XXI ENGEMA
Encontro Internacional sobre Gestão Empresarial e Meio Ambiente

ISSN: 2359-1048
Dezembro 2019

ENVIRONMENTAL POLLUTION INDEX OF ROAD TRANSPORTATION: sector evidence in Uberlandia-MG.

LORENA COSTA BAESSE

LUCAS CONDE STOCCO
UNIVERSIDADE FEDERAL DE UBERLÂNDIA

ANDRÉ SELISTRE DONEGA
FACULDADE DE ECONOMIA, ADMINISTRAÇÃO E CONTABILIDADE DE RIBEIRÃO PRETO (FEA-RP/USP)

GUILHERME DE SOUZA PESTILHO
FACULDADE DE ECONOMIA, ADMINISTRAÇÃO E CONTABILIDADE DE RIBEIRÃO PRETO (FEA-RP/USP)

RODRIGO RUAS DE JESUS SILVA

ENVIRONMENTAL POLLUTION INDEX OF ROAD TRANSPORTATION: sector evidence in Uberlandia-MG.

1. Introduction

The evolution of road transport, starting in the 1950s, occurred at an extremely rapid pace in Brazil. Between 1945 and 1952, the number of trucks and buses in circulation in the country jumped from 103,000 to 265,000, a growth of more than 157 % in just seven years (INSTITUTE OF INTERAMERICAN AFFAIRS, 1954). In the 1960s, freight movement was largely transferred from railroads and cabotage to highways. Since then, the highways were responsible for about 73 % of all freight movement in Brazil. (BARAT, 1978). A modern highway system would be the fastest way to achieve the great national objective of social, economic and political integration of the country (GALVÃO, 1996).

From the business point of view, transportation is part of the logistics or distribution system of companies operating in the market. Road freight transport is an essential activity for the economy of the country, since without it the production of the other economic sectors would not be of any advantage, since the goods produced could not reach their final consumers. Thus, all economic agents depend directly or indirectly on transportation to meet their needs, and this is a socioeconomic link (CARVALHO, 2011).

As a result of economic growth, anthropogenic emissions of gases and particulates tend to intensify progressively, leading to an increase in their concentration in the atmosphere. Some of these gases and particles have proven effects on human health and the environment, which is why they are considered "atmospheric pollutants". Among these, carbon monoxide (CO), hydrocarbons (HC), particulate matter (PM), and nitrogen oxides (NO2) are highlighted (SANTANA, 2012).

Air quality degradation is an important threat to human health, especially in urban centers, and has been associated with worsening of respiratory, cardiovascular and neurological diseases, especially in children and the elderly. Studies also indicate the correlation between exposure to some pollutants and the occurrence of different types of cancer (WHO, 2000; GOUVEIA et al., 2006, BRUNEKREFF, 2012).

According to Santana (2012), the impacts of air pollution on ecosystems also merit attention. The deposition of air pollutants in plants can lead to a reduction in their photosynthesis capacity, leading to, for example, a fall in agricultural productivity. Acidification of rainwater and dust contaminating water resources, aquatic biomes and soil are also a consequence of the anthropic introduction of pollutants into the atmosphere.

For the National Council for the Environment (*CONSELHO NACIONAL DO MEIO AMBIENTE - CONAMA*), in its Resolution 03/1990 (Art. 1), "air quality standards are concentrations of atmospheric pollutants which, if exceeded, could affect the health, safety and wellbeing of the population, as well as causing damage to fauna and flora, material damage, and damage to the environment in general" (BRASIL, 2012).

Thus, the present study aims to contribute to this discussion, and to analyze the characteristics of freight transportation in the city of Uberlandia and to quantify the main atmospheric pollutants.

2. Literature overview

2.1 Freight Transportation in Minas Gerais Triangle Region (Triângulo Mineiro)

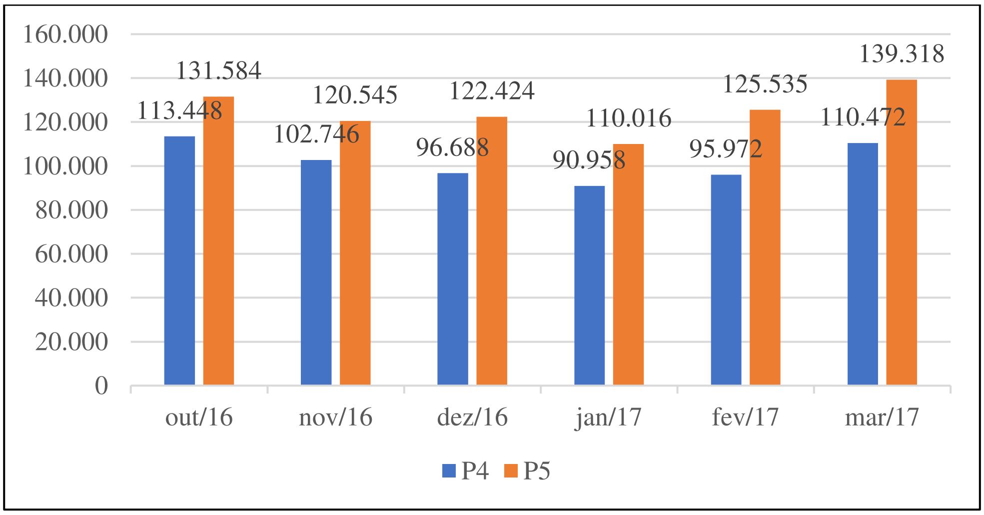
The spatial distribution of transport logistics in the Brazilian territory has a predominance of highways, mainly concentrated in the Center-South of the country (IBGE, 2014). According to the National Transportation Confederation (*Confederação Nacional de Transportes - CNT*), 61.1 % of all freight transported in Brazil uses the road system; 21.0 % railroads, 14 % by waterways, rivers, and seaport terminals, and only 0.4 % by air.

According to the government of Minas Gerais state, the Triângulo Mineiro region is one of the most productive and promising regions in the country, due to agribusiness. The Triângulo Mineiro represents 7 % of the state's total exports, which alone accounts for 13.8 % of Brazil's external sales, causing an intense flow of freight transportation in the region. The main products exported in the region are: sugar, coffee, corn, soy and its derivatives. Also significant is the production and export of poultry, beef and pork.

The National Land Transport Agency (*Agência Nacional de Transportes Terrestres – ANTT*), the National Department of Transport Infrastructure (*Departamento Nacional de Infraestrutura de Transportes – DNIT*), and the Minas Gerais and Goiás states highway concessionary company (*Concessionária de Rodovias Minas Gerais Goiás S.A.*) - MGO Rodovias, entered into an agreement transferring to the concessionaire the section of highway BR-050 in the state of Minas Gerais (MGO, 2017). From then on, MGO has had monthly traffic control in this region. Section P4 (Araguari 2) and section P5 (Uberaba), are the sections that have access to the city of Uberlandia, the city related to this research. In this way it is possible to calculate the average of the quantity of freight vehicles that pass through the city of Uberlandia per month, using BR-050.

According to the traffic control of MGO, presented by Figure 1 the average monthly number of trucks passing through section P4 is 101,714 and in section P5 is 124,904 trucks.

Figure 1 - Traffic Control - MGO (Sections P4 and P5)



Source: MGO Rodovias.

2.2 Fleet description

According to ANTT, Brazil has a total of 1,682,398 freight vehicles, including cooperatives, companies and self-employed, representing a total of 494,815.

Table 1 - Freight transport vehicles in Brazil- ANTT

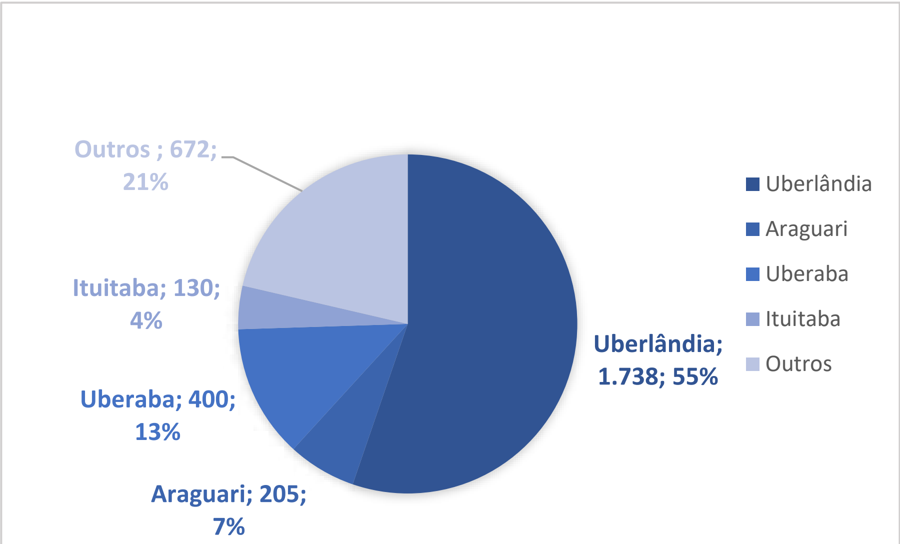
	Self-employed	Companies	Cooperatives	Total
Registrations Issued	380,825	113,715	275	494,815
Vehicles	564,404	1,095,122	22,872	1,682,398

Source: Agência Nacional de Transportes Terrestres (ANTT).

The large number of self-employed is due to the custom that companies have to aggregate their fleets with vehicles owned by third parties (self-employed truck drivers). All that is needed is to comply with some contractual requirements and formalities, and the self-employed truck drivers start to transport the products under the responsibility of the companies, thus integrating the business activity (*MINISTÉRIO DO MEIO AMBIENTE*, 2017).

In the Triângulo Mineiro region in the state of Minas Gerais, according to the Triângulo Mineiro Transport Union (*Sindicato de transporte do Triângulo Mineiro – SETTRIM*), a total of 3,145 transporters, including self-employed, companies and cooperatives, are cataloged. In the city of Uberlandia 1,738 transporters are located, which corresponds to 55 % of the total (SETTRIM, 2017), Figure 2 represents the numbers.

Figure 2 - Quantity of Transporters by Municipality



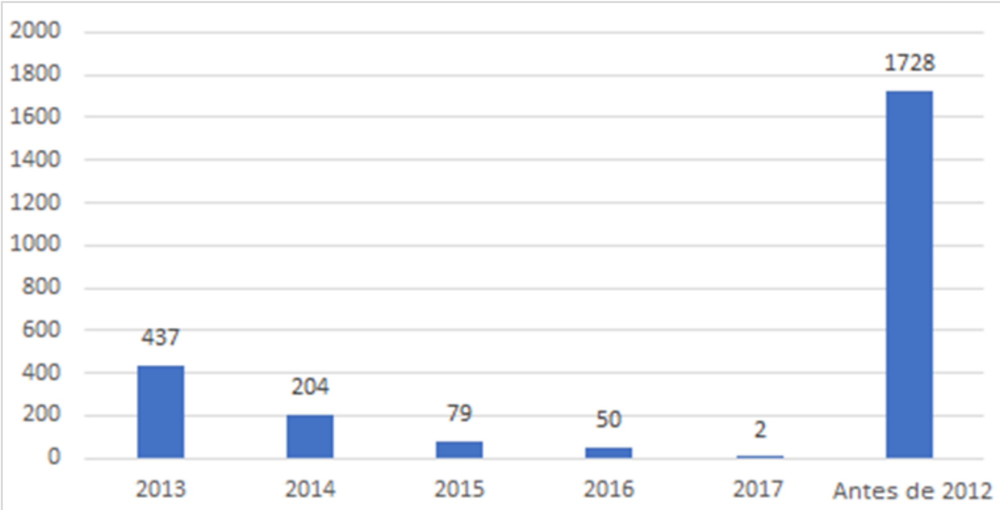
Source: SETTRIM.

According to the data collected in Uberlandia, of the 1,738 transporters, only 80 companies and 1 cooperative carry out monitoring of emission of atmospheric pollutants, which is carried out together with the *Despoluir* program and SETTRIM, and use as emission parameter limits the maximum levels found in CONAMA Resolution No. 418, of November 25, 2009 (SETTRIM, 2017).

As such, this research considered only the transporters of Uberlandia that have already been monitoring the emission of atmospheric pollutants as the target audience. A total of 81 transporters (80 companies and 1 cooperative) were identified, having a total of 2,503 vehicles to be evaluated.

As all types of trucks use a diesel cycle engine, it is not necessary to know the truck model to know which type of diesel fuel each truck uses, just the age of the truck. According to data collected for this research, in Uberlandia only 31 % of the vehicles have new technologies for the use of S10 Diesel, 69 % are older than necessary for S10, and use S500 diesel.

Figure 3 - Year of manufacture of each vehicle in Uberlandia



Source: ANTT.

S10 diesel is only used for new diesel engines manufactured from 2012, which have new emission control technologies, i.e. only for vehicles under six years old. S10 diesel enables the reduction of emissions of particulate matter by up to 80 % and of nitrogen oxides by up to 98 % (PETROBRAS, 2017).

Currently, it is estimated that Brazil has about 230 thousand trucks with more than 30 years of use. These vehicles have outdated technology and pollute more than new trucks (MINISTÉRIO DO MEIO AMBIENTE, 2017). One of the reasons for this is the use of S500 diesel that causes these vehicles have a higher rate of atmospheric emissions.

2.3 Use of diesel oil in Brazil

According to the definition of the National Agency of Petroleum, Natural Gas and Biofuels (*Agência Nacional de Petróleo, Gás Natural e Biocombustíveis - ANP*), (BRASIL, 2017), diesel is described as a petroleum-derived liquid fuel composed of hydrocarbons with chains of 8 to 16 carbons, in addition to nitrogen, sulfur and to a lesser extent, oxygen. Diesel oil, in its various denominations, is the main fuel commercialized in the Brazilian market and is mainly used in diesel engines of internal combustion and compression ignition (PETROBRAS, 2017).

Freight transportation in Brazil is mainly supported by the use of vehicles powered by diesel engines, by road. To meet the domestic market, Petrobras refineries are operated with priority for the production of this fuel, corresponding to 34 % of the volume of petroleum processed in the country (FERRARI et al., 2005). Several types of diesel and respective applications are found in the market; in the national territory ANP establishes S10 and S500 diesel oil for road use, S1800 diesel oil for non-road use, and marine diesel DMA/DMB for use by marine vessels.

The pollutants emitted by the combustion of diesel promote ecological problems recognized worldwide, such as the destruction of the ozone layer, increase of global warming, and acid rain (KNOTHE, 2005). Diesel engines emit particulate matter, black smoke, and carry various carcinogenic compounds with a high impact on human health and ecosystems (CORREA, 2006).

The compounds of diesel engine emissions are classified into two forms: those that do not cause damage to health, i.e., O_2, CO_2, H_2O and N_2; and those that provoke health problems, being subdivided into compounds that have emission regulations, which are: carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_X), sulfur oxides (SOx), and particulate matter (PM); and those that are not yet under regulation, being aldehydes, ammonia, benzene, cyanides, toluene and polynuclear aromatic hydrocarbons (PAH) (NEEFT et al., 1996).

Diesel exhaust is very complex, being composed of three phases: solids, liquids and gases (DEGOBERT, 1995). Operation under diesel engine oxidizing conditions at lower temperatures can be compared with gasoline engines, with lower production of CO_2, NO_X, CO and hydrocarbons (HC). However, this process also results in high emission levels of particulate matter (PM) and compounds responsible for the odor characteristic of the diesel emission, the latter emission being much worse during low temperature operating conditions (NEEFT et al., 1996).

Hydrocarbons from diesel emissions are generally heavier than those from gasoline emissions; in addition, polycyclic aromatic hydrocarbons (PAH) and alkyl derivatives thereof may be present in the diesel thus resisting the combustion process, volatilizing and escaping into the atmosphere by exhaustion. (SCHEEPERS; BOS, 1992).

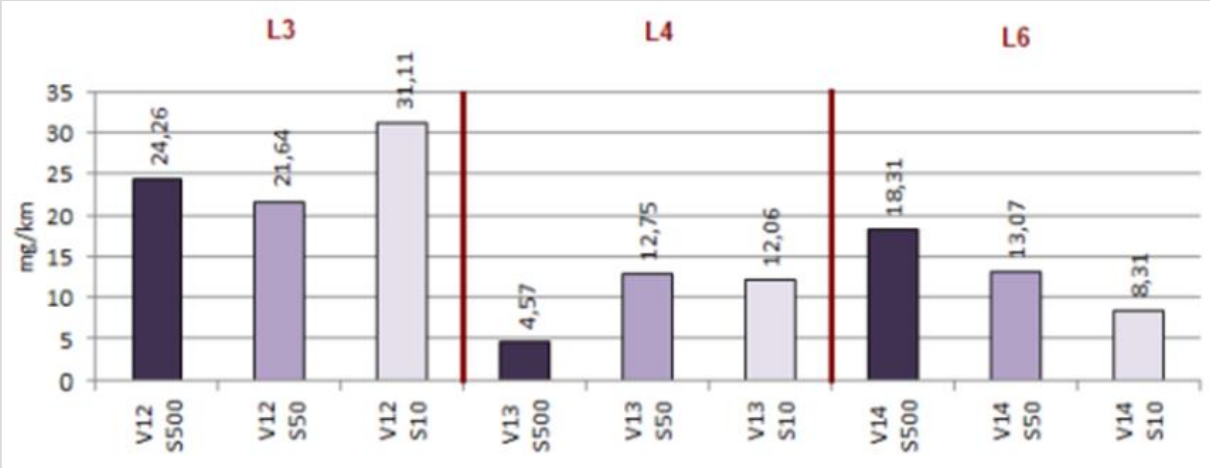
2.4 Emitting sources of atmospheric pollutants from diesel oil

2.4.1 Particulate Matter

In 2011, Petrobras signed a cooperation agreement with the University of São Paulo (*Universidade de São Paulo - USP*) and the Catholic University of Rio de Janeiro (*Universidade Católica do Rio de Janeiro - PUC-RJ*) to study the influence of the main emitting sources on the formation of particulate matter (PM), especially PM2.5 (particulate matter with a diameter of less than 2.5 µm). This initiative was called the “Sources Project” (*Projeto Fontes*). One of the specific objectives of the project was the characterization of the PM collected from the exhaust gas of vehicles typical of the diesel, gasoline and ethanol fleet. (VICENTINI, P, C, 2015).

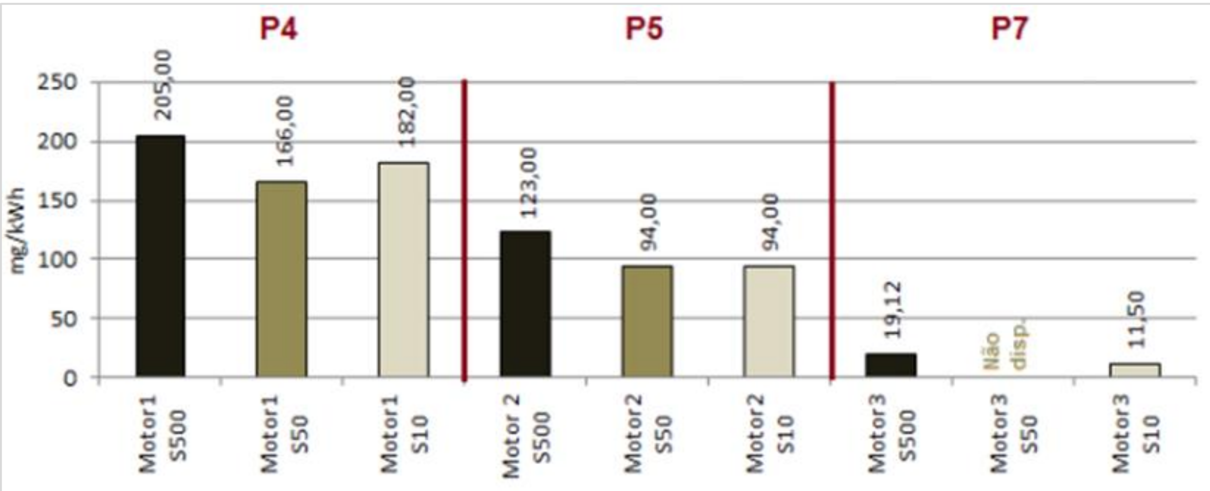
The level of PM emission in light diesel vehicles is much higher than that of Otto cycle vehicles and motorcycles. For vehicles of previous phases (L3 and L4 of PROCONVE) there was no evidence of a decrease in PM emission due to the reduction of the sulfur content of the fuel, while in the more recent vehicles (L6) this was noticeable. In heavy diesel engines, this influence is perceived when the sulfur content of the diesel oil was reduced to below 500 ppm, but it was not evident between the contents of 50 and 10 ppm.

Figure 4 - PM2.5 emission in light diesel cycle vehicles



Note: Emission factors for light diesel cycle vehicles with S500, S50 and S10.
Source: Projeto Fontes.

Figure 5 - PM2.5 emission in heavy diesel cycle vehicles



Note: Emission factors for heavy diesel cycle vehicles with S500, S50 and S10
Source: Projeto Fontes.

2.4.2 PROCONVE

On May 6, 1986, CONAMA Resolution No. 18 created the Air Pollution Control Program for Automotive Vehicles (*Programa de Controle de Poluição do Ar por Veículos Automotores – PROCONVE*), coordinated by IBAMA, which defined the first emission limits for light vehicles, and contributes to meeting the Air Quality Standards (*Padrões de Qualidade do Ar*) instituted by the National Air Quality Control Program (*Programa Nacional de Controle de Qualidade do Ar* – PRONAR) (BRASIL, 2017).

Table 2 - PROCONVE implementation strategy for heavy vehicles (P PHASES)

Fase	Implantação	Característica / inovação
P-1 e P-2	1990-1993	Já em 1990 estavam sendo produzidos motores com níveis de emissão menores que aqueles que seriam requeridos em 1993 (ano em que teve início o controle de emissão para veículos deste tipo com a introdução das fases P-1 e P-2). Nesse período, os limites para emissão gasosa (fase P-1) e material particulado (fase P-2) não foram exigidos legalmente.
P-3	1994-1997	O desenvolvimento de novos modelos de motores visaram a redução do consumo de combustível, aumento da potência e redução das emissões de óxidos de nitrogênio (NOx) por meio da adoção de *intercooler* e motores turbo. Nesta fase se deu uma redução drástica das emissões de CO (43%) e HC (50%).
P-4	1998-2002	Reduziu ainda mais os limites criados pela fase P-3.
P-5	2003-2008	Teve como objetivo a redução de emissões de material particulado (MP), NO_x e HC.
P-6	2009-2011	Em janeiro de 2009 deveria ter se dado o início à fase P-6, conforme Resolução CONAMA nº 315/2002, e cujo objetivo principal, assim como na fase cinco, era a redução de emissões de material particulado (MP), NOx e HC.

Source: PROCONVE.

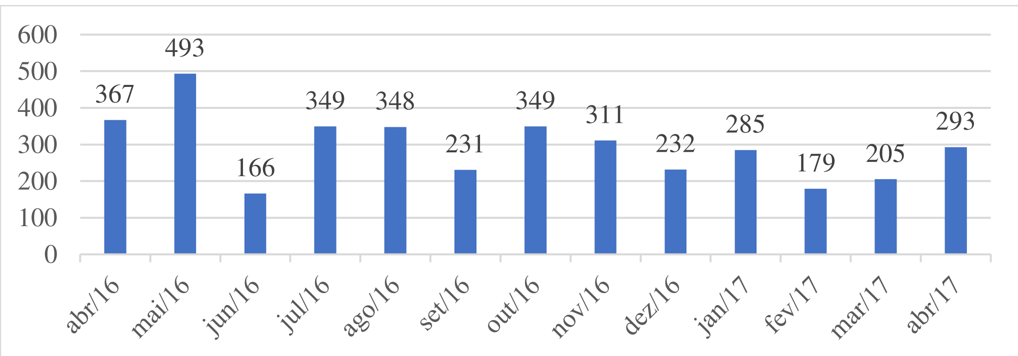
2.5 Opacity

The *Despoluir* project, a national project to control atmospheric emissions by automotive vehicles, is managed in Uberlandia by SETTRIM. In this project the diesel cycle vehicles are subjected only to the opacity test that evaluates the amount of light that crosses a certain matter, in this case classifying the opacity of the emitted smoke (SETTRIM, 2017).

The test is performed with a device called an opacimeter, which emits a beam of light, thus measuring the light permeability in the exhaust smoke. The vehicle is subjected to at least four accelerations to capture the smoke; this smoke is analyzed by the opacimeter, which in turn compares the result with the values referenced by the current federal standard of CONAMA.

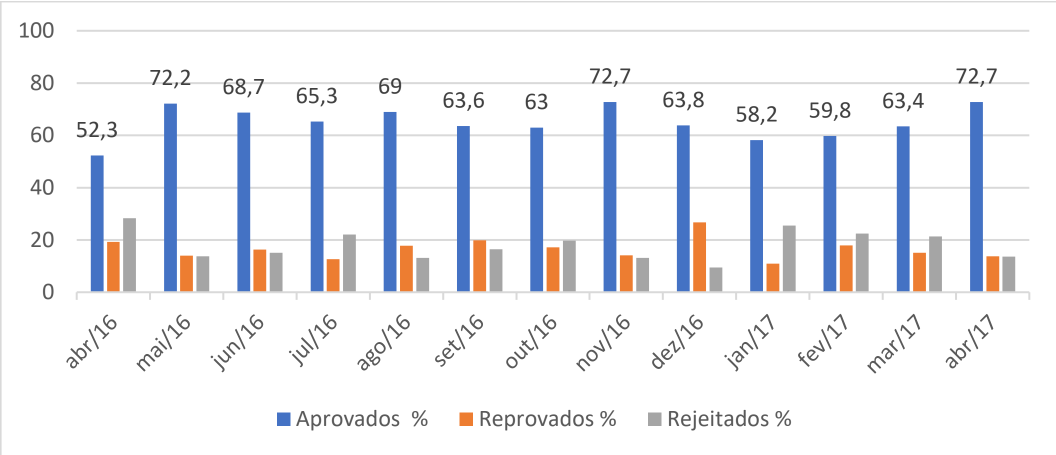
According to the data obtained by the opacity test, the average number of vehicles inspected monthly is approximately 293, out of the total of 2,503. Most of the vehicles were approved in the test, with an annual approval average of approximately 65 %.

Figure 6 – Vehicles Inspected per Month



Source: SETTRIM.

Figure 7 – Result of Opacity Test



Source: SETTRIM.

3. Method

A bibliographical review was carried out, based on the definition of the main objective of developing an atmospheric pollution index, generated by the distribution of road transport in the city of Uberlandia. The purpose of the review was the need for information that made it possible to verify the variables necessary to calculate the pollution index, and perform an analysis on freight transportation in the Triângulo Mineiro region.

For this, different databases were explored, among them the CAPES journal portal and its thesis database, ANTT, CNT, and the digital thesis and dissertation library of USP. After the interpretation of the selected works, it was possible to find information on the number of transporters in Brazil, as well as the number of freight vehicles and their average age.

Subsequently, an open interview was held with employees of the Union of Freight Companies of the Triângulo Mineiro (*Sindicato das Empresas de Cargas do Triângulo Mineiro* – SETTRIM). The open interview is used when the researcher wants to get as much information about a topic as possible, according to the interviewee's view, as well as to obtain a greater detail of the subject in question (MINAYO, 1993). The questions were answered in an informal conversation, where it was possible to survey the transport and logistics companies of the municipality of Uberlandia through the industrial company registration, and collect data on the characterization of the fleet.

3.1 Calculation for emissions of Hydrocarbons (HC), Carbon Monoxide (CO) and Nitrogen Oxide (NOx)

The US Environmental Protection Agency (EPA) methodology for calculating atmospheric emissions was used as reference, however, for effective use it was necessary to make some adjustments for the Triângulo Mineiro region and adjust the year of manufacture of the vehicles from 2017, since the source of the table used was from 2009. In this way it provided data for vehicles from 2009. The change of the year of manufacture of the vehicles in the table does not interfere in the final result, since what matters is the age of the vehicle, thus keeping the emission and deterioration values consistent.

In order to obtain emission rates for hydrocarbons (HC), carbon monoxide (CO) and nitrogen oxides (NOx), the actual values offered by the EPA of emission factors and deterioration factors for the years 2017 to 2005; and for the years 2004 to 1994 an average of the values of the factors released by the EPA, shown in Table 3, were performed.

Table 3 - Emission (EF) and deterioration (DF) factors for hydrocarbons, carbon monoxide and nitrogen oxides, in grams per mile, for heavy diesel vehicles at high altitudes.

Year of manufacture	Hydrocarbons		Carbon monoxide 1		Nitrogen oxides	
	FE	FD	FE	FD	FE	FD
2017 to 2005	4.82	0	16.665	0.08	6.49	0
2004 to 1994	5.026	0	17.363	0.084	13.902	0

Source: EPA.

The EPA provides data for two types of region, one low altitude and the other high altitude. The state of Minas Gerais is considered the highest altitude in Brazil due to the characteristics of its relief, thus justifying the use of the factors for high altitude regions.

The average annual value of 124,800 kilometers was performed by making the summation of the monthly average, provided by the CNT survey, of 10,400 km/month. Lastly, data on the Uberlandia state fleet that were provided by SETTRIM were required, in which only 2,503 freight vehicles were considered, corresponding to the vehicles that carry out emission monitoring of atmospheric pollutants in the city of Uberlandia. Data from the fleet of diesel vehicles were organized by age group as stipulated by the EPA and are presented in Table (1).

The calculation of the emission rate of the indicated pollutants is equivalent to the multiplication of the deterioration factor by the average number of kilometers, divided by 10,000 miles, added to the emission factor of vehicles, and it is possible to estimate by Equation (1):

$$total\ emission = \sum Ni\left(FEi + FDi * \frac{Milhasi}{10.000}\right) \quad (1)$$

It is important to note that the data in Table (1), provided by EPA, are in grams per mile, so conversions are required to deliver the result in grams per kilometer, based on the ratio of one mile corresponding to 1.609344 kilometers. Based on the emission and deterioration factors presented in Table (1) and the distribution of the fleet of diesel-powered heavy vehicles per year of manufacture, the total emission of each pollutant in grams can be estimated by equation (2):

$$total\ emission = \sum Ni\left(\frac{FEi}{1{,}609344} + \frac{FDi}{1{,}609344} * \frac{124800km}{10.000 * 1{,}609344km}\right) \quad (2)$$

Where, N_i represents the total of vehicles with year of manufacture "i"; FEi and FDi are the emission and deterioration factors for each pollutant, in grams per mile, for each vehicle with year of manufacture belonging to the "i" range; and $Milhas_i$ corresponds to the accumulated total of miles traveled by vehicles with year of manufacture belonging to the "i" range.

3.2 Calculation for the emission of particulate matter with a diameter of less than 2.5 µm (PM2.5).

For the calculation of the emission estimate of the particulate matter, the "*Projeto Fontes*" was used as a reference, which is a study carried out through the cooperation agreement between Petrobras with USP and PUC-RJ to analyze the influence of the main emitting sources on the formation of particulate matter (PM), especially PM2.5 (particulate matter with a diameter of less than 2.5 µm).

Through the data provided by this study, it was possible to apply its results to the fleet data of the vehicles studied herein, thus determining the average particulate matter produced by the vehicles monitored in Uberlandia.

4. Results

4.1 Hydrocarbons

$$total\ emission = \sum Ni\left(\frac{FEi}{1{,}609344} + \frac{FDi}{1{,}609344} * \frac{124800km}{10.000 * 1{,}609344km}\right)$$

$$emission\ (2017\ \text{to}\ 2005) = 1770\left(\frac{4{,}82}{1{,}609344} + \frac{0}{1{,}609344} * \frac{124800}{10000 * 1{,}609344}\right)$$

$$emission\ (2017\ \text{to}\ 2005) = 1770 * 2{,}9950$$

$$emission\ (2017\ \text{to}\ 2005) = 5301{,}16\ g/year$$

$$emission\ (2004\ \text{to}\ 1994) = 733\left(\frac{5{,}026}{1{,}609344} + \frac{0}{1{,}609344} * \frac{124800}{10000 * 1{,}609344}\right)$$

$$emission\ (2004\ \text{to}\ 1994) = 733 * 3{,}1230$$

$$emission\ (2004\ \text{to}\ 1994) = 2289{,}18 g/year$$

$$total\ emission = emission\ (2017\ a\ 2005) + emission\ (2004 + 1994)$$

$$total\ emission = 5301{,}16 + 2289{,}16$$

$$total\ emission = 7590{,}32\ g/year = 7{,}6kg/year$$

For the fleet of 2,503 heavy freight vehicles in Uberlandia, 7.6 kg of hydrocarbons are emitted every year.

4.2 Carbon Monoxide

$$total\ emission = \sum Ni\left(\frac{FEi}{1{,}609344} + \frac{FDi}{1{,}609344} * \frac{124800km}{10.000 * 1{,}609344km}\right)$$

$$emission\ (2017\ \text{to}\ 2005) = 1770\left(\frac{16{,}665}{1{,}609344} + \frac{0{,}08}{1{,}609344} * \frac{124800}{10000 * 1{,}609344}\right)$$

$$emission\ (2017\ \text{to}\ 2005) = 1770(10{,}355 + 0.0497 * 7{,}7547)$$

$$emission\ (2017\ \text{to}\ 2005) = 1770(10{,}355 + 0{,}38) = 1770 * 10{,}740$$

$$emission\ (2017\ \text{to}\ 2005) = 19010{,}52\ g/year$$

$$emission\ (2004\ \text{to}\ 1994) = 733\left(\frac{17{,}363}{1{,}609344} + \frac{0{,}084}{1{,}609344} * \frac{124800}{10000 * 1{,}609344}\right)$$

$$emission\ (2004\ \text{to}\ 1994) = 733(10{,}78 + 0.0521 * 7{,}7547)$$

$$emission\ (2004\ \text{to}\ 1994) = 733(10{,}78 + 0{,}4047) = 733 * 11{,}18$$

$$emission\ (2004\ \text{to}\ 1994) = 8198{,}42\ g/year$$

$$total\ emission = emission\ (2017\ \text{to}\ 2005) + emission\ (2004 + 1994)$$

$$total\ emission = 8198{,}42 + 19010{,}52$$

$$total\ emission = 27208{,}94\ g/year = 27{,}2kg/year$$

For the fleet of 2,503 heavy freight vehicles in Uberlandia, 27.2 kg of carbon monoxide are emitted per year.

4.3 Nitrogen Oxide

$$total\ emission = \sum Ni\left(\frac{FEi}{1{,}609344} + \frac{FDi}{1{,}609344} * \frac{124800km}{10.000 * 1{,}609344km}\right)$$
$$emission\ (2017\text{ to }2005) = 1770\left(\frac{6{,}49}{1{,}609344} + \frac{0}{1{,}609344} * \frac{124800km}{10.000 * 1{,}609344km}\right)$$
$$emission\ (2017\text{ to }2005) = 1770\left(\frac{6{,}49}{1{,}609344}\right)$$
$$emission\ (2017\text{ to }2005) = 1770 * 4{,}03 = 7137{,}87g/year$$

$$emission\ (2004\text{ to }1994) = 733\left(\frac{13{,}902}{1{,}609344} + \frac{0}{1{,}609344} * \frac{124800km}{10.000 * 1{,}609344km}\right)$$
$$emission\ (2004\text{ to }1994) = 733\left(\frac{13{,}902}{1{,}609344}\right)$$
$$emission\ (2004\text{ to }1994) = 733 * 8{,}638 = 6677{,}4\ g/year$$

$$total\ emission = emission\ (2017\text{ to }2005) + emission\ (2004 + 1994)$$
$$total\ emission = 7137{,}87 + 6677{,}4$$
$$total\ emission = 13815{,}27g/year = 13{,}82kg/year$$

For the fleet of 2,503 heavy freight vehicles in Uberlandia, 13.82 kg of nitrogen oxide are emitted per year.

4.4 Particulate Matter

Emission of PM2.5 in heavy diesel cycle engines:

- For S500 diesel

$$\bar{x} = \frac{P4 + P5 + P7}{3} \qquad \bar{x} = \frac{\frac{205mg}{km} + \frac{123mg}{km} + \frac{19{,}12mg}{km}}{3}$$

$$\bar{x} = \frac{347{,}12mg/km}{3}$$
$$\bar{x} = 115{,}70\ mg/km$$

The average particulate matter (PM2.5) emitted by freight vehicles using S500 diesel is 115.70 mg/km per vehicle.

- For S10 diesel

$$\bar{x} = \frac{P4 + P5 + P7}{3} \qquad \bar{x} = \frac{\frac{182mg}{km} + \frac{94mg}{km} + \frac{11{,}50mg}{km}}{3} \qquad \bar{x} = \frac{\frac{287{,}50mg}{km}}{3}$$

$$\bar{x} = 95{,}83\ \mathrm{mg/km}$$

The average particulate matter (PM2.5) emitted by freight vehicles using S10 diesel is 95.83 mg/km per vehicle.

Total emission average of PM2.5 in heavy diesel cycle engines for S500 and S10 diesel

$$\bar{x} = \frac{\bar{x}S500 + \bar{x}S10}{2} \qquad \bar{x} = \frac{\frac{115{,}70\mathrm{mg}}{\mathrm{km}} + \frac{95{,}83\mathrm{mg}}{\mathrm{km}}}{2} \qquad \bar{x} = 105{,}76\mathrm{mg/km}$$

Total emission generated by the vehicles of Uberlandia

$$T = a\bar{x}S500 + b\bar{x}S10$$

$$T = 1728\ \times 115{,}7 + 775 \times 95{,}83 \quad T = 199.929{,}6 + 74.268{,}25$$

$$T = 274.197{,}85\mathrm{mg/km} = 274{,}2\ g/km$$

a: number of S500 fleet vehicles in Uberlandia;

b: number of S10 fleet vehicles in Uberlandia.

$\bar{x}$S500: Average emission of vehicles using S500 diesel

$\bar{x}$S10: Average emission of vehicles using S10 diesel

The emission of particulate matter (PM 2.5) generated by the vehicles of the sample of this research, which corresponds to 2,503 freight vehicles, is 274.2 g/km.

$$PM\ indicator = \frac{Total\ emissions\ generated}{Pollution\ average} = \frac{274197{,}85}{264717{,}28} = 1{,}04$$

5. Final considerations

Atmospheric pollution is a problem that has many causes and consequences. In order to tackle this problem, it is necessary to have a vision that encompasses several spheres. In this case, there is a system of air quality management that takes as its guiding principle for its actions, compliance with air quality standards, incorporating the instruments of environmental management, but also maintaining direct dialogue with management systems, such as health, urban planning and energy.

When conducting data collection in the municipality of Uberlandia, it was possible to notice that most of the city’s freight transportation companies do not have an effective environmental management system, since of the 1,738 companies (including self-employed and cooperatives), only 81 carry out air quality monitoring in their fleet. In this work it was decided to have as a research sample only the companies that perform this monitoring, since they have registered with SETTRIM with their fleet being characterized, thus, it is possible to identify the variables necessary to perform the calculations of quantification of atmospheric pollutants, while the other companies do not have this cataloged data. In this way this research has a much smaller fleet (2,503 vehicles) than the actual fleet of the city of Uberlandia.

Using as reference the standards used by the EPA and the *Projeto Fontes*, it was possible to calculate the amount of the main atmospheric pollutants, in which the results were: Carbon Monoxide (CO) 27.2 kg/year, Nitrogen Oxide (NOx) 13.82 kg/year, Hydrocarbons (HC) 7.6 kg/year and Particulate Matter 274.2 g/km.

In this sense, having as essential reference the air quality standards, it is possible to observe that the city of Uberlandia does not have effective air quality management, and must make use of instruments that lead and motivate the freight transportation companies to integrate with existing and available resources.

References

BARAT, J. **The evolution of transport in Brazil**. Niterói: Ipea, 1978.

BRAZIL. Ministry of the Environment. **Proconve.** 2017. Available at: <http://www.mma.gov.br/estruturas/163/_arquivos/proconve_163.pdf> Accessed: April 2017

BRAZIL. **Constitution of the Federative Republic of Brazil of 1988**. Available at <http: // www. planalto.gov.br/ccivil_03/constituicao/constitui%C3%A7ao.htm> Accessed: March 2017.

BRUNEKREEF, B.; ANNESI-MAESANO, I.; AYRES, J.G.; FORASTIERE, F.; FORSBERG, B.; KÜNZLI, N.; PEKKANEN, J.; SIGSGAARD. T. Ten principles for clean air. **European Respiratory Journal**, v. 39, n. 3, 2012.

CORREA, S.; ARBILLA, G. Aromatic hydrocarbons emissions in diesel and biodiesel exhaust. **Atmospheric Environment**: v. 40, n. 35, 2006.

ENVIRONMENTAL PROTECTION AGENCY. AP-42: Compilation of air pollutant emission factors. Available at <http://www.epa.gov/oms/ap42.htm>. Accessed: 10 June 2008.

GALVAO, O. Transport development and regional integration in Brazil: a historical perspective. **Planning and Public Policies**. v. 1, n. 13, p. 1 - 32. Jun, 1996.

GOUVEIA, N., FREITAS, C.U., MARTINS, L. C., MARCÍLIO, I. O. Hospitalizations due to respiratory and cardiovascular causes associated with atmospheric contamination in the city of São Paulo, Brazil. **Cadernos de Saúde Pública**, v. 22, n. 12, p. 2669-2677, 2006.

GOVERNMENT OF MINAS GERAIS. **Meet Minas, 2017. BRAZILIAN INSTITUTE OF GEEOGRAPHY AND STATISTICS.** Structural Surveys. 2014.

INSTITUTE OF INTERAMERICAN AFFAIRS. **Brazilian technical studies, Joint Brazil-US Economic Development Commission**, Washington, DC, 1954.

KNOTHE G, VAN, G, J, KRAHL, J. **The biodiesel handbook**. Taylor & Francis Usa: Champaign, 2005.

NATIONAL CONFEDERATION OF TRANSPORTATION. **Technical Papers - Articles**. 2017. Available at: <http://www.cnt.org.br/Publicacoes/artigos> Accessed: April 2017.

NATIONAL CONFEDERATION OF TRANSPORTATION. **CNT Energy Efficiency Survey on Road Freight Transport.** Brasília, 2015.

NATIONAL DEPARTMENT OF INFRASTRUCTURE AND TRANSPORTATION. **Road Infrastructure.** 2017.

NATIONAL PETROLEUM AGENCY, NATURAL GAS AND BIOFUEL. **Statistic data.** 2017. Available at <http://www.anp.gov.br/wwwanp/dados-estatisticos> Accessed: April 2017.

NATIONAL TRANSPORT AGENCY. **Highways**. 2017. Available at: <http://www.antt.gov.br/rodovias/index.html> Accessed: March 2017.

PETROBRAS. Diesel oil. 2017. Available at: <http://www.anp.gov.br/wwwanp/petroleo-derivados/155-combustiveis/1857-oleo-diesel> Accessed: April 2017.

SANTANA, E.; BORGES, K.C.; FERREIRA, A. L.; ZAMBONI, A. **Air quality standards Compared experience Brazil, USA and European Union**. Institute of Energy and Environment, Jul. 2012.

SCHEEPERS, P. T. J.; BOS, R. P.; International Archives of Occupational and Environmental Health. **Environmental Sciences**. v. 1, n. 8, 1992.

TRADE UNION OF THE CARGO TRANSPORTATION OF TRIANGLE MINING. Interview open. Uberlandia, Abr. 2017.

WHO. **Air quality guidelines for Europe. WHO regional publications**. European series. Copenhagen: n. 91 2000.