Quantification of CO2 Emissions by Top-down Method of Manaus Public and Private Transport Fleet

Maurício de Jesus Carretilha
mauriciocarretilha@gmail.com
FAMETRO University Center – Brazil

Fabiana Rocha Pinto
fabiana.floresta@gmail.com
Engineering Coordination at FAMETRO University Center – Brazil

David Barbosa de Alencar
david002870@hotmail.com
Galileo Institute of Technology and Education of the Amazon – ITEGAM

Gisele de Freitas Lopes
gikalps@gmail.com
Galileo Institute of Technology and Education of the Amazon – ITEGAM

Abstract

Air pollutants emitted by motor vehicles make a major contribution to air pollution in large urban centers, accounting for about 75% of emissions. The estimation of GHG emissions by the "Top-down" method used in the National Energy Balance - BEN, provides for the conversion of all fuel consumption measures to a common unit. Thus, the study aimed to guide the monitoring and monitoring of the concentrations of pollutant gases emitted by diesel combustion vehicles, comparing CO2 emissions in 2018, in two public and private transport fleets in the city of Manaus. - AM Based on the application of the Top-Down methodology generating the data in the comparative table of public and private transport companies, it is evident that CO2 emissions for both fleets present a high air pollution index suggesting the adaptation of the vehicle fleet. by adopting similar fuel with lower pollutant content. The data obtained in the study show that fuels with low emission factors should be used in urban public transport vehicles.

Keywords: Pollutants; Diesel; Carbon dioxide.

1. Introduction

Over time, due to the significant increase in the population living in urban areas, there has been a greater demand for transport and quantity of goods transported, sharply aggravating emissions of pollutant gases emitted by motor vehicles, changing the air characteristics (MANZOLI, 2009).

In view of the debate on global warming and climate change, it is necessary to analyze the causes and propose improvements to avoid the possibility of disastrous consequences for humanity in the future.

Air pollutants emitted by motor vehicles make a major contribution to air pollution in large urban centers, accounting for about 75% of emissions (INEA, 2009).

With regard to air quality, National Environmental Council Resolution (CONAMA) No. 3 of June 28, 1990, determines air quality standards and concentrations of air pollutants that, if exceeded, may affect the health, safety and well-being of the population, as well as causing damage to flora and fauna, materials and the environment in general (BRAZIL, 1990).

Vehicle sources produce emissions from the combustion of different types of fuel, including direct greenhouse gases (GHG) such as carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O), as well as as other pollutants such as carbon monoxide (CO), non-methane hydrocarbons (NMHC), sulfur oxides (SOx), particulate matter (MP) and nitrogen oxides (NOx) which cause or contribute to air pollution being indirect precursors of the greenhouse effect (IPCC, 2006).

In this sense, the Resolution 251/99 of the National Environment Council (CONAMA), concerned with global warming, establishes some criteria, procedures and maximum opacity limits for exhaust emission to assess the state and maintenance of motor vehicles, in national territory, to be used for the Inspection and Maintenance Programs of Vehicles in Use (MMA, 2014).

Inventory of air pollutant emissions is a strategic instrument for the management of the atmospheric resource and reflects the intensity with which different users use this common environmental resource. The inventory identifies the emitters of air pollutants, characterizing the pollutants emitted, the periodicity of the emission and their location. Both fixed and mobile sources, which need to be continuously inventoried in order to direct preventive or corrective measures that ensure the improvement and maintenance of air quality (LYRA, 2006).

To assess the effects on air quality according to an emission source, an emission inventory is required. Inventories catalog and quantify all necessary information about the relevant air pollutants. For this reason, they are essential for understanding local and global air quality (PARRISH, 2006).

Inventories are used as a subsidy for the application of mathematical models of atmospheric pollutant dispersion. They assist in the interpretation of data and provide information for the application of related impact mitigation policies and actions (BUTLER, 2007).

Specifically from vehicle emission inventories, answers are obtained on the amount of pollutants that have been emitted by motor vehicles and what is the contribution of each of the categories of vehicles evaluated (XIE; CAI, 2007).

The estimate of GHG emissions by the “Top-down” method recommended by the Ministry of Mines and Energy - MME, in 1999, in the National Energy Balance - BEN, provides for the conversion of all fuel consumption measures to a common unit.

As a result of the growth of the automobile sector, the amount of road vehicles on the city streets has polluted the air through the burning of fuels in their engines, and depending on the level of concentration, the environment cannot tolerate and dissipate this pollution.

2. Materials and Method

The adopted methodology will be based on the methods for the elaboration of vehicle emission inventories used by the Environmental Protection Agency (EPA) and the 1st National Inventory of Atmospheric Emissions by Road Motor Vehicles (BRASIL, 2011).

In the first stage, the number of vehicles circulating by both public and private fleets was surveyed, as well as the monthly and annual consumption respectively, with the calculation of the emission rate according to the year of consumption. These data were obtained from companies under the confidentiality of names.

Estimated rates of CO2 GHG emissions will be calculated by the top-down method using the following equations:

$$CC = AC \times Fconv \times 45.2 \times 10\text{-}3 \times Fcorr \quad \text{(Eq. 1)}$$

Where:

tEP (Brazil) = 45.2 x 10-3 TJ (tera-joule = 1012 J);

CC = energy consumption in TJ;

AC = fuel consumption (m3, l, kg);

Fconv = conversion factor of the physical unit of measurement of the amount of fuel to tEP based on the fuel's higher calorific value (PCS) (values may vary from year to year according to the annual BEN publication. 2000 of the Fconv are: gasoline (0.771 tEP / m3), anhydrous alcohol (0.520 tEP / m3), hydrated alcohol (0.496 tEP / m3), diesel (0.848 tEP / m3), dry natural gas (0.857 tEP / 103m3);

Fcorr = PCS correction factor for PCI (lower calorific value), where in BEN the energy content is based on PCS, but for the IPCC, the conversion to common energy unit is given by multiplying the consumption of PCI. For solid and liquid fuels o Fcorr = 0.95 and gaseous fuels o Fcorr = 0.90 (MCT).

To assess the carbon emitted from fuel combustion, equation 1 will give rise to equation 2, which requires energy consumption to be estimated.

$$EC = CC \times Femiss \times 10\text{-}3 \quad \text{(Eq. 2)}$$

Where:

EC = Carbon Content expressed in Giga gram of Carbon (1 GgC = 1,000 tons of Carbon);

CC = energy consumption in TJ;

Femiss = Carbon emission factor per tonne of carbon per tert-joule (tC / TJ). The IPCC 1996 and MCT 1999 values of the Femiss are: gasoline (18.9 tC / TJ); anhydrous alcohol (14.81 tC / TJ); hydrated alcohol (14.81 tC / TJ); diesel (20.2 tC / TJ); dry natural gas (15.3 tC / TJ); 10-3 = tC / GgC.

To mark equation 3 the expressed carbon content is required. Thus, according to the MME (1999), CO2 emissions can be calculated as a function of their molecular weights, where 44 t CO2 corresponds to 12 t C or 1 t CO2 = 0.2727 t C.

$$ECO2 = EC \times 44/12 \quad \text{(Eq. 3)}$$

Where:

ECO2 = CO2 emission;

EC = emission of C.

Emission factors should be corrected, since a car with older technology has higher pollutant emission rates compared to a zero kilometer vehicle (TEIXEIRA, 2008).

Corrected emission factors for used vehicles are obtained by the product of vehicle emission factors in the year in question by a deterioration factor. Total annual emission rates will be calculated for the carbon monoxide (CO) pollutant.

3. Results and Discussion

The increasing concentration of gases in the atmosphere and the consequent climate change have mobilized governments to take measures to estimate anthropogenic CO2 emissions.

Numerous public policies have been implemented in recent years that have created direct impacts on vehicle pollutant emission levels. These measures focus in general on the setting of automotive vehicle emission ceilings and fuel improvement measures (CARVALHO, 2011).

Due to the potential difference of gases in relation to their contribution to global warming, their CO2 equivalence measurement was determined. It is used to buy the emissions of various Greenhouse Gases (GHG), based on the amount of carbon dioxide (CO2) that would have the same global warming potential as the Global Warming Potential (GWP). a certain period of time, estimating and quantifying how much of the environmental impact was generated by the same amount of a different gas species (SEIFFERT, 2009).

Burning fossil fuels is the world's leading cause of carbon dioxide (CO2) emissions, and is the main greenhouse gas. According to Mattos (2011), in a large city, among all sectors that consume fossil fuels, the road transport sector is the largest consumer.

The first international agreement on climate change was signed on March 21, 1994 by 182 countries, including Brazil. This agreement aimed to stabilize the concentration of gases associated with global warming, including carbon dioxide (CO2), but this agreement did not specify the concentration limit (SILVA; DIAS, 2012).

The data collected from the Public (articulated and urban) and private (micro and van) Transport Fleet differ in their number of cars and models. Presenting the operating fleet of 382 vehicles (mandatory), including 38 spare vehicles, totaling a total fleet of 420 vehicles, which consumes fossil fuel of diesel type (Table 1).

Table 1. Description of measurements taken of liters of diesel spent in 2018.

YEAR 2018	**Diesel Consumption Quantity (l)**
January	1.215.870
February	1.250.000
March	1.368.000
April	1.369.200
May	1.370.320

June	1.368.900
July	1.299,850
August	1.276.900
September	1.367.230
October	1.287.500
November	1.370.000
December	1.299.871
Total	**15.914.451**

Source: Adapted from the report on vehicle fleets analyzed (2018).

The public transport sector has a significant share in both GHG and pollutant emissions that contribute to global warming and to the damage caused to the population's health.

GHGs come from mobile combustion in the sector's vehicles, which accounts for about 30% of the world's commercial energy consumption and 60% of total world oil consumption (IEA, 2009). In Brazil, diesel consumption in 2009 accounted for 53% of the sector's total CO2 emissions (BRAZIL, 2012).

Diesel oil is a petroleum-derived fuel consisting primarily of hydrocarbons. Besides presenting carbon and hydrogen, they also present sulfur and nitrogen, being formulated through the mixture as kerosene, gas oils, heavy naphtha, light diesel, heavy diesel, etc., coming from the various crude oil processing stages (CNT, 2012).

The importance of fuel quality is a fundamental factor for emission control and, consequently, for the proper functioning of the engines. Under optimum conditions, all carbon from diesel fuel would burn into carbon dioxide (FERNANDES, 2011).

As a result of the growth of the automobile sector, the amount of road vehicles on the city streets has polluted the air through the burning of fuels in their engines, and depending on the level of concentration, the environment cannot tolerate and dissipate this pollution.

The private transport company has the operating fleet of 300 vehicles, which also consumes diesel-type fossil fuel (Table 2).

Table 2. Description of the amount of fuel spent (l) by the private transport fleet in 2018.

YEAR 2018	**Amount of fuel spent (l)**
January	265.632
February	253.583
March	253.909
April	252.265

May	251.764
June	247.897
July	253.895
August	256.371
September	256.829
October	254.139
November	255.159
December	257.487
TOTAL	**3.049.921**

Source: Adapted from the report on the analyzed transport fleets (2018).

Although the car, compared to the use of buses and bicycles, is a more comfortable and convenient means of transportation, it nevertheless has negative impacts on the urban community.

According to Carvalho (2011), bus systems, which account for more than 60% of urban commuting and more than 95% of commuting, are responsible for only 7% of total carbon dioxide emissions. Automobiles and light commercial vehicles, with less than 30% of total travel, contribute half of the emissions of this pollutant.

In diesel engines, known as compression-ignition engines, where air enters the cylinder through the intake manifold, this air is compressed at high temperatures and pressure.

According Fontana (2009), when in contact with air at high temperatures, the fuel vaporizes quickly and when mixed with air, cause spontaneous chemical reactions resulting in the phenomenon known as spontaneous ignition or self-ignition.

Thus understanding the process of gas emission based on predictive models becomes necessary for the knowledge of different methodologies (Table 3).

Table 3 - Comparison of CO2 emissions by public and private transport companies in 2018.

Year 2018	CO2 emission (t) (Public transportation)	CO2 emission (t) (Private Transportation)
January	3.279.220	716.410
February	3.371.200	683.910
March	3.689.400	684.790
April	3.692.730	680.360
May	3.695.800	679.010
June	3.691.900	668.580
July	3.505.700	684.750
August	3.443.800	691.430

September	3.387.400	692.680
October	3.472.400	685.410
November	3.694.900	688.160
December	3.505.800	694.440
Total	**42.430.250**	**8.249.930**

Source: Own Authorship (2019).

Top Down is a practical method for obtaining the values that are closest to the reality of carbon dioxide (CO_2) emissions and is even adopted by the Brazilian government for the preparation of the national inventory of polluting gases.
Fuel category is not distinguished by category (sector), only the total CO_2 obtained through the consumption of a certain volume is estimated (MATTOS, 2011).
The use of fuels that are viable to use the fleet is recommended. The Top Down method was developed by the Intergovernmental Panel on Climate Change (IPCC, 2006), a body linked to the United Nations (UN).
Based on the application of the Top-Down methodology in the comparison of public and private transport companies, it is evident that CO_2 emissions for both fleets present a high air pollution index, suggesting the adaptation of the vehicle fleet by the adoption of fuel. similar with lower pollutant emission.

4. Conclusion

The data obtained in the study prove that the use of low emission factor fuels should be used in urban public transport vehicles, favoring environmental and financial gains.
It can be said that the quantities of GHG emitted by road transport (public and private) are high due to the high motorization index and the growing exponential evolution of the vehicle fleet.
Inventorying GHG emissions from these activities provides tools for understanding the evolution of the greenhouse effect. CO_2 has been continuously added to the atmosphere at high concentrations, which may be the subject of further studies to monitor the rise in temperature.

5. References

BRAZIL. CONAMA Resolution No. 3 of June 28, 1990. Provides for air quality, provided for in PRONAR. Official Gazette of the Union Federative Republic of Brazil. Brasilia, DF, 22 ago. nineteen ninety.

BRAZIL. Ministry of Mines and Energy (MME). National Energy Balance 2012. Base Year 2011: Preliminary Results. Rio de Janeiro: EPE, 2012.

BRAZIL. 1st National Inventory of Atmospheric Emissions by road motor vehicles. Ministry of the Environment, Brasilia, Brazil. 2011

BUTLER, T.M. et al. The representation of emissions from megacities in global emission inventories.

Atmospheric Environment, v. 42, no. 4, p. 703-719, 2008.

CARVALHO, C. H. R. Relative pollutant emissions from motorized passenger transport in large Brazilian urban centers. Institute of Applied Economic Research - IPEA, Brasilia, DF. 2011

NATIONAL TRANSPORT CONFEDERATION (CNT). The impacts of the poor quality of Brazilian diesel oil. Brasilia: 2012

FERNANDES, M. R. Formulation of new diesel based fuels performance and emissions evaluation. 2011. 154 Thesis: (Doctorate in Chemical Engineering) Federal University of Rio Grande do Norte, UFRN, Brazil. 2011

FONTANA, J. D. Biodiesel: For readers from 9 to 90 years. Curitiba: Ed. UFPR, 2011.

IEA. Transport, Energy and CO2. OEDC Publishing, Paris. October, 2009.

INEA - State Environmental Institute. Rio de Janeiro State Air Quality Report - Base Year 2010 and 2011. Rio de Janeiro. 2013

IPCC Guidelines for National Greenhouse Gas Inventories - Revised. 1996

IPCC - Intergovernmental Panel on Climate Change. Guidelines for National Greenhouse Gas Inventories. Volume I and II. 2006

LYRA, D. G. P. Inventory of atmospheric emissions from the metropolitan region of Salvador. 2006

MANZOLI, A. Analysis of Vehicle Emissions on Short Urban Routes with GPS Tracking. 2009, 200p. Thesis (Doctorate in Civil Engineering). University of Sao Paulo, Sao Carlos. 2009

MMA Ministry of the Environment. CONAMA Resolution 251/99.

MME Ministry of Mines and Energy - National Energy Balance - BEM. 1999

MATTOS, L. B. R. The importance of the transport sector in greenhouse gas emissions - The case of Rio de Janeiro. Master's Dissertation in Energy Planning, Federal University of Rio de Janeiro, Rio de Janeiro, RJ. 2011

PARRISH, D. D. Critical evaluation of US on-road vehicle emission inventories. Atmospheric Environment, v. 40, no. 13, p. 2288-2300, 2006.

SEIFFERT, M.B.S. Carbon Market and Kyoto Protocol: business opportunities in the pursuit of sustainability. Sao Paulo: Atlas, 2009.

SILVA, P. C. S .; DIAS, V. B. Climate change in the Amazon region and its impact on the international environmental project. LEA Class Books, v.1, n.1, p.32-51, 2012.

TEIXEIRA, E. C. Study of emissions from mobile sources in the metropolitan region of Porto Alegre, Rio Grande do Sul. Quim Nova, 31 (2), 244–248. 2008

XIE, S .; CAI, H. Estimation of vehicular emission inventories in China from 1980 to 2005. Atmospheric Environment. Beijing, p. 8963-8979. Aug 09 2007