Benefits of new PROCONVE phases for light duty vehicles, considering vehicle refueling emissions in the São Paulo Metropolitan Area

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ABSTRACT

In the period from 2006 to 2018, the analysis of vehicle emissions data calculated with the methodology of CETESB - São Paulo State Environmental Agency, in São Paulo Metropolitan Area (SPMA), demonstrates the reduction of emissions by 52% for carbon monoxide (CO), 51% for non-methane exhaust hydrocarbons (NMHCexha), 64% for non-methane hydrocarbons by evaporative emissions (NMHCevap), 38% reduction for nitrogen oxides (NOx) and 59% for particulate matter (MP). However, vehicle refueling emissions increased by around 38% in the same period, due to the lack of regulation. CONAMA Resolution 492/2018 establishes the new L7/L8 phases of PROCONVE, where maximum fuel vapor emission limit is fixed at 50 $mg.L^{-1}$, during the filling of fuel tank. The objective of this work is to estimate the fuel vapor emissions that can be avoided by the establishment of the new limit, with occupational and environmental benefits.

RESUMO

No período de 2006 a 2018, a análise dos dados de emissões veiculares calculados com a metodologia da CETESB - Companhia Ambiental do Estado de São Paulo na Região Metropolitana de São Paulo, demonstra a redução das emissões em 52% para o monóxido de carbono (CO), 51% para os hidrocarbonetos não metano de escapamento (NMHCexha), 64% para os hidrocarbonetos não metano de emissão evaporativa (NMHCevap), 38% de redução para os óxidos de nitrogênio(NO_x) e 59% para o material particulado (MP). No entanto, as emissões de abastecimento veicular aumentaram cerca de 38% no mesmo período, devido à ausência de regulamentação. A Resolução n° 492/2018 do CONAMA estabelece as novas fases L7/L8 do PROCONVE, onde o limite máximo de emissão de vapor de combustível é fixado em 50 $mg.L^{-1}$, durante o abastecimento do tanque de combustível. O objetivo deste trabalho é estimar as emissões de vapor de combustível que podem ser evitadas a partir do estabelecimento do novo limite, com benefícios ocupacionais e ao meio ambiente.

GENERAL INFORMATIONS

Nowadays, even in times of pandemic and social isolation, air quality has attracted the attention of the general population, as well as researchers from various fields. Satellite images obtained from April to May 2020 have indicated significant decreases in detected levels of air pollutants, such as carbon monoxide (CO) and nitrogen oxides (NOx). Thus, the correlation between vehicle emissions and air quality in large urban centers is evident. Figure 1 indicates the 33% reduction in levels of nitrogen dioxide (NO_2) measured in SPMA in first half of year 2020.

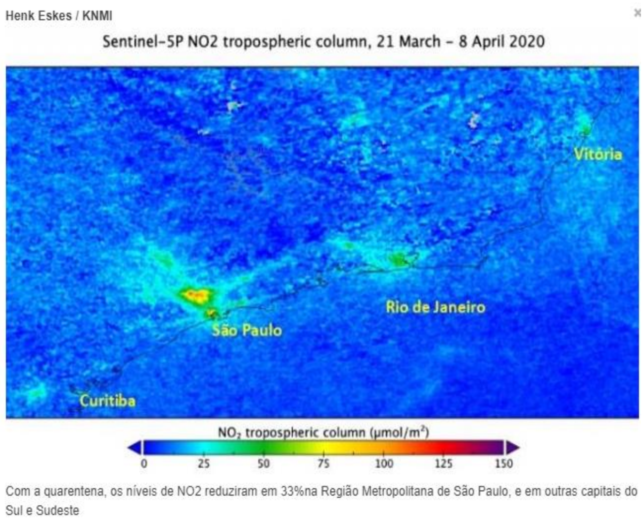

Figure 1. Reduction in the levels of nitrogen dioxide
Fonte:https://www.ipen.br/portal_por/portal/interna.php?secao_id=39&campo=14122 [1]

The drop in the levels of atmospheric pollutants can be attributed to reduction of vehicular and industrial activity. There were about 7,3 million vehicles in SPMA current fleet in 2018, consisting of categories of Otto cycle engine light-duty vehicles and Otto and Diesel cycles engines light-duty trucks, motorcycles, buses and heavy-duty trucks. Therefore, social isolation and consequent decrease in vehicular activity, in this period, contributed to the drop in vehicle pollutant emissions in São Paulo city and its metropolitan area. Thus, it is essential to identify sources of pollution and obtain emissions estimates of stationary and mobile sources in this period.

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INTRODUCTION

Air Pollution Control Program by Motor Vehicles (PROCONVE / PROMOT) was initially implemented in 1986 by the National Environment Council (CONAMA) with the implementation of Resolution 18/1986. Since then, the program has achieved measurable and objective results. For light-duty vehicles, the carbon monoxide (CO) emission limits were reduced from 24.0 $g.km^{-1}$ in the L1 phase of PROCONVE to 1.3 $g.km^{-1}$ in the current L6 phase. For non-methane hydrocarbons (NMHC) the limits have been reduced from 0.16 $g.km^{-1}$ in the L4 phase to 0.05 $g.km^{-1}$ in the L6. The nitrogen oxides (NOx) limits had a reduction of 2.0 $g.km^{-1}$ in the L1 phase, to 0.08 $g.km^{-1}$ in the L6 phase. The total-aldehydes limits decreased from 0.15 $g.km^{-1}$ (L2 phase) to 0.02 $g.km^{-1}$ in L6 phase and the particulate matter dropped from 0.05 $g.km^{-1}$ to 0.025 $g.km^{-1}$ from L3 to L6 phases. Evaporative emissions are also controlled. Program's main goal is to "reduce levels of pollutant emissions in motor vehicles, in addition to encouraging national technological development, both in automotive engineering and in methods and equipment for carrying out pollutant tests and measurements" [2].

The CONAMA Resolution 492/2018 [3] establishes the news PROCONVE L7/L8 phases beginning in the year 2022, where the fuel vapor emission maximum limit is fixed at 50 $mg.L^{-1}$ during filling fuel tank.

The purpose of this study is to estimate the fuel vapor emissions from vehicle refueling that can be avoided in the SPMA by the establishment of the new limit of 50 mg. L^{-1}.

Emissions of automotive fuels vapors, even gasoline or ethanol, have a high degree of toxicity for both the workers and the environment. Currently, when refueling a vehicle tank, about 1.14 g. L^{-1} of gasoline's vapor or 0.37 $g.L^{-1}$ of ethanol's vapor are emitted to the environment.[4]

A simple query to the chemical safety information sheet (FISQP) [5] of ordinary gasoline sold at Brazilian market shows that in addition to the risk of flammability / explosion, it can cause irritation to eyes, respiratory tract and skin, increase the likelihood of developing cancer, impair fertility and the development of fetuses, induce drowsiness and dizziness or even be fatal if inhaled or ingested by workers.

It must always be emphasized that the vehicular fuel vapors contribute to ozone formation, considering they are a type of volatile organic compounds that together with nitrogen oxides and solar radiation produce tropospheric ozone, damaging the air quality of big cities and urban agglomerations.

In 2018, despite the emissions of NOx and VOC pollutants amounts show a downward trend, the air quality standard of 8 hours ozone was exceeded in 18 days in the SPMA [6]. These data also reinforce the need to reduce these pollutants.

It can be seen that the vehicle emissions of pollutants regulated by PROCONVE / PROMOT showed reductions in the studied period. Figures 2 and 3 show the vehicle emissions values estimates for non-methane hydrocarbons exhaust ($NMHC_{exha}$) and non-methane hydrocarbons evaporative ($NMHC_{evap}$) from Otto cycle engine (Otto) light-duty vehicles (LDV) and light-duty trucks (LDT) in the period from 2006 to 2018.

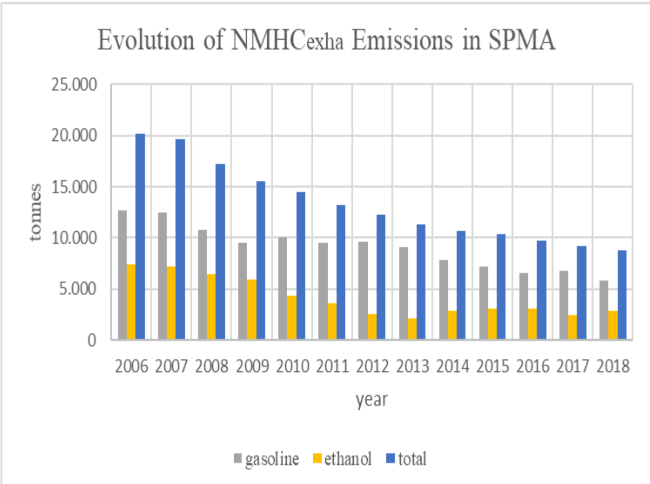

Figure 2. Temporal evolution of $NMHC_{exha}$ emissions from Otto LDV/LDT, from 2006 to 2018 [8].

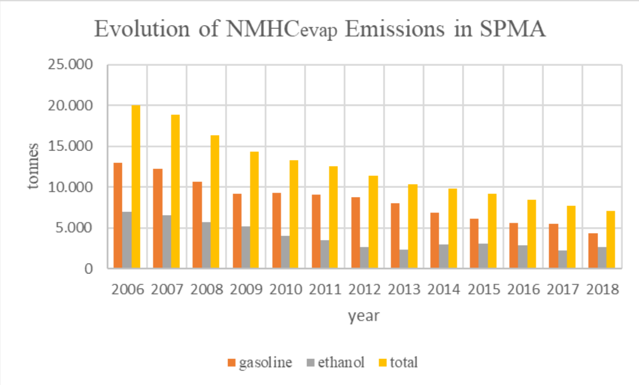

Figure 3. Temporal evolution of $NMHC_{evap}$ emissions from Otto LDV/LDT, from 2006 to 2018.[8]

The evolution of refueling emissions from Otto LDV/LDT in the SPMA increased significantly from 2006 to 2018 as shown in figure 4. The highest refueling emissions amount were observed in the year 2017, exceeding about 6000 tons total (gasoline and ethanol). Considering natural renewal of fleet and fuels consumption, the analysis of data demonstrated that the vehicle refueling emissions increased around 38% in the same period, due to the lack of regulation, as depicted in figure 4.

In 2018, it can be seen that there was a reduction in emissions from vehicles in the Otto LDV/LTD, due to the decrease in the consumption of common gasoline and the increase in the consumption of hydrated ethanol, as shown in figure 5.

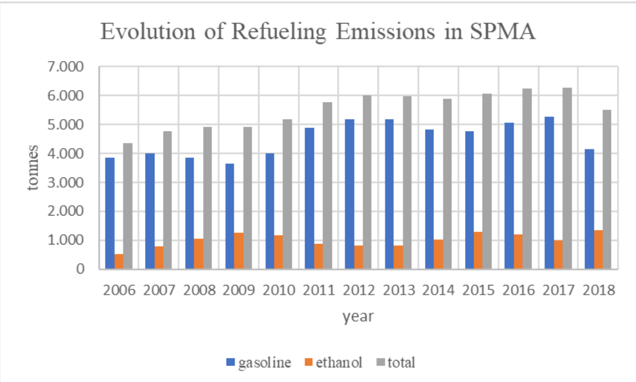

Figure 4. Temporal evolution of refueling emissions from Otto LDV/LDT in the metropolitan area of São Paulo, from 2006 to 2018.[8]

In the SPMA, from 2006 to 2018, the size of current fleet had been an increase of 32% in LDV (gasoline, ethanol and flex-fuel engines), 77% in Otto and Diesel cycle engine LDT, 20% in the Diesel cycle engines heavy-duty trucks and buses and the 86% increase in motorcycles (gasoline and flex fuel engines).

The figure 5 indicates the temporal evolution of the Otto LDV/LDT current fleet in the SPMA, from 2006 to 2018.

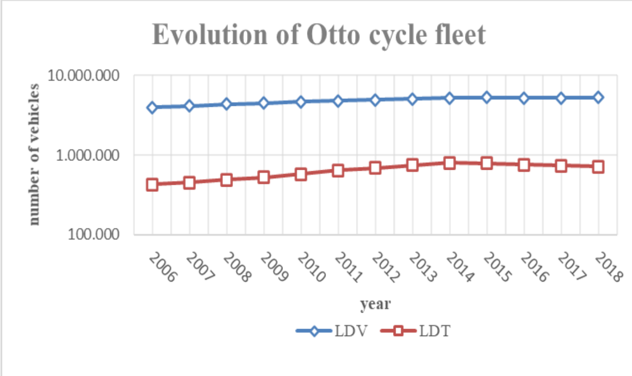

Figure 5. Evolution of Otto LDV/LDT in the SPMA, from 2006 to 2018.[8]

According to Goldemberg et al[7], the distribution of gasoline or ethanol consumption in flex-fuel vehicles is function of difference between the prices of gasoline and ethanol sold in the state of São Paulo. The methodology of distribution was based on the behavior of consumer (driver) front of retail price in the gas station.

As depicted in figure 6, it should be noted that the consumption of common gasoline is complementary to the consumption of ethanol, due to the use of flex-fuel vehicles. However, the common gasoline refueling emission factor is about 3 times higher than the similar from ethanol.

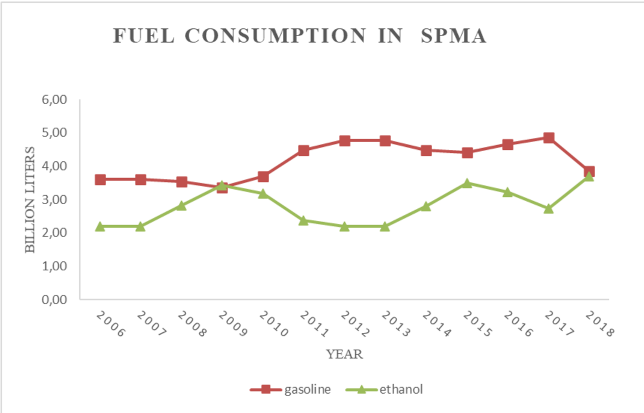

Figure 6. Temporal evolution of gasoline and ethanol consumption in the SPMA, from 2006 to 2018.[8]

METHODOLOGY

The methodology is divided into two major stages: the first one consisting of the characterization of the current fleet, involving the age of vehicles, scrapping profile and fuel consumption to adjust the vehicle activity. The second step, regarding the effective calculation of emissions, considers specific emission factors for each pollutant.

The equation 1 is used to calculate refueling emissions:

$$E_{refueling} = \sum Fe.((Flex\ Fuel\ Parcel(\%).Ve.\ Iu)/\ A) \quad \text{(equation 1)}$$

Where:

- $E_{refueling}$ is the annual emission rate of the pollutant considered (kg. year^{-1});
- Fe is the fuel emission factor considered (g.L^{-1});
- Flex Fuel parcel is the percentage of flex-fuel vehicles in the current fleet fueled with gasoline or ethanol in the year under study (%);
- Ve is the number of units for each type of vehicle, age and fuel considered;
- Iu is the amount of vehicular activity. It is specific to each type and age of the vehicle and it is expressed by annual mileage traveled (km. year^{-1}); and
- A is the autonomy or the distance traveled by the vehicle when consuming one liter of fuel (km. L^{-1}).

The current fleet comprises all vehicles with up to 40 years old. It was considered that vehicles of current fleet are in adequate maintenance conditions, according to manufacturers recommendations. The Table 1 shows the Flex Fuel parcel (%) in the current fleet per year.[7]. The Flex Fuel parcel represents the percentage of vehicles fueled with ethanol or gasoline in the specified year.

Table 1. Flex Fuel parcel applied in this study.

Year	***Flex Fuel Parcel (%)***	
	ethanol	**gasoline**
2006	89	11
2007	97	3
2008	96	4
2009	91	9
2010	91	9
2011	49	51
2012	57	43
2013	63	37
2014	63	37
2015	63	37
2016	48	52
2017	50	50
2018	71	29

The figures 7 and 8 indicate the reference mileage intensity that represents the distance traveled per age and type of vehicle. This variable needs to be adjusted according to fuel consumption observed in the region of interest.

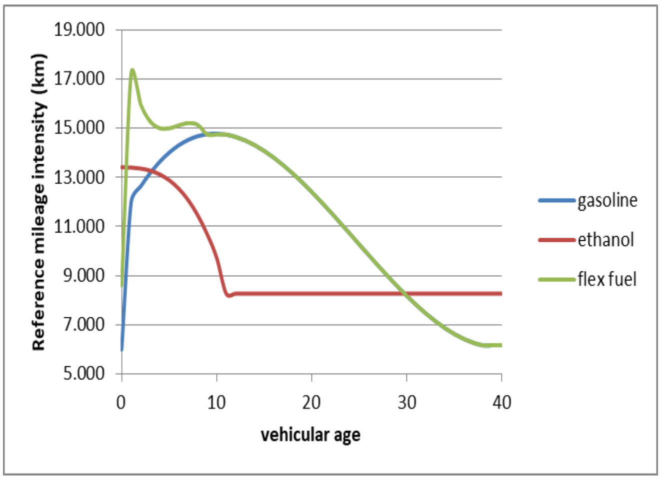

Figure 7. Reference mileage intensity of Otto LDV adopted[8].

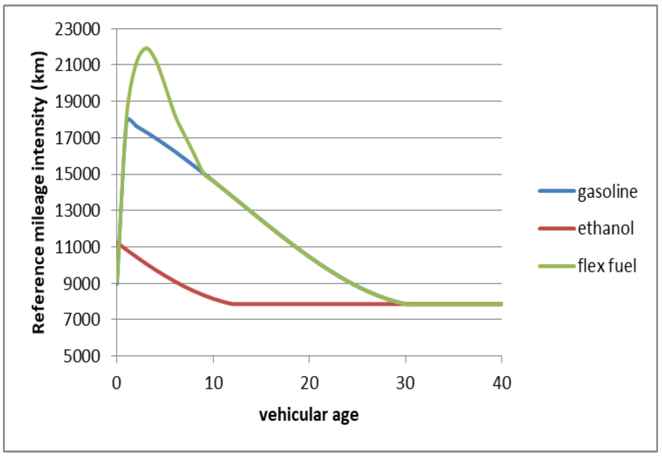

Figure 8. Reference mileage intensity of Otto LDT adopted[8].

RESULTS AND DISCUSSION

The Table 2 shows the quantification of the results obtained, according to the percentage of the fleet replaced by vehicles that comply with the new refueling emission limits from PROCONVE L7/L8. The values of emissions avoided and the corresponding percentages of emissions avoided are presented.

In these scenarios which the current fleet of the SPMA would be partially replaced by vehicles that met the 50 mg.L^{-1} new requirement for the refueling emission standard from PROCONVE L7/L8, the results indicated the withdrawal of until about 1400 tons of gasoline and 700 tons of ethanol from the environment.

Table 2. Results obtained in replacement of the fleet in studied scenario.

Replacement rate (%)	*Replaced vehicles (n). 10^3*	*Refueling emission avoided (tons)*	*Refueling Emission avoided (%)*
10	589	357	6
20	1179	830	15
30	1768	1161	21
40	2358	1789	33
50	2947	2169	39

In figure 9, a graphic is shown in which the part of Otto LDV/LDT current fleet in the SPMA is gradually switched from 10% to 50% by vehicles respecting the new PROCONVE L7 / L8 limit of refueling emission, considering only the year 2018.

Considering the total emissions of non-methane hydrocarbons that include exhaust, evaporative and refueling emissions, the Table 3 shows the percentage of total non-methane hydrocarbon emissions avoided, following the rate of fleet replacement at SPMA in 2018.

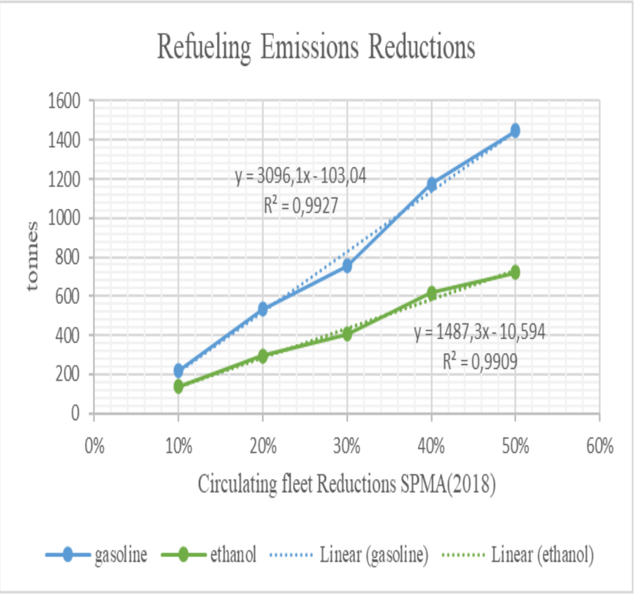

Figure 9. Graphic of refueling emissions reductions curves as function of the percentage of change in Otto LDV/LDT fleet in the SPMA, in 2018.

Table 3. Results obtained in replacement of the fleet, considering the total emissions of non-methane hydrocarbons in the SPMA, in 2018.

Replacement rate (%)	*Emission avoided in NMHC total emission(%)*
10	2
20	4
30	5
40	8
50	10

CONCLUSIONS

The results obtained with the implementation of PROCONVE / PROMOT are objective and measurable since the beginning of the program in Brazil. In this way, the new phases continue with the objective of reducing vehicle emissions and improving air quality in cities and metropolitan regions.

Considering new phases of PROCONVE L7 / L8 for light-duty vehicles and with the gradual change of current fleets in large cities and metropolitan regions, a large removal of pollutants of the environment can be achieved, as showed in the scenario considered in this study, with occupational and environmental benefits.

However, the implementation of new refueling emission limit is schedule for 2023 until 2025, when 100% of new vehicles will be complying the standard. Considering the low rate of fleet renew, significative environmental benefits will be achieved only in the next decade, when at least 50% of current fleet will be controlled. Faster results depend on the development of new programs of accelerated fleet renew.

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