Urban Climate 24 (2018) 111–120

Contents lists available at ScienceDirect

Urban Climate

journal homepage: www.elsevier.com/locate/uclim

Emission estimates for an on-road flex-fuel vehicles operated by ethanol-gasoline blends in an urban region, Brazil

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ARTICLE INFO

Keywords:
Exhaust gas emissions
Flex-fuel vehicles
Real-time traffic
VSP

ABSTRACT

Vehicle emissions have become the dominant source of air pollutants in many cities. Relatively few studies have examined the impact of different ethanol concentrations into fuel on exhaust emissions from flex-fuel vehicles on real-time traffic conditions. In this study, emissions analyses of carbon monoxide, carbon dioxide, nitrogen oxides and hydrocarbons were carried out in a flex-fuel vehicle in an urban route in the Fortaleza city/Brazil. The vehicular exhaust emissions of the pollutants above mentioned were measured through a portable analyzer. Route was performed with different ethanol/gasoline blends (27%, 85%, and 100% ethanol). VSP methodology was used in this work. On-board system data used could register instantaneous emissions as a function of vehicle dynamics. It was observed that the acceleration operation mode was the major responsible for highest emissions of CO, CO_2 and NO_x for all blends tested. C_xH_y emissions of < 0.005 g km^{-1} were registered. The results show the relevance of performing sampling in real-time traffic conditions, since the emission standards set by approved real-time traffic conditions do not often represent local reality.

1. Introduction

Road transportation is a key sector of the energetic economy as it supports the economic and social development of a country, especially related to efficient logistic of goods, resources, and mobility. Stability of several sectors, such as industrial, commercial, services and transportation, is usually driven by the quality and availability of energy sources. Indeed, the most energetic consumption in Brazil and world as well is demanded by the transportation sector (Policarpo et al., 2018; Saboori et al., 2014).

The ceaseless growth of vehicle fleet in the major urban areas such as São Paulo and Rio de Janeiro in Brazil, Detroit and Tokyo has intensely contributed with pollutant emissions, increasing atmospheric pollution (Pacheco et al., 2017; Zhang et al., 2013). Regulations for emissions standards to nitrogen oxides (NO_x), carbon monoxide (CO), hydrocarbons (C_xH_y) and particulates from mobile sources are becoming more stringent all over the world because most of them can induce severe human health damage (Billionnet et al., 2012; Muttamara and Leong, 2000; Zhang and Batterman, 2013).

Brazil has accounted 90,000 million of vehicles in 2016. Accordingly, located in the Brazil's northeast in the Ceará state, the Fortaleza city appeared as the seventh biggest national fleet, > 1 million vehicles in 2016 (Cassiano et al., 2016; Cavalcante et al.,

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https://doi.org/10.1016/j.uclim.2018.01.005
Received 29 July 2017; Received in revised form 19 December 2017; Accepted 28 January 2018

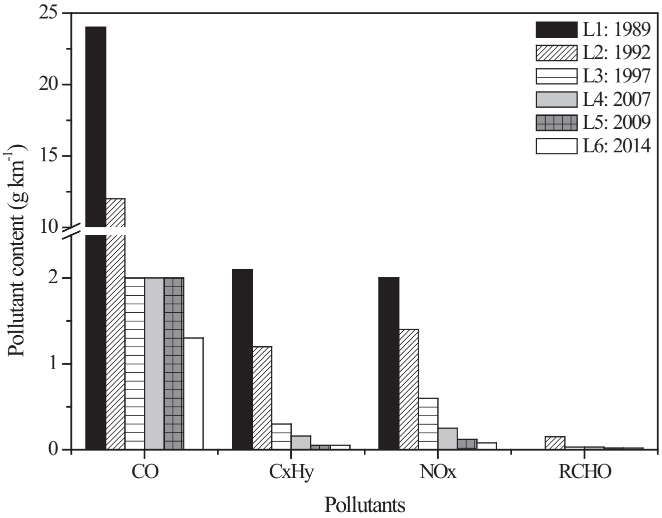

Fig. 1. Brazilian emission standards for light-duty vehicles (IBAMA, 2011).

2012; Policarpo et al., 2018; Sousa et al., 2015). As referred by Policarpo et al. (2018), the vehicle fleet of Fortaleza city has almost doubled between 2010 and 2015, and about 50,000 new vehicles per year have been added to the fleet. Nationally, the Brazilian National Council for the Environment (*Conselho Nacional do Meio Ambiente* – CONAMA) has created many programs to control pollutant emissions by light- and heavy-duty vehicles and motorcycles (IBAMA, 2011; Souza et al., 2013).

Fig. 1 shows the emission standards for conventional pollutants set by Brazilian's pollution control program for Otto-cycle vehicles through years, since the implementation. In this context, several countries have been adopting renewable fuels to reduce pollutant emissions. In 2003, Brazil introduced Otto-cycle vehicles powered by gasoline and/or hydrated ethanol, called as flex-fuel vehicles (FFV). Besides that, the Brazilian light-duty vehicles powered by gasoline have been using the ethanol/gasoline blend (27 vol% of ethanol) (Cassiano et al., 2016; De Melo et al., 2018; Policarpo et al., 2018). Europe established that 10% of fuels must come from renewable sources until 2020 (EC, 2009; Suarez-Bertoa et al., 2015). At about the same time, USEPA expects to introduce 136 million litters of biofuels that will be mixed in the gasoline, like in Brazil (Unger et al., 2010).

Vehicular emissions are strictly related to the driving style. To estimate exhaust emissions, typical tests named driving cycle are usually carried out, in which parameters such as speed, acceleration, distance, driving time, duration, and frequency of idles and starts are measured through on-board devices (Cassiano et al., 2016; Dardiotis et al., 2015; Surawski et al., 2012). The main focus of driving cycle procedure is to simulate a standard driving to predict real-world traffic driving style (Dardiotis et al., 2015; Oliveira et al., 2011; Silva et al., 2009; Suarez-Bertoa et al., 2015). To gather such data, the Predictive Emissions Monitoring System (PEMS) are often used. Brazil has adopted a driving cycle based on the American standards for light-duty and light commercial vehicles (FTP – Federal Test Procedure 75). This procedure is also described in detail by Brazilian standard NBR 6601. Other examples of standard procedures for driving cycles are the European (NEDC – New European Driving Cycle), the Japanese (JC08 test cycle), and the American (CAFE – Corporate Average Fuel Economy).

Regarding FFV, the impacts of atmospheric emissions caused by different concentrations of ethanol in the fuel blend when it is mixed with gasoline are scarce in literature (Dardiotis et al., 2015; Melo et al., 2012; Rodrigues Filho et al., 2016; Ruth and Baklanov, 2012; Suarez-Bertoa et al., 2015). Increased ethanol contents in the fuel may lead to increasing in organic compounds that act as ozone precursors and other pollutants species that may pose significant health risks. Analyses like these should be performed to fully quantify the environmental and health impacts of these reactions for all conditions and regions worldwide (Clairotte et al., 2013).

Thus, the goal of this work is to assess emissions of CO, CO_2, NO_x (NO and NO_2), and C_xH_y released by a flex-fuel vehicle in a real-time traffic through a Portable Emission Measurement System (PEMS), which is an on-board system. Furthermore, the Vehicle Specific Power (VSP) methodology (Jiménez-Palacios, 1999) was also applied for evaluation of vehicle emissions and to correlate the investigated real circuit to the different fuel blends.

2. Materials and methods

Three different ethanol/gasoline blends (27%, 85%, and 100% ethanol vol.) named as E27, E85, and E100, respectively, were tested for the real-time traffic. In Brazil, flex-fuel vehicles typically run on either E27, E100 or any mixture of them. E27 is known as C gasoline, which is a mixture of 27% of anhydrous ethanol and A-type gasoline (pure gasoline). E100 is the hydrated ethanol, composed by 96% of ethanol and 4% of water (vol.). These blends are regulated by the National Petroleum, Natural Gas and Biofuels Agency (*Agência Nacional do Petróleo, Gás Natural e Biocombustíveis* – ANP). E85 is a common blend used at many countries, included United States of America and European Union region. To get the E85 blend, it was combined C-type gasoline (E27) with hydrated ethanol (E100), accounting the water content. The hydrous ethanol (EHC) can have up to 4.9% v/v of water (Belincanta et al., 2016).