Vehicular particulate matter emission factors in two road tunnels of São Paulo, Brazil

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INTRODUCTION

The metropolitan area of São Paulo (MASP) is the biggest megacity of South America with more than 21 million inhabitants. Former studies showed that MASP main particulate matter (PM) sources have changed over the last decades from mainly industrial to vehicular and soil suspension (Andrade *et al.*, 1993, Andrade *et al.*, 2017) emission. Nowadays, the study of the vehicular emissions have became a important matter of concern. Measurements inside traffic tunnels are very useful to estimate the fleet emission under real driving conditions. Previous São Paulo tunnels measurements were performed in 2004 (Sánchez-Ccoyllo et al., 2009) and 2011 (Pérez-Martínez et al., 2014).

This study presents concentrations and emission factors data for particulate matter with aerodynamic diameter less than 10 µm (PM10) and 2.5 µm (PM2.5).

The tunnels selected in this study were the same of the previous experiment in 2011, the Rodoanel Tunnel (RAT) and the Jânio Quadros Tunnel (JQT). The JQ was also considered in the 2004 experiment. The sampling occurred between October and November of 2018. Heavy-duty vehicles (HDV) are prohibited to run in JQT, so light-duty vehicles (LDV) are the main fleet there. RAT is located in a road beltway that carries both light and heavy-duty vehicles.

MATERIAL AND METHODS

PM2.5 and PM10 were sampled simultaneously using two MiniVol™ Air Sampler (Airmetrics, 5 L/min) with a PM2.5 inlet and quartz fiber filter (inside and outside of the tunnels), a Partisol™ sequential air sampler (ThermoFisher Scientifc, 16,6 L/min) with a PM2.5 inlet and Teflon filters (outside the tunnels), and a dichotomous ambient particulate sampler with polycarbonate filters (inside the tunnels). Four high volume sampler HiVol (Energética, 1000 L/min) was used with PM10 and PM2.5 inlets inside and outside the tunnels.

To calculate the emission factors, CO and CO2 concentrations was measured as well. The measurements were made using Thermo electron (48B) for CO and the Picarro-G1301 for CO2.

A photographic composition of the experiemnt is ilustrated in the figure 2.

The emission factors (EF) was calculated using the calculation proposed by Marr et al. (1999) and applied in tunnel measurement by McGaughey et al. (2004). The EF can be calculated by the following expression:

$$E_{PM} = 1000\left(\frac{\Delta[PM]}{\Delta[CO_2] + \Delta[CO]}\right)\omega$$

where E_{PM} is the emission factor of the particulate matter, Δ[PM] is the concentration of the pollutant (subtracted from the background value measured outside the tunnel, in µg/m³), and Δ[CO2] and Δ[CO] are CO2 and CO concentrations and ω is the fuel's carbon fraction (0.77). The concentration units of CO2 and CO used was µgC/m³, with a 12 g/mol conversion.

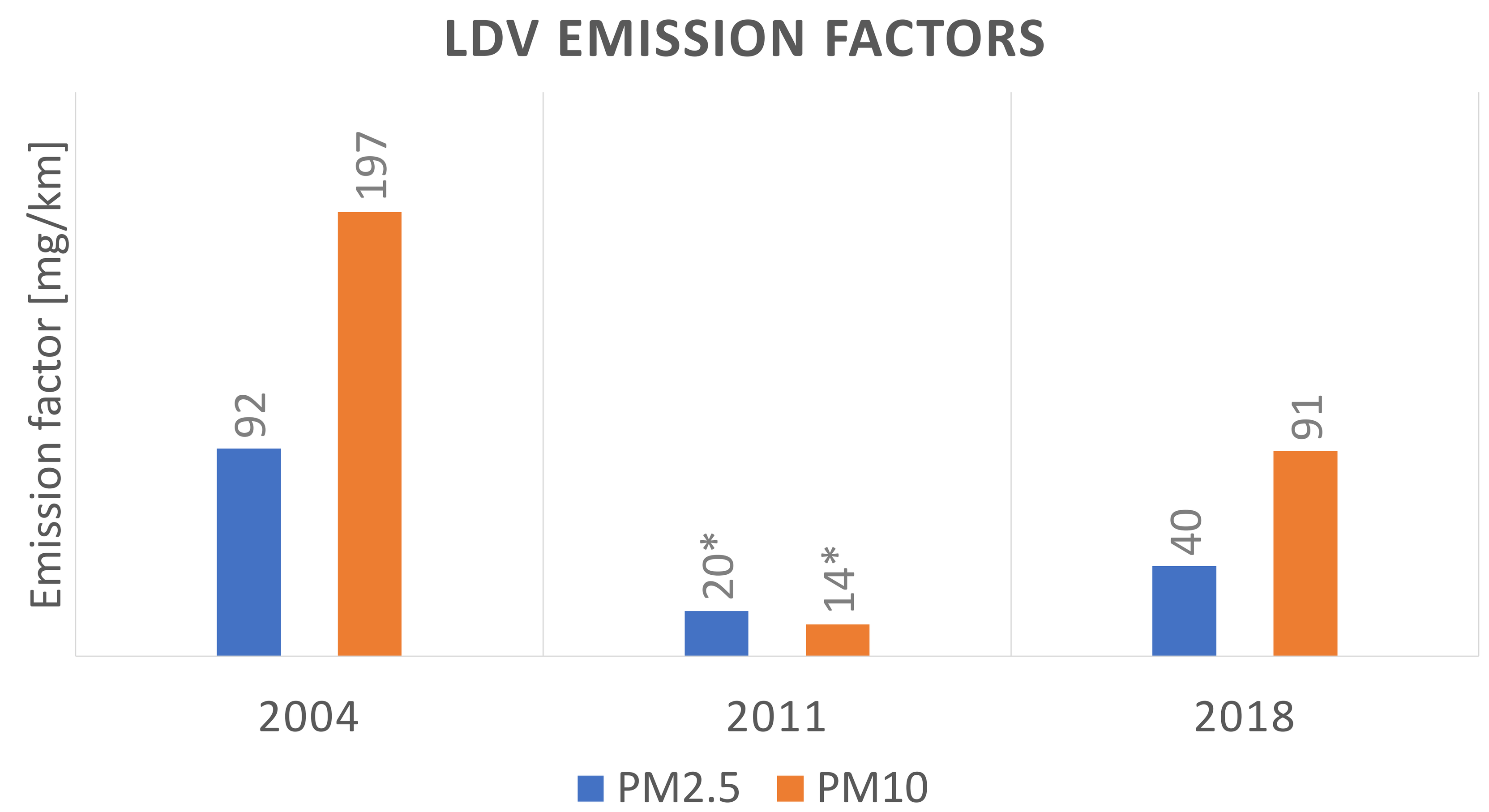
The HDV EF was calculated using traffic data and fuel consumption parameters to discount the LDV contribution to the TRA data as used in the previous studies.

RESULTS

Inside the RAT the mean concentration of PM2.5 was 64±19 µg/m³ and of PM10 was 73±19 µg/m³. Inside JQT the mean concentration of PM2.5 was 53±7 µg/m³ and of PM10 was 74±18 µg/m³. The emission factor of PM2.5 calculated for the light-duty vehicles is 40±6 mg/km, for the heavy-duty is 81±25 mg/km. For the PM10, the emission factor calculated for the light-duty vehicles is 91±16 mg/km, for the heavy-duty is 127±36 mg/km.

A comparison of the emission factors with the early studies is in the figure 1. A clear drop in the heavy-duty vehicles emission factors can be seem with the years. It is a reflex of the modernization of the fleet and the efectiveness of the health policies implementeds by the CETESB agency to drop the vehicular fleet emissions. A numerical raise in the light-duty vehicles emission factos was found, however, Pérez-Martínez et al. (2014) (2011 tunnel study) point out a LDV EF value problem, that could be due to the presence of traffic congestion episodes.

The black carbon and PM10 emission factors are still being calculated. Elementar concentrations will be measured as well to contribute with the characterization of the PM. Soil resuspension particulate matter was sampled and will be analyzed to improve the data quality.



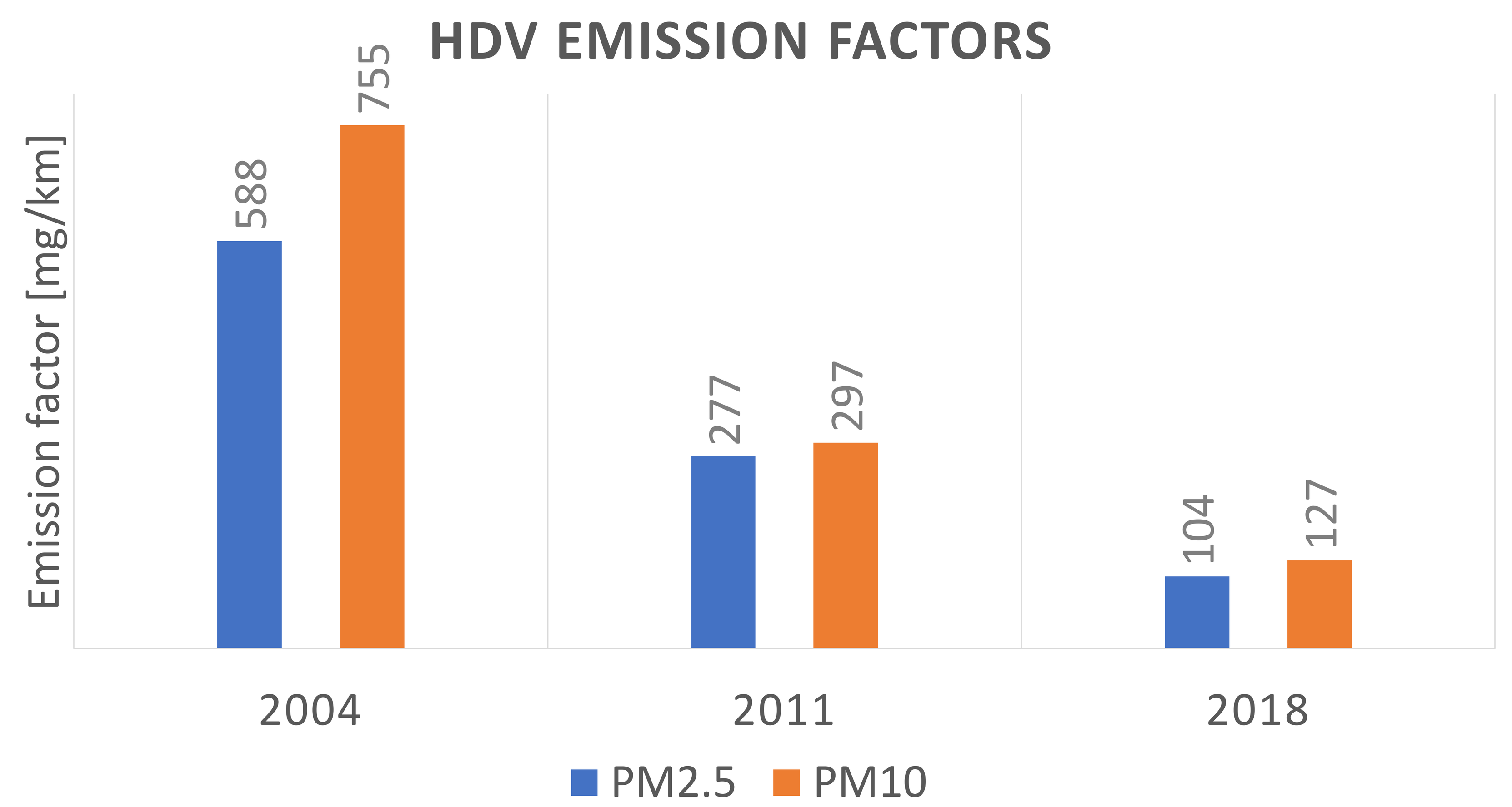


Figure 1: Emission factors of particulate matter (diameters less than 2.5 and 10 µm, PM2.5 and PM10 respectively) of light-duty vehicles (LDV) and heavy-duty vehicles (HDV) in São Paulo calculated in 2004, 2011 and 2018. The emission factor for 2004 was calculated by Sánchez-Ccoyllo et al. (2009). The emission factor for 2011 was calculated by Pérez-Martínez et al. (2014). The 2011 light-duty vehicles emission factors measurement presented issues due to the presence of traffic congestion episodes.

Figure 2: Photographic composition showing in the upper line, left to right: part of the team involved in the sampling on the Rodoanel's outer sample site; inner sample site in the Rodoanel tunnel's maneuvering bay and the entrance's outside view of the maneuvering bay. In the bottom line, left to right: Jânio Quadros' outer sample site and two views of the inner sample site in the Jânio Quadros tunnel.

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