3 g/m2.day) roads.

4. Conclusion

In the present study vehicle and non-vehicle exhaust emissions on low (JNU road and Qutub institutional area), medium (IIT Delhi main road and JNU main road) and high-density (Munirka – Mahipalpur) roads were investigated. The real-world exhaust emission measurements indicated highest at Munirka – Mahipalpur road (0.09 g/s) with an average speed of 28 kmph. The minimum real-time exhaust emissions were found to be lowest on JNU and Qutub institutional area (0.03 g/s), where the average speed of the vehicle was 34 kmph. Even though the emission concentrations are within the BS IV standards, when it accounted for the entire vehicular fleet in Delhi city it would be in high concentrations. The Silt load measurements on the low, medium and high-density roads are carried out. Results showed high value (44 g/m2.day) was found to be at high-density road and least (3 g/m2.day) at low-density road.

5. Acknowledgment

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