ANALYSIS OF THE INFLUENCE OF DIENITRO ON CO AND NOₓ EMISSIONS IN DIESEL PUBLIC TRANSPORT BUSES WITH EGR AND SCR SYSTEMS

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ABSTRACT

Transport of people and goods has always been associated with the generation of some pollution, whether atmospheric, sound or visual. Managing the urban environment presents a major challenge: preserving environmental resources and also ensuring decent living conditions for the current population and for future generations. In the era of motorized and carbonized transport, vehicles are the main source of emission of atmospheric pollutants, mainly in large urban centers and important precursors of ozone. An important advance in minimizing vehicle emissions was the introduction of cleaner and additive fuels into the Brazilian market. The aim of this study was to evaluate the influence of the use of 0.15% dienitro on S50 Diesel in engines with EGR (Exhaust Gas Recirculation) and S10 Diesel in engines with SCR (Selective Catalytic Reduction) and EGR system. The tests were performed with a gas analyzer directly on the exhaust of vehicles with engine speed of 1300 rpm. Results show CO emission reductions of 72.8, 37.9, 15.7% and NOₓ emission reductions of 48.0, 48.5 and 31.0%, respectively for the S50 EGR, S10 SCR and S10 EGR system. This additive has a slight increase of 1 or 1.5 points in cetane number, low vaporization enthalpy (energy to vaporize) and high combustion enthalpy, ie, Dienitro increased cetane number, faciliting the start of combustion and reducing CO. On the other hand, a fuel that releases less energy during combustion consequently produces lower temperatures within the combustion chamber, ie additives with lower combustion enthalpy have lower NOx emissions.

Keywords: Diesel. Emissions. Pollutants. Dienitro.

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1 Introduction

The rapid urbanization over the last fifty years has already shown changes in microclimate regions and this can be associated to global climate changes. In Brazil, population growth in large cities occurred in the 1970s with economic and industrial growth. The urbanization increased the sources of pollution and consequently the gas emissions.

Urban air quality is determined by a complex system of polluting sources that can divided into fixed (industries, burning, ovens, boilers, etc.) or mobile (motor vehicles, etc). The continuous increase in pollution sources without proper control has contributed to the increase of atmospheric emissions, constituting one of the most serious threats to the quality of life of its inhabitants, in metropolitan areas [1].

It is now clear that large sources of pollution, such as industries, have been removed from large urban centers and vehicles have become major urban polluters. With regard to vehicular emissions, sources of important ozone precursors in cities, the expansion of the circulating fleets, associated with the technological characteristics of older vehicles and fuels in use, led to a worrying increase in polluting emissions levels [2].

According to Koslowski [3], the compounds of vehicular emission, as much of diesel engines, as of gasoline or of mixed fuels, can be classified into two types: those that do not cause damage to health, that is oxygen (O_2), carbon dioxide (CO_2), water (H_2O) and nitrogen (N_2); and those that present direct health and ecosystem risks, which are subdivided into compounds whose emissions are regulated, which are: carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), sulfur oxides (SO_x) and particulate matter (PM); and those not yet regulated: aldehydes, ammonia, benzene, cyanides, toluene and polycyclic aromatic hydrocarbons (PAH).

In response to the increasing restriction of particulate

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matter emission levels by the legislation of many countries, diesel vehicle manufacturers are continually developing methods to reduce particulate emissions as well as other pollutants from diesel combustion, which can be divided into two types: a) which seeks to reduce the particulate matter by improving the process that occurs in the combustion engine, and b) which seeks the removal of the particulate from the exhaust compounds after they are formed and before they are released into the atmosphere. The first type includes improvements in diesel and lubricant oils, the use of additives or mixed fuels, and the development of engines. In the other type, particulate filters are included, the use of these filters with diesel additives, oxidation catalysts, and catalytic converter for particulates [4-5].

It is known that the quality of diesel can be improved by the additives, such as amine detergents, polymeric dispersants, metal deactivators, demulsifiers, ignition accelerators, antistatics, smoke suppressants, antioxidants, biocides and vegetable oils. Thus, it can be seen that the best strategy for reducing emissions is in measures that are not related to machines, but rather to improvements in fuel [4].

Among the additives, the best known are ignition or cetane improvers, lubricity improvers, stabilizers, antioxidants and biocides.

Dienitro additive is a combustion enhancing additive, formulated from natural products, citrus essential oils, derived from four elements, are extracted through rigorously processed distillation, fractionation and extraction processes. Its chemical composition is: ester of fatty acids, linalyl acetate, linalool, eucalyptol, bulnesol, guaiol, limonene, alpha pinene, terpinolene, alpha terpinene and other terpenes and its function is to contribute to the reduction of emissions and consumption in cycle engines Diesel, solving the chemical problems associated with the degradation or decomposition of diesel oil.

The main of this paper is to study the influence of the additive Dienitro on carbon monoxide (CO) and nitrogen oxide (NO_x) emissions in collective transport buses to the S50 Diesel with EGR (Exhaust Gas Recirculation) system and S10 Diesel with SCR (Selective Catalytic Reduction) and EGR systems.

According to PROCONVE, among the main improvements in the technological standard of the vehicle sector are the inclusion of catalysts, electronic injection, electronic emission monitoring systems, gas recirculation systems, noise reduction, turbochargers, filtration systems, more efficient engines and cleaner fuels. There is a perception that PROCONVE has been increasing the entry of new technologies into vehicles and the production of cleaner fuels [6].

In the last decades, the improvements made in the diesel engines relative to the combustion process itself have resulted in a great progress to minimize the emission of particulates [7].

In order to improve the process that occurs in the combustion engine, several studies have been carried out using mixtures of fuels, mainly those formed by a reasonable proportion of other fuel and the diesel itself, in order to obtain a satisfactory reduction of the emissions of these engines [6].

In general terms, the properties of diesel can be directly related to the increase or decrease of a certain pollutant in the composition of the exhaust. It is therefore found that both the quality of the diesel and the type of engine determine the composition of the exhaust and thus the amount of particulate material produced by these machines, although it should be remembered that the composition of the lubricating oil also affects emissions from diesel engines [8].

The Dienitro additive, although not created as a cetane improver, raises the cetane by 1 or 1.5 points and therefore acts directly on the combustion process and its function is to contribute to the reduction of emissions and consumption in diesel cycle engines, solving the chemical problems associated with the degradation or decomposition of diesel oil.

Dienitro reduces the ignition delay, facilitating the start of combustion, contributing to a more even fuel burn, providing better utilization of heat output and bringing the engine closer to the designed conditions, generating more pressure in the combustion chamber (more torque and power) and lower fuel consumption. In addition, there is a reduction in the formation of particulate matter (soot) and gaseous pollutants due to better fuel burning. In some cases, the engine may even alter operating noise as carbon deposits on the pistons cause mechanical balancing failures that force the piston to friction against the cylinder, causing vibration and premature wear of the sealing rings. With a complete burn, there is no formation of this deposit, which contributes, in the long run, to engine durability. Due to its low additive level and how it is formulated with organic substances, Dienitro does not change the fundamental characteristics of the fuel. It is formulated from natural products consisting of the mixture of terpenic and sesquiterpene compounds, fatty acid and nitrogen esters and alcohols (Table 1).

Terpene and sesquiterpene compounds comprise the class of essential oils obtained from plant extracts, preferably those containing: carvacrol, menthol, eugenol, geranyl, geranial, germacrene, linalol, linalin acetate, eucalyptol, terpinolen alfa terpinen and limonene in quantity exceeding 5% and containing

terpinene, guaiol, bulnesol, 1,4-cineole, alpha-felandrene, beta-pinene, mircene and neral in quantity exceeding 1%.

The fatty acid esters used may be obtained from vegetable oils or animal fats (beef tallow).

The nitrogenous compounds used comprise the class of amines and amides, with number of carbons ranging from 1 to 4 and compounds that have in their molecules nitrogen and hydrogen (ammonia).

The amine class nitrogen compounds may preferably have from zero to three carbons in their molecules and the amide class nitrogen compounds may preferably have from zero to one carbon in their molecules.

Straight and/or branched chain alcohols have a number of carbons ranging from 1 to 5, with the preferred alcohol being isopropyl.

The additive is comprised of the mixture of:
- 60 to 65% of essential oil;
- 32 to 37% fatty acid ester;
- 0.9 to 1.2% nitrogenous compound; and
- 1.8 to 2.4% alcohol.

The application of Dienitro at predetermined dosages promotes the reduction of pollutant emissions, impacting the priority on air quality, restoring the intrinsic properties of the engine, maximizing its cost-benefit ratio, including directly reducing its specific consumption.

In combustion, air and fuel are the main elements. Air is basically made up of 21% oxygen (O_2) and 79% nitrogen (N_2). The fuel has different characteristics and compositions, depending on the origin of the oil to be distilled, consisting of carbon and hydrogen as main components (C_xH_y).

Starting from the simplified chemical combustion equation 1:

• Air + Fuel → CO_2 + H_2O + thermal energy + unburnt gases (1)
• (O_2 + N_2) + (C_xH_y) → CO_2 + H_2O + thermal energy + NO_x + SO_x + CO

In the case of a stoichiometric mixture between air and fuel, there is superior performance in thermal energy, which is then transformed into mechanical energy.

However, this does not always occur, ie yields differ according to combustion. Dienitro additive aims to improve the result of the combustion equation by improving fuel characteristics.

It can then be said that between the formation of the mixture and the ignition there is a delay, which on the one hand is physical, and that the use of Dienitro favors, and a chemical delay, related to the oxidation time which, as a consequence of the action of the additive on the physical delay, this chemical delay is much less in the added fuel compared to the fuel without Dienitro. This way, the Dienitro generates higher pressure, releasing more energy into the fuel chamber. Dienitro allows more homogeneous combustion throughout the combustion chamber, better burning fuel and reducing the percentage of incompletely burned fuel, reducing gas emissions and fuel consumption, as well as increasing engine power and torque.

Thus, with the addition of Dienitro, the chemical combustion equation (2) becomes as follows:
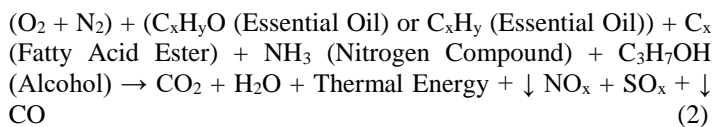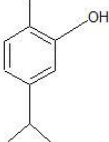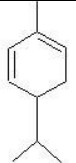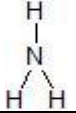
(O_2 + N_2) + (C_xH_yO (Essential Oil) or C_xH_y (Essential Oil)) + C_x (Fatty Acid Ester) + NH_3 (Nitrogen Compound) + C_3H_7OH (Alcohol) → CO_2 + H_2O + Thermal Energy + ↓ NO_x + SO_x + ↓ CO (2)

Table 1 – Constituents of Dienitro additive

Constituent	Molecular Formula	Flat Structural Formula
Carvacrol (Essential Oil greater than 5%)	$C_{10}H_{14}O$	
Felandreno Alpha (Essential Oil greater than 1%)	$C_{10}H_{16}$	
Beef Tallow (Fatty Acid Ester)	C_{14} a C_{22}	-
Ammonia (Nitrogen Compound)	NH_3	
Isopropyl Alcohol	C_3H_7OH	

2 Materials and Methods

A gas emissions analyzer was used to perform the gas emissions measurement before and after the addition of Dienitro to Diesel (Fig.1) on three buses. One of them was a vehicle of the brand Volkswagem buses model 17.230 OD, bodywork Mascarelo, manufactured in the year 2011 (S50 diesel fuel) and another manufactured in the year 2014 (S10 diesel fuel). The 17.230 OD chassis has a front engine, the MAN/D 0834230. 4/4.6-liter engine, Max. 226 hp and 2.400 rpm and torque 226 N.m and EGR recirculation system.

And the other vehicle was a brand Mercedes, model OF-1.519 MBB, bodywork Marcopolo, manufactured in the year 2015 (S10 diesel fuel). The OF-1.519 chassis is equipped with the OM-924 LA (Proconve P-7) 4-cylinder electronic engine with a power output of 208 hp, which provides fuel economy and high torque at low revs with SCR system.

Twenty measurements were taken for each vehicle within 2 days, allowing the calculation of the average gas emission rate. Concentrations were determined in the unit ppm (particles per million) and converted to a reading average in unit mg/N.m³ (milligrams per normal cubic meter) with and without the additive, as well as calculated in tons per year.

Measurements were taken at the time the vehicles were at 1300 rpm (revolutions per minute); at a stabilized temperature between 70 and 90 °C; with no load and with the fuel supply and choke controls at rest.

The addition of the Dienitro was performed manually, before filling with diesel, at a rate of 1.5 liters of additive per 1000 liters of diesel (0.15%), ie the additive was always added to the tank before the addition of fuel to ensure mixing.

A non-parametric Statistical Analysis was performed using the Wilcoxon-Mann- Whitney in the Mini Tab Program. Such a test is applied in situations where you have a pair of independent samples and want to test whether the populations giving rise to these samples can be considered similar or not. For this test, the difference between the medians was used and the 95% confidence level was obtained as a result. NO_x measurements were taken by calculating the NO and NO_2 difference, which are also measured by the electrochemical principle.
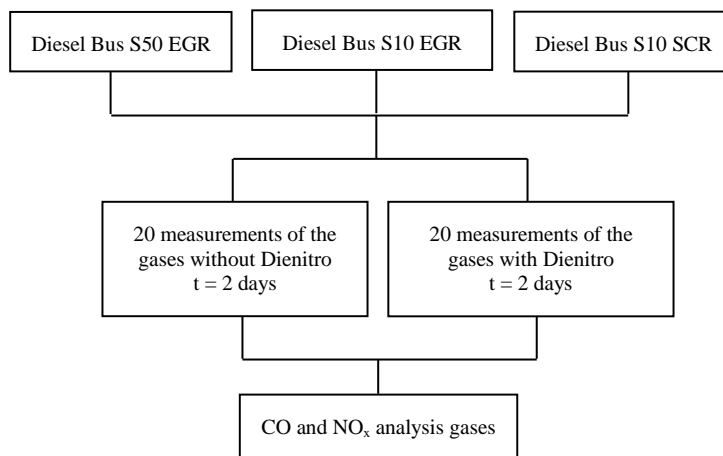

Figure 1 - Flowchart of the main steps involved in CO and NO measurements in diferente types of diesel

Firstly, without the use of the additive, the measurements were carried out to verify the pollution generated by the vehicles and, subsequently, the pollution generated by vehicles added with Dienitro was measured.

The emission reduction in ton/year was also estimated by calculating the exhaust emission flow of each vehicle and the displacement × rotation of the vehicles.

3 Results and Discussion

Several properties of fuels influence the emission in diesel engines. Unlike gasoline engines, where combustion begins with well-defined ignition, combustion in diesel engines begins with multiple ignition cores at different locations in the combustion chamber. The air-fuel ratio varies throughout the combustion chamber due to varying degrees of air-fuel mixture.

The presence or absence of oxygen is another factor that alters this relationship. Additives can influence the entire combustion process, from ignition delay to exhaust gases. The whole set of physical and chemical processes involved in combustion are directly influenced by the properties of the additives (viscosity, cetane number, heat of combustion, amount of oxygen, etc.) are determining factors in the emission of atmospheric pollutants by diesel engines.

In general, an additive containing a high cetane number will lead to a reduction in the ignition delay, ie it will facilitate the start of the combustion process. This reduction in ignition delay will also reduce the rapid combustion phase of the air and fuel premix, generating a smoother release of energy into the combustion chamber. The milder energy release is related to no fuel accumulation in the combustion chamber. When the ignition

delay is large, a high amount of fuel is accumulated in the engine's combustion chamber, generating high temperature spikes soon after combustion begins. Therefore, the temperature peaks within the chamber tend to be lower when using a high cetane number additive.

However, other properties may also influence ignition delay. Additives that have high latent heat values will require a large amount of energy to vaporize in the combustion chamber and contribute to the combustion process not reaching temperatures as high as those of pure reference fuel. This vaporization process can reduce the chamber temperature and thus increase the ignition delay [9-10]

3.1 CO Emissions

CO emission, as can be seen in Tables 2 and 3 and Figures 2 to 4, was reduced by the addition of Dienitro. In this article, the ignition delay was not measured, but as the only altered factor was the fuel formulation (keeping the pump and injector in the same conditions), one can estimate the change that the additive caused in the ignition delay.

Another important feature to be evaluated in fuels is the amount of thermal energy released in the combustion process. Additives that exhibit a high energy release during the combustion process tend to increase the chamber temperature and reduce the poorly mixed regions in the combustion chamber.

To evaluate the energy release during the combustion process of the additive diesel oil, the relationship between the pure additive combustion enthalpy and the CO emission is an important parameter to be evaluated in the formation of this pollutant. Additives with higher combustion enthalpy are known to generate the lowest CO emissions.

The additive generated a lower CO emission, indicating a more complete combustion. This additive has a slight increase of 1 or 1.5 points in cetane number, low vaporization enthalpy (energy to be vaporized) and high combustion enthalpy.

The CO reduction of S10 diesel was lower than that found in studies with vehicles using S50 diesel as expected; because S10 diesel has a reduction mainly in sulfur content (10 parts per million); which reduces the amount of NO_x, SO_x and other particles during burning; compared to the S50 (50 parts per million) [11].

As a result of the authors' studies [3; 12], it was observed that S10 diesel has a small reduction in pollutant emissions compared to S50 diesel.

Another important factor in CO generation is related to the presence of alcohol in Dienitro. CO is produced, directly or indirectly, by combustion of fuels. In optimal combustion (3), oxygen (O_2) and carbon (C) combine to produce CO_2.

FULL COMBUSTION: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ (3)
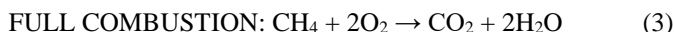
However, CO formation occurs when the O_2 available during combustion is inadequate (4) to form CO_2 [13].

SEMI-FULL COMBUSTION: $CH_4 + 3/2O_2 \rightarrow CO + 2H_2O$
    (4)
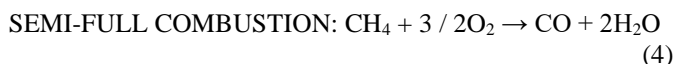
Previous studies [14-15] observed an increase in CO emission with diesel alcohol blending. The reason for this observation is that the amount of oxygen required to produce CO increases with the mixing of alcohols. Higher content of alcohol mixtures may result in higher CO emission at higher engine load to a limited extent as a result of a lower combustion temperature caused by the significant latent heat of vaporization that alcohols possess. At a higher compression ratio and higher load, the combustion temperature becomes higher. This results in a higher affinity of oxygen with carbon. The influence of an oxygen atom on the oxidation reaction of alcohol will be increased. As a result of this condition, CO is converted to CO_2 and CO formation decreases.

Increasing of the rotation speed of the engine adds to the engine temperature which gives rise to the CO_2 production [16-17] because combustion is the basic step for production of the CO [18].

3.2 NO_x Emission

The formation of NO_x highly depends on cylinder temperature, the oxygen percentage of fuel, and residence time for the ignition reaction to take place. The combustion chamber detached into their atomic states and partake in a series of reaction at high combustion or flame temperature (high ignition time), N_2 of air (air have 79% N_2 and 21% O_2) and oxygen of fuel. The three of leader reactions producing thermal NO_x was showed in Zeldovich Mechanism [19-20]:

$N_2 + O \rightarrow NO + N$ (5)
$N + O_2 \rightarrow NO + O$ (6)
$N + OH \rightarrow NO + H$ (7)

By adding an oxygenated fuel on the diesel fuel, NO_x emissions increase due to generation of the necessary oxygen for NO_x formation.

Nitrogen oxide formation is available at high chamber temperatures, ie, the lower fuel chamber temperature reduces the emission of nitrogen oxides [21-22].

As NO_x intensifies with increasing engine load, this response decreases with increasing engine speed. Because increasing engine speed causes a lower temperature, it does not reach the temperature required to produce NO_x. Since NO_x formations are extremely dependent on the temperature of combustion, ie due to shorter ignition delay, there is a smaller fuel accumulation during combustion which in turn leads to reduction in NO_x emissions.

The reductions of NO_x emissions by adding Dienitro to diesel can be seen in Tables 2 and 3 and Figures 2 to 4. The amounts of nitrogen oxide are also influenced by the combustion heat of fuels. A fuel that releases less energy during combustion produces, consequently, lower temperatures within the combustion chamber, that is, lower temperatures within the combustion chamber, ie additives with lower combustion enthalpy have lower NO_x emissions.

Table 2 - Results of CO and NO_x gas measurements for vehicles, without and with additives

Fuel/System	Condition	CO (mg/Nm³)	NO_x (mg/Nm³)
S50/EGR	Average Without Dienitro	12,318.7	3,845.4
	Average With Dienitro	3,353.3	1,999.3
S10/EGR	Average Without Dienitro	3,933.2	2,126.9
	Average With Dienitro	2,444.4	1,096.4
S10/SCR	Average Without Dienitro	13,492.7	3,146.4
	Average With Dienitro	11,368.0	2,169.5

Table 3 - Variation of emissions of vehicles with and without Dienitro

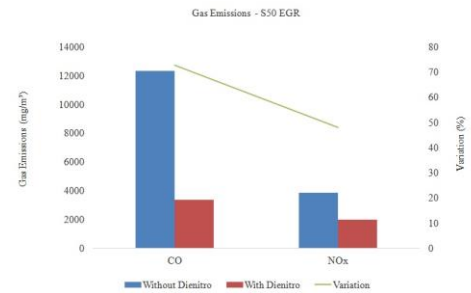| Fuel/System	Gases	Average Without Dienitro (mg/Nm³)	AverageWith Dienitro (mg/Nm³)	Variation (mg/Nm³)	Variation (%)
S50/EGR	CO	12,318.7	3,353.3	- 8,965.4	-72.8
	NO_x	3,845.4	1,999.3	- 1,846.1	-48.0
S10/EGR	CO	3,933.2	2,444.4	-1,488.8	-37.9
	NO_x	2,126.9	1,096.4	-1,030.5	-48.5
S10/SCR	CO	13,492.7	11,368.0	-2,124.7	-15.7
	NO_x	3,146.4	2,169.5	-976.9	-31.0

Figure 2 - Emissions of CO and NO_x gases for the vehicle S50 EGR (Volkswagen), without and with additivation
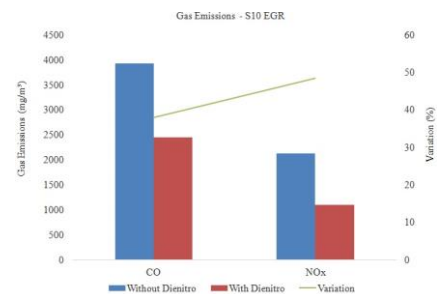

Figure 3 - Emissions of CO and NO_x gases for the vehicle S10 EGR (Volkswagen), without and with additivation
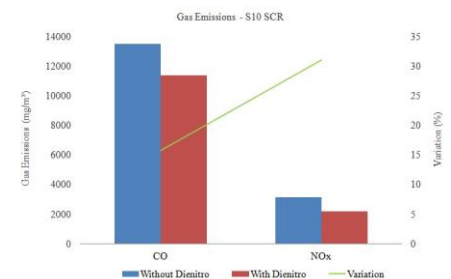

Figure 4 - Emissions of CO and NO_x gases for the vehicle S10 SCR (Mercedes), without and with additivation

Heywood [23] also noted in his study on Internal Combustion Engine Fundamentals that NO_x emissions depend on the combustion chamber temperature and the oxygen availability. Consequently, NO_x emissions from diesel to Dienitro are lower than those from diesel, because the rate of heat release from diesel to Dienitro is lower. Prasad et al. [24] also reported in his study of Performance Evaluation of Inedible Vegetable Oils as Substitute Fuels in Low Heat Rejection Diesel Engines; a reduction when using Jatropha oil as an additive in low heat rejection diesel engines.

Fayyazbakhsh [25] in his study of the influence of additives-fuel on diesel engine performance and emissions shows that with addition of the nitro methane and cerium on the diesel–ethanol fuel, the minimum NO_x emission was achieved and on improvement of the engine performance because of the increase cetane number.

For CO and NO_x gases there were greater reduction for the S50 EGR and there is less reduction for the S10 SCR. Some authors [26-27] concluded that the SCR system is more efficient in the reduction of NO_x in relation to the EGR and that, due to the motor configurations, the SCR system has been shown to be less polluting in idle conditions, differently from what was observed in this study.

However, the effects of exhaust gas recirculation, EGR, on combustion, could be observed in the study by Jacobs et al. [28], on the Impact of Recirculation of Exhaust Gas Performance and Emissions of a Reinforced Diesel Engine on a Detroit Diesel engine in which it was possible to identify the temperature emitted during the combustion. Comparing the obtained results, it was possible to observe clearly the effects of the EGR on the peak temperature of the flame. As an example, the peak temperature obtained with the injection in the top dead center, 0°, without EGR was around 2700 K, with the recirculation of 20% of the exhaust gases at the reached temperature was approximately 2400 K.

Moreover, Squaiella [29] also observed in his study of the Effect of Exhaust Gas Recirculation System in the control of NO_x emissions, in Diesel Engines, a great reduction of NO_x. These results were mainly achieved with increases in EGR rates; it was observed that reducing the percentage of oxygen mass at admission from 23.3% to 17.5% reduces the NO_x formation by approximately 13%, thus demonstrating that the effect of reducing the peak of the combustion temperature caused by flame diffusivity is primarily responsible for the reduction of NO_x formation; it can also be observed that the levels of CO emissions were maintained, even with an increase in EGR rates.

Comparing the vehicles, the CO reduction was more significant for the EGR vehicle with respect to the SCR. It is also assumed that Dienitro additivity changes the transformation of ammonia (NH_3) and carbon dioxide (CO_2), and consequently the reaction of ammonia (NH_3) with nitrogen oxides (NO_x) is influenced and the release nitrogen (N_2) and water (H_2O), as well as gases in general, can be altered.

In general, it can be said that, for both vehicles with S50 and S10 diesel, a satisfactory result was obtained for CO and NO_x, gases that present direct risks to health and ecosystems.

3.3 Calculation of the Reduction of the Emission of Gases (ton/year)

The reduction in gas emissions in tons per year was measured based on the flow obtained by the rotation and cylinder capacity of vehicle engines.

The calculation based on the rotation and the capacity of the cylinder of the engines refers to the theoretical calculation of the flow, that is to say, as the engines of the vehicles have a cylinder capacity of 4,600 cm^3 and 4,800 cm^3, it is considered that with each rotation of the engines there will be an exhaustion of 4.6 and 4.8 liters of gases, respectively.

In this way, the calculation of the flow can be obtained by equation 8:

Flow [m^3/h] = (cylinder capacity [liters]/1,000) x (Rotation [rpm] x 60) (8)

Table 4 shows the flow rate, obtained by equation 8, of 358.8 m^3/h for the vehicle with a cylinder capacity of 4,600 cm^3 and 374.4 for the with a cylinder capacity of 4,800 cm^3.

Table 4 - Vehicles flow rate.

Model Vehicle	Cylinder capacity (cm^3)	Cylinder capacity (liters)	Rotation (rpm)	Flow (m^3/h)
17230VW	4,600	4.6	1,300	358.8
OF 1519 MBB	4,800	4.8	1,300	374.4

The reduction of gas emissions in tons per year can be calculated by equation 9:

Emission Reduction [ton/year] = Emission Reduction [ton/Nm^3] x Flow [m^3/h] x Bus hours worked per year [h/year] (9)

Tables 5 and 6 show the reduction of CO and NO_x emissions, calculated by equation 9, making a total of 19.91 tons/year of CO emission reduction, as well as 6.12 tons/year of NO_x emission reduction.

Table 5 - Reduction of CO emissions in ton/year.

	CO Gas			
System	Emission Reduction (mg/Nm^3)	Flow (m^3/h)	Work (h/ano)	Emission Reduction (ton/ano)
S50 EGR	8,965.0	358.8	4,380.0	14.09
S10 EGR	1,488.8	358.8	4,380.0	2.34
S10 SCR	2,124.7	374.4	4,380.0	3.48
Total				19.91

Table 6 - Reduction of NO$_x$ emission in ton/year.

	NO$_x$ Gas			
System	Emission Reduction (mg/Nm³)	Flow (m³/h)	Work (h/ano)	Emission Reduction (ton/ano)
S50 EGR	1,846.1	358.8	4,380.0	2.90
S10 EGR	1,030.5	358.8	4,380.0	1.62
S10 SCR	976.9	374.4	4,380.0	1.60
Total				6.12

4 Conclusion

Fuel additives are produced from different formulations and mixtures to analyze the effect of different parameters on engine performance, gas emissions and fuel properties. In this paper, the diesel Dienitro percentage and engine speed are controlled parameters.

Based on these experiences the use of Dienitro reduced CO and NO$_x$ emissions in all additive fuels, as this additive has a slight increase of 1 or 1.5 points in cetane number, low enthalpy vaporization (energy to vaporize) and high enthalpy combustion, ie Dienitro increased the cetane number, facilitating the start of the combustion process and reducing CO emission. In this way CO is converted to CO$_2$ and the formation of CO decreases.

NOx emissions were reduced due to shorter ignition delay and less fuel accumulation during combustion.

However, it can be noted that for CO and NO$_x$ gases there was a greater emission reduction for EGR S50 and a smaller reduction in emission for SCR S10.

ANÁLISE DA INFLUÊNCIA DO DIENITRO NA EMISSÃO DE CO E NOx EM ÔNIBUS DE TRANSPORTE PÚBLICO À DIESEL COM SISTEMAS EGR E SCR

RESUMO: O transporte de pessoas e mercadorias sempre esteve associado à geração de poluição, seja atmosférica, sonora ou visual. A gestão do ambiente urbano apresenta um grande desafio: preservar os recursos ambientais e também garantir condições de vida decentes para a população atual e as gerações futuras. Na era do transporte motorizado e carbonizado, os veículos são a principal fonte de emissão de poluentes atmosféricos, principalmente em grandes centros urbanos e importantes precursores do ozônio. Um avanço importante na redução de emissões de veículos foi a introdução de combustíveis mais limpos e aditivos no mercado brasileiro. O objetivo deste artigo foi avaliar a influência do uso de dienitro a 0,15% no diesel S50 em motores com EGR (Recirculação de Gases de Escape) e diesel S10 em motores com sistema SCR (Redução Catalítica Seletiva) e EGR. Os testes foram realizados com um analisador de gases diretamente no escapamento de veículos com rotação do motor de 1300 rpm. Os resultados mostram reduções de emissão de CO de 72,8, 37,9, 15,7% e reduções de emissão de NO$_x$ de 48,0, 48,5 e 31,0%, respectivamente para os sistemas S50 EGR, S10 SCR e S10 EGR. Esse aditivo apresenta um ligeiro aumento de 1 ou 1,5 pontos no número de cetano, baixa entalpia de vaporização (energia para vaporizar) e alta entalpia de combustão, ou seja, o Dienitro aumentou o número de cetanos, facilitando o início da combustão e reduzindo o CO. O combustível que libera menos energia durante a combustão produz, consequentemente, temperaturas mais baixas dentro da câmara de combustão, ou seja, aditivos com menor entalpia de combustão têm menores emissões de NO$_x$.

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