Assessment of the impacts of traffic restriction during COVID-19 pandemic on vehicle emissions of local pollutants and greenhouse gases (GHG) in São Paulo State

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ABSTRACT

The COVID-19 pandemic imposed many restrictions on urban mobility in several Brazilian municipalities, causing a decrease in the circulation of people and vehicles in several regions in São Paulo State. This work aims to present the changes in vehicle emissions estimates obtained with CETESB methodology (Environmental Agency of São Paulo State), in the years 2019 to 2020. The indicators of adjusted use intensity, of annual distance covered and greenhouse gases emissions (GHG) per inhabitant, are compared; in addition to fuel consumption and circulating fleet. There was a reduction of about 7% in adjusted use intensity indicator, as well as a 9% reduction in annual distance covered indicator and a 6% reduction in greenhouse gases emissions (GHG) indicator per inhabitant. There was a reduction in pollutant emissions due to mobility restrictions, especially in Otto cycle vehicles (CO, VOC) because Diesel cycle vehicles have a different profile of use. However, reductions in emissions of particulate matter (PM) and nitrogen oxides (NOx) were also observed. There have been reductions in greenhouse gases emissions (GHG), due to decreased consumption of fossil fuels.

RESUMO

A pandemia de COVID-19 impôs muitas restrições à mobilidade urbana em diversos municípios brasileiros, provocando a diminuição da circulação de pessoas e veículos em diversas regiões no estado de São Paulo. Este trabalho tem o objetivo de apresentar as alterações nas estimativas das emissões veiculares obtidas com a metodologia empregada pela CETESB (Companhia Ambiental do Estado de São Paulo), nos anos de 2019 e 2020. São comparados os indicadores da intensidade de uso ajustada, de distâncias anuais percorridas e da emissão de gases de efeito estufa (GEE) veicular por habitante; além do consumo de combustíveis e a frota circulante. Houve a redução de cerca de 7% no indicador de intensidade de uso ajustada, assim como a redução de 9% no indicador de (distâncias anuais percorridas e de 6% no indicador de emissão de gases de efeito estufa veicular(GEE) por habitante. Houve redução nas emissões de poluentes devido às restrições de mobilidade, principalmente nos veículos do ciclo Otto (CO, COV), pois os veículos do ciclo Diesel possuem um perfil de uso diferenciado. No entanto, também foram observadas reduções nas emissões de material particulado (MP) e óxidos de nitrogênio (NOx). Ocorreram reduções nas emissões de gases de efeito estufa (GEE), devido à diminuição do consumo de combustíveis fósseis.

GENERAL INFORMATIONS

The COVID-19 pandemic has changed the urban mobility of capitals and metropolitan regions. Figure 1 shows an image obtained by NASA (National Aeronautics and Space Administration) that demonstrates the reduction of nitrogen dioxide (NO_2) levels in a Chinese area, in the year 2020. The mandatory social isolation and teleworking made people use less cars and consume fewer products, thus reducing emissions of local pollutants and greenhouse gases (GHG).

It can be noted that in 2020 the State Decree nº. 64,881, of March 22, 2020; established the quarantine measure in São Paulo State, with restrictions on activities in order to avoid the possible contamination or spread of the coronavirus.

This quarantine took effect from 03/24/2020, extending throughout the year, as a necessary measure to face the COVID-19 pandemic. [1]

This work aims to present the changes in the estimates of vehicular emissions obtained with the methodology used by CETESB (Companhia Ambiental do Estado de São Paulo) in the period of the COVID-19 pandemic, caused mainly due to decrease in circulation of people and vehicles. in several areas in São Paulo State.

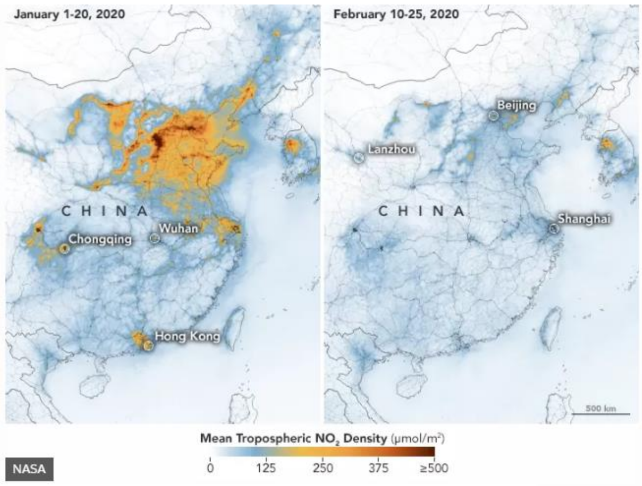

Figure 1. Satellite images show pollution in China before and after the Coronavirus outbreak. Source:(NASA)[2]

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INTRODUCTION

Figure 2 shows the estimated rate of social isolation in São Paulo State, from February 2020 to February 2021. The highest rates of isolation could be observed in March 2020, where stricter measures were adopted to control agglomerations and/or movement of people.

Figure 2. Social isolation index obtained from February 2020 to February 2021, in São Paulo State.[3]

The figure 3 indicates the decrease in consumption of hydrated ethanol and gasoline in 2020, during the COVID-19 pandemic. The diesel oil consumption profile is typical for commercial and cargo transport, which has remained constant in recent years.

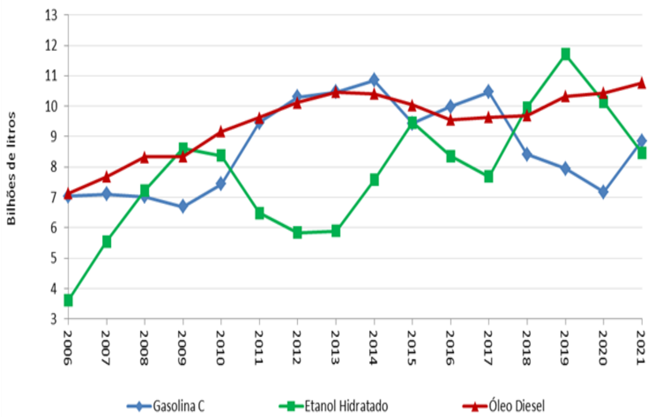

Figure 3. Evolution of fuel consumption in the highway segment, in São Paulo State.
Source: CETESB(2022)[4]

Normally, the consumption of gasoline is complementary to the consumption of hydrated ethanol and varies according to the prices of the two fuels and use in flex fuel vehicles, which is a fleet that is increasingly present in the circulating fleet of municipalities and metropolitan area of São Paulo State.

The indicator of annual distances traveled (km/year) showed a significant reduction, from 160.10^9 km/year to 145.10^9 km/year (about 9,4%), since it is strongly dependent on vehicular activity, as shown in Figure 4.

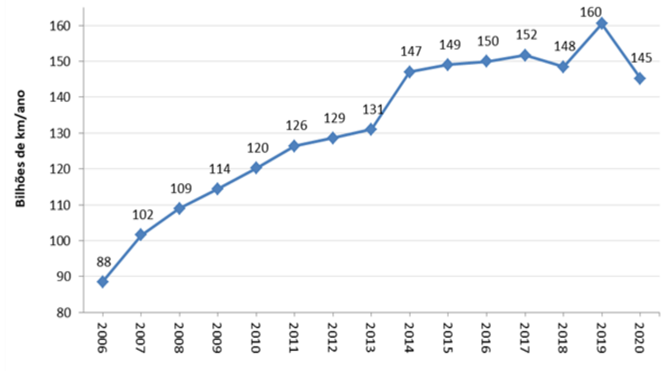

Figure 4. Evolution of the annual distance traveled indicator in São Paulo State
Source: CETESB(2022)[4]

The figure 5 shows the evolution of the adjusted use intensity indicator in São Paulo State from 2006 to 2020. There was a reduction from $15{,}1.10^3$ km/year to $14{,}1.10^3$ km/year, reflecting the drop in use of fuels, mainly gasoline and hydrated ethanol.

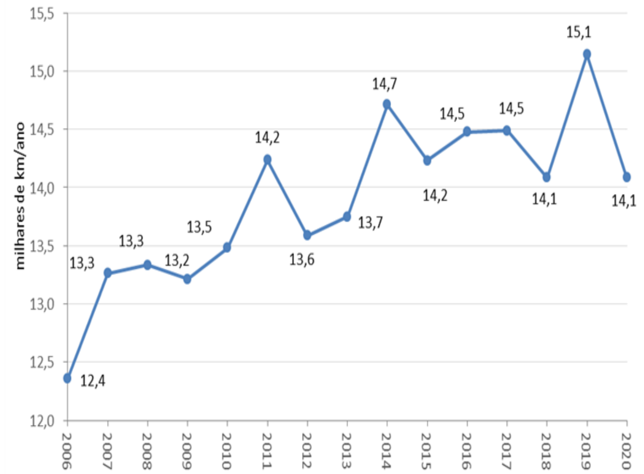

Figure 5. Evolution of the adjusted intensity of use indicator, in São Paulo State.
Source: CETESB(2022)[4]

In Figure 6, the indicator of greenhouse gas (GHG) emissions from vehicles per inhabitant in São Paulo State decreased from 0.87 t CO_2eq per inhabitant to 0.82 t CO_2eq per inhabitant, from 2019 to 2020, due to the reduction of gasoline consumption in cars. The downward trend that had been occurring since 2014 was reversed due to the small increase in gasoline consumption in 2017 and fell again in 2020, mainly due to the reduction in gasoline consumption in cars.

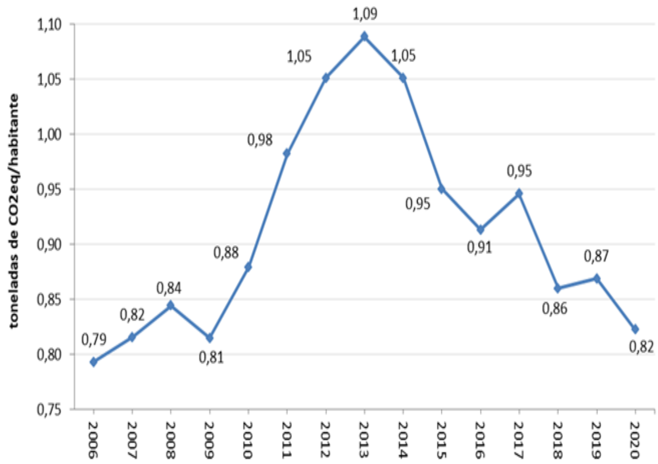

Figure 6. Evolution of the vehicular greenhouse gas (GHG) emissions indicator per inhabitant, in São Paulo State.
Source: CETESB(2022)[4]

METHODOLOGY

The calculation is divided into two major steps: the first consists of characterizing the current fleet, involving fleet age, scrapping profile and fuel consumption to correct the intensity of use. The second step, referring to the effective calculation of emissions, considers the specific emission factors for each pollutant.
For all vehicle categories, the pollutants considered were:

- Carbon monoxide (CO);
- Volatile Organic Compounds (VOC);
- Nitrogen oxides (NOx);
- Particulate matter (PM); and
- Carbon dioxide equivalent (CO_2eq) composed of the gases CO_2, CH_4 and N_2O weighted by the GWP (Global Warming Potential), over a 100-year horizon IPCC[5].

To calculate vehicular emissions, it is necessary to obtain data from several databases, such as:

1. Annual licensing of new vehicles in the last 40 years, from the National Association of Motor Vehicle Manufacturers [6].
2. Annual consumption of diesel oil, from the National Agency of Petroleum, Natural Gas and Biofuels [7].
3. Vehicle survival rates (scrap curves) [4].
4. Reference intensity of use (km/month), from the Environmental Company of the State of São Paulo [8].
5. Average new vehicle emission factors by category, by pollutant and by year of manufacture [4].
6. Vehicle range data by category and year of manufacture [4].

7. Data on the registered vehicle fleet, by category and by year of manufacture (for the calculation of emissions by regions or municipalities) [4].

The general equation for calculating vehicle emissions used is equation 1:

$$E = Fe \times Fr \times Iu \qquad \text{(equation 1)}$$

Where:

- E is the emission rate of the pollutant considered (g/month);
- Fe is the emission factor of the pollutant considered. It is specific to each type of vehicle, age and fuel used. It is expressed as the mass of pollutants emitted per kilometer traveled (g pollutant/km);
- Fr is the fleet of vehicles in use for each type of vehicle, age and fuel considered. It is expressed in number of vehicles; and
- Iu is the vehicle usage intensity. It is specific for each type and age of vehicle, expressed in monthly mileage traveled (km/month).

The emission factors by category/fuel and pollutant result from the weighted average of emission tests of the best-selling new vehicle models, for the monitoring of PROCONVE/PROMOT[4]

The fleet in circulation comprises all vehicles with up to 40 years of manufacture. For this work, it was considered that the vehicles of the circulating fleets are in adequate conditions of maintenance, according to the recommendations of the manufacturers. Figure 7 shows the survival rate used in the calculation of the circulating fleet in São Paulo State, from 2017 to 2020.

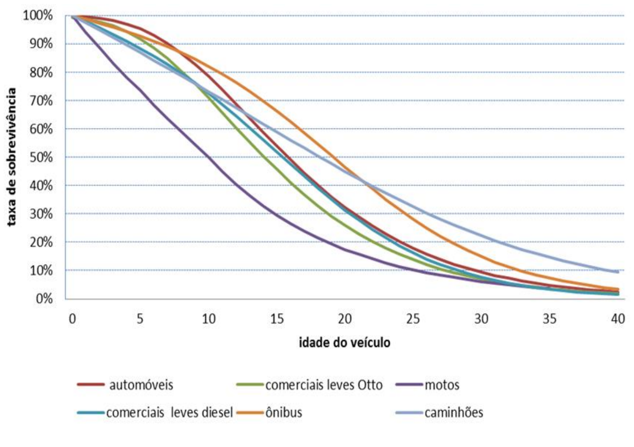

Figure 7. Survival rate of vehicles by category, as a function of age, up to 40 years.
Source: CETESB(2022)[4]

The reference usage intensity represents the mileage or distance traveled per month and by vehicle type. This variable represents a diversified fleet, where there are light duty and heavy duty vehicles, in addition to motorcycles, and each category has its own profile of use. Thus, the reference use intensity variable needs to be adjusted according to the fuel consumption observed in the region of interest. The estimates of intensity of reference use or monthly mileage traveled by category were used, varying according to the age of the vehicle. From the values of reference intensity of use and the volume of fuel consumed in the studied areas, the adjustment of the intensity of use or the monthly mileage traveled was carried out.

RESULTS AND DISCUSSION

The table 1 shows the annual variation in fuel consumption in São Paulo State, from 2017 to 2021. It can be seen that in the period 2019/2020 there was a significant reduction in the consumption of gasoline and hydrated ethanol, and a maintenance in the consumption of diesel oil. In the 2020/21 period, there was a recovery in the consumption of gasoline, a reduction in the consumption of ethanol and an increase in the consumption of diesel oil, which has a different consumption profile, more dependent on cargo transport.

Table 1. Annual variation in fuel consumption in São Paulo State, from 2017 to 2021.Source: ANP(adapted)[7]

Fuel	annual variation in fuel consumption São Paulo State			
	17/18	18/19	19/20	20/21
gasoline C	-20%	-6%	-10%	23%
Hydrous ethanol	30%	17%	-13%	-16%
Diesel oil	1%	7%	1%	3%

Figure 8 shows the evolution of the monthly consumption of gasoline in the road segment in 2017, 2018, 2019 and 2020, in São Paulo State. We can highlight the higher consumption of gasoline in 2017 and usually an increase in March of each year. However, specifically in 2020, there was a large reduction in the consumption of this fuel in March and April 2020, corresponding to the beginning of the COVID-19 pandemic. Consumption increased over the months until the end of 2020.

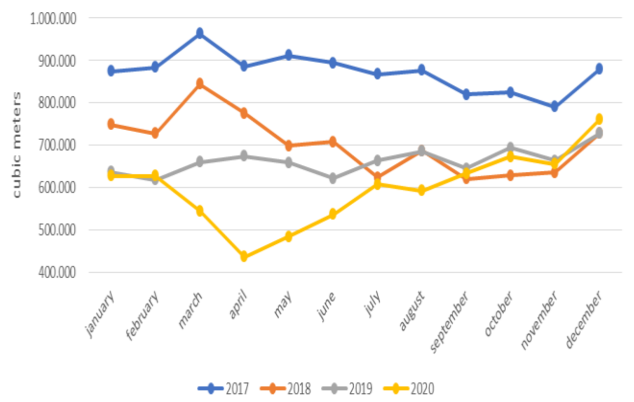

Figure 8. Evolution of the monthly consumption of gasoline in the highway segment in 2017, 2018, 2019 and 2020, in São Paulo State. Source: ANP(adapted)[7]

As shown in the figure 9, the evolution of the monthly consumption of hydrated ethanol in the road segment in 2017, 2018, 2019 and 2020, in São Paulo State. The highest consumption of hydrated ethanol in 2019 can be highlighted. Coincidentally in 2020, there was a large reduction in the consumption of this fuel in March and April 2020, at the beginning of the COVID-19 pandemic. Consumption increased over the months until the end of 2020. The fuels used in Otto cycle vehicles have complementary consumption, depending on the availability of gasoline and hydrous ethanol and the average price of each, at gas stations in Sao Paulo State.

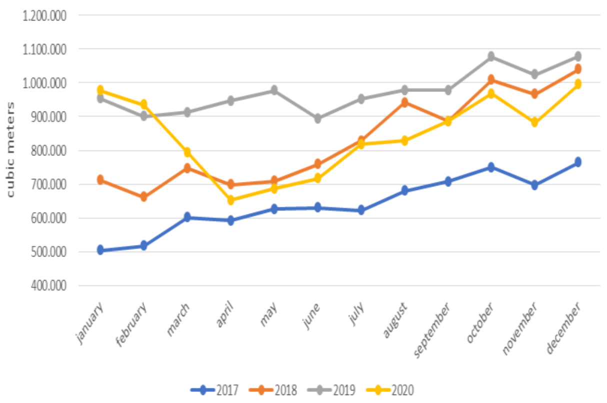

Figure 9. Evolution of the monthly consumption of hydrated ethanol in the road segment in 2017, 2018, 2019 and 2020, in São Paulo State.
Source:ANP(adapted)[7]

Figure 10 indicates the evolution of monthly consumption of diesel oil in the road segment in 2017, 2018, 2019 and 2020, in São Paulo State. The consumption profile of diesel for road use is different from the consumption profile of gasoline and hydrous ethanol, due to commercial use and cargo transport. Thus, the consumption of diesel oil remains growing and/or stable in the period observed.

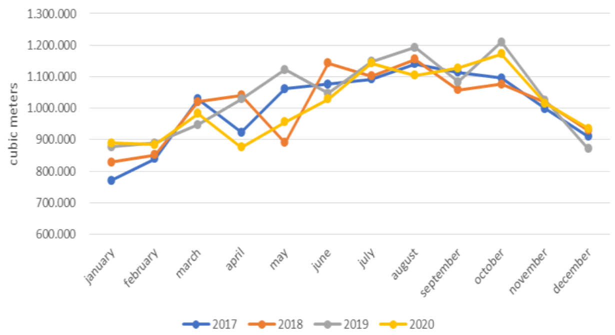

Figure 10. Evolution of monthly diesel oil consumption in the highway segment in 2017, 2018, 2019 and 2020, in São Paulo State.
Source: ANP(adapted)[7]

The figure 11 shows the evolution of CO emissions, in tonnes per month, from 2017 to 2020 in São Paulo State. For the most part, carbon monoxide (CO) emissions are attributed to Otto cycle cars and light commercial vehicles. The highest CO emissions occurred in 2019, while in 2018 there was a large variation. However, in 2020 there were significant decreases, such as a reduction in the months from March to April, followed by a growth until July, with another growth peak in October.

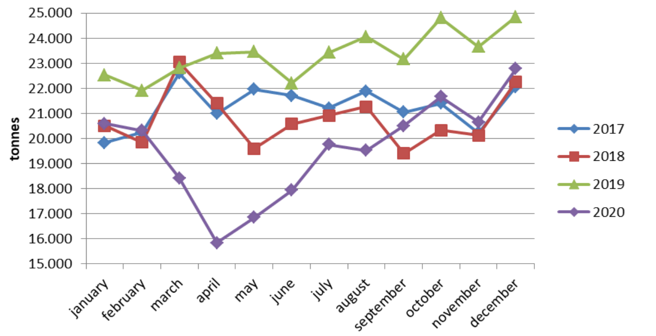

Figure 11. Evolution of CO emissions (t/month) in São Paulo State, from 2017 to 2020.

The figure 12 indicates the evolution of VOC emissions in tonnes per month, from 2017 to 2020 in São Paulo State. Volatile organic compound (VOC) emissions are also primarily attributable to Otto cycle automobiles and light commercial vehicles. The highest VOC emissions occurred in 2017, but in 2020 there were significant decreases, such as a large reduction from March to April, followed by an increase until July, with another growth peak in October.

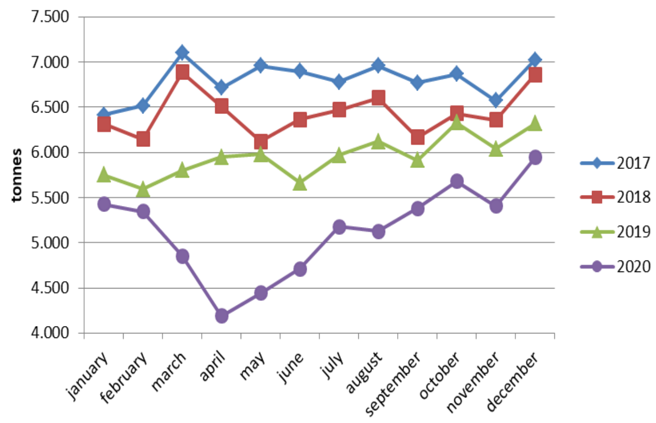

Figure 12. Evolution of VOC emissions (t/month) in São Paulo State, from 2017 to 2020.

The figure 13 shows the evolution of NOx emissions in tonnes per month, from 2017 to 2020 in São Paulo State. Emissions of nitrogen oxides (NOx) are also mainly attributed to diesel cycle vehicles. The highest NOx emissions occurred in 2017, but in 2020 there were also significant decreases, such as a large reduction in April, followed by an increase until July, with another growth peak in October.

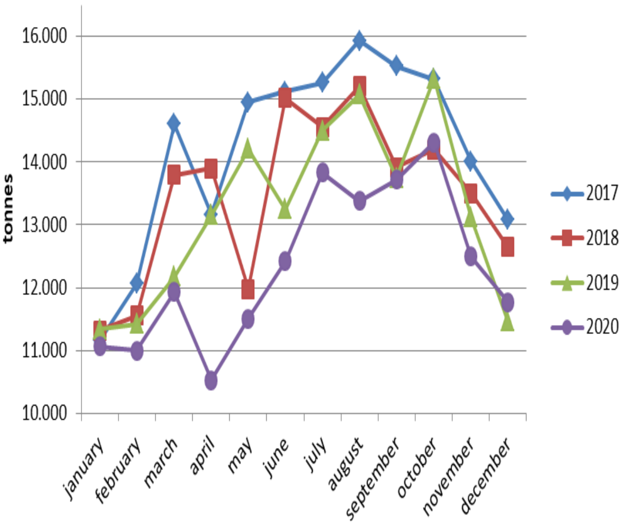

Figure 13. Evolution of NOx emissions (t/month) in São Paulo State, from 2017 to 2020.

The figure 14 indicates the evolution of PM emissions in tonnes per month, from 2017 to 2020 in São Paulo State. Particulate matter (PM) emissions are also mainly attributed to diesel cycle vehicles. The highest PM emissions occurred in 2017, but in 2020 there were also significant decreases, such as a large reduction in April, followed by an increase until July, with another growth peak in October.

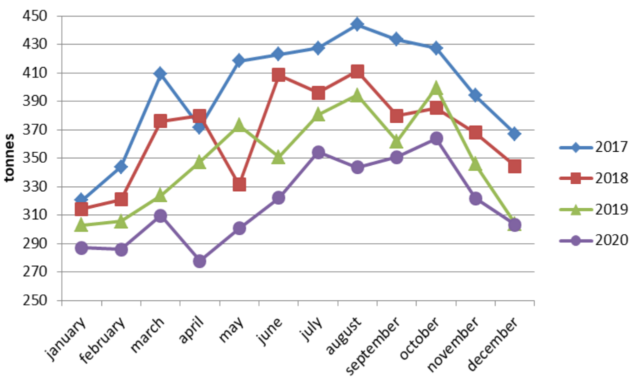

Figure 14. Evolution of PM emissions (t/month) in São Paulo State, from 2017 to 2020.

The figure 15 shows the evolution of carbon dioxide equivalent emissions (CO_2eq) in tonnes per month, from 2017 to 2020 in São Paulo State. The highest emissions of carbon dioxide equivalent (CO_2eq) occurred in 2017, but in 2020 there were significant decreases, such as a large reduction in April, followed by an increase until July, with another growth peak in October.

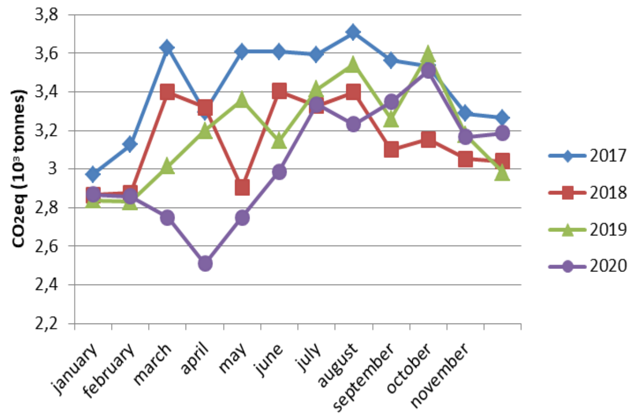

Figure 15. Evolution of carbon dioxide equivalent emissions (CO_2eq) -thousand - t/month) in São Paulo State, from 2017 to 2020.

CONCLUSIONS

Attributed mainly to Otto cycle cars and light duty commercial vehicles, variations in vehicle emissions of carbon monoxide (CO) from 2017 to 2020, and volatile organic compounds (VOC) in São Paulo State were presented, which indicated significant reductions during the period of the COVID-19 pandemic. The results correspond to the consumption of gasoline and hydrous ethanol registered in São Paulo State, in the corresponding period.

For diesel oil, the consumption indicated in the period presented, a different profile due to the intensive use of this fuel in the transport of goods/cargo that was not interrupted during the COVID-19 pandemic. But vehicle emissions also indicated a less significant drop in emissions of particulate matter (PM) and nitrogen oxides (NOx).

Considering carbon dioxide equivalent (CO_2eq) of vehicular origin, a reduction in emissions was also observed in the period of the COVID-19 pandemic, corresponding to the use of fossil fuels.

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