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Issuances of Automotive Vehicles and the Impacts on Air Quality in the Largest City in the Brazilian Amazon

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Received: 15 October 2018; Accepted: 3 November 2018; Published: 8 November 2018

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Abstract: Manaus, a city of more than two million people, suffers problems arising from strong sunlight and aggravated by several factors, such as traffic congestion and greenhouse gas emissions generated by evaporation and burning of fuel. The present study examined Carbon Monoxide (CO) and Nitrogen Dioxide (NO_2) emissions in an urban area of the city using different methodologies. CO and NO_2 were measured using automated and passive analyzers, respectively. Meanwhile, direct monitoring of these pollutants was performed in vehicular sources in the vicinity of sampling locations. Results showed that levels of carbon monoxide vary over time, being higher during peak movement of vehicles. NO_2 values have exceeded the recommendations of the World Health Organization (WHO), and monitoring at source showed high levels of CO and NO_2 emissions to the atmosphere.

Keywords: vehicle; pollution; measurement and environment

1. Introduction

The study of chemical interactions occurring in the atmosphere is very complex. The atmosphere is similar to a natural laboratory. However, unlike in laboratory research, where researchers perform specific experimental reactions with controlled atmospheric variables, the atmosphere involves a series of chemical reactions that are difficult to monitor, mainly owing to low concentrations, altitude variation, and slow reactions. This is why studies on the chemical reactions occurring in the atmosphere and their consequences are growing, despite the difficulties they present [1].

Moreover, in addition to natural components, any portion of atmospheric air contains primary pollutants emitted by pollution sources and as a result of reactions occurring among these, from chemical reactions among them, a relative amount of secondary pollutants. The composition of atmospheric air, the chemical reactions occurring in the atmosphere, the movement of air masses, the energy balance, and meteorological conditions are all factors responsible for observed atmospheric phenomena that have intensified in recent times [2].

Until the Constitution of 1988, environmental concerns in Brazil permeated constitutional standards. Environmental impact studies, for example, were introduced into Brazilian law through Act number 6803/1980, which obliged companies linked to petrochemical, clorochemical, and carbochemical industries and nuclear installations to present special studies of alternatives and impact assessments [3].

After the UN Conference on the Environment held in Stockholm in 1972, there was an increase in ecological awareness, a phenomenon that came to be reflected in legislative processes ensuring protection and preservation of the environment [4].

In Brazil, the environment acquired constitutional status after the 1988 Constitution. The Magna Carta reveals some central axes: The environment as a fundamental right; the conservation of biological diversity and ecological processes; the creation of specially protected territorial areas; the need for prior study of the environmental impact of activities potentially causing significant degradation; and environmental education [5]. It consciously seems to promote the idea that development at any cost causes profound changes in the environment and society. Some noteworthy examples of the most damaging consequences are those resulting from accelerated urbanization processes [6].

Manahan [7], when analyzing the climatic differences between urban and rural areas, confirms the impacts of urbanization on the climate of cities worldwide. According to the author, urbanization induces a strong effect on microclimates. In rural areas, vegetation and water bodies have a moderating effect, absorbing modest amounts of solar energy and releasing it slowly. In contrast, in cities, stone, concrete, and asphalt pavements strongly absorb solar energy and reradiate heat back to the urban microclimate.

There are many studies concerning the consequences of population increases for environmental imbalance, considering that the process of expansion of cities has supported itself through the availability of abundant and cheap energy sources. Reference data from the National Energy Report (BEN) indicates that the domestic supply of energy in Brazil grew by 5.6% in 2007, from 226.1 million tonnes of oil equivalent (TOE) in 2006 to 238.8 million TOE in 2007. This growth was greater than the growth of the economy (5.4%) registered by IBGE (Brazilian Institute of Geography and Statistics) [8].

In 2012, total demand for oil products stayed at 2.274 million barrels of oil equivalent (BOE) per day, 6.6% more than in 2011. The production of oil, at a negative rate of 1.7%-including LNG (liquefied natural gas) and shale oil-reached the amount of 2.16 million bbl/day (barrels per day). In this context, there were net imports of oil and oil products on the order of 211 thousand BOE/day in 2012 [9].

Manaus is the Amazon's largest city and its population has exploded in recent decades as a result of development policies that prioritized the state's capital at the expense of other municipalities. Consequently, as in other cities in Brazil, the process of development occurred unsustainably, when considering the increase in population and the growing number of motor vehicles. Geographically located near the Equator (latitude 03°07′00″ N, longitude 059°57′00″ W, and altitude 67.00 m) and with an area of 11,401 km^2, Manaus is home to a population of 2,145,444 inhabitants [10].

These data give a population density of 188.18 inhabitants per km^2. Throughout the Amazonas state, density is only two inhabitants per km^2, revealing a huge concentration of population in the state's capital. Since 1970, the city's population has grown from 300,000 to over 2 million inhabitants. In 2000, Manaus was the ninth most populous city in Brazil and grew to take eighth place in 2004 [10]. Population growth in Manaus is demonstrated in Table 1.

The increased number of thermoelectric power plants (UTEs), which is also proportional to population growth (since it is the basis of the power generation matrix), contributes directly to indices of carbon monoxide, nitrogen oxides, and others pollutants in the atmosphere caused even by urban traffic of the modern cities [11].

However, it is important to note that the polluting power of UTEs is not greater than the contribution of vehicles, because the transportation sector consumes high levels of energy and is responsible for over 50% of fuel consumption globally. This can be attributed primarily to development processes, which were dependent on petrol and diesel, particularly for the energy industry and transport sector [6].

Table 1. Population growth in Manaus [10,12].

Year	Inhabitants
1970	284,000
1980	635,000
1990	1,100,000
2000	1,405,835
2004	1,592,555
2005	1,644,690
2007	1,646,602
2008	1,709,010
2009	1,738,641
2010	1,802,014

The image of Figure 1 shows the geographic panorama of the location of the UTEs installed in the city of Manaus.

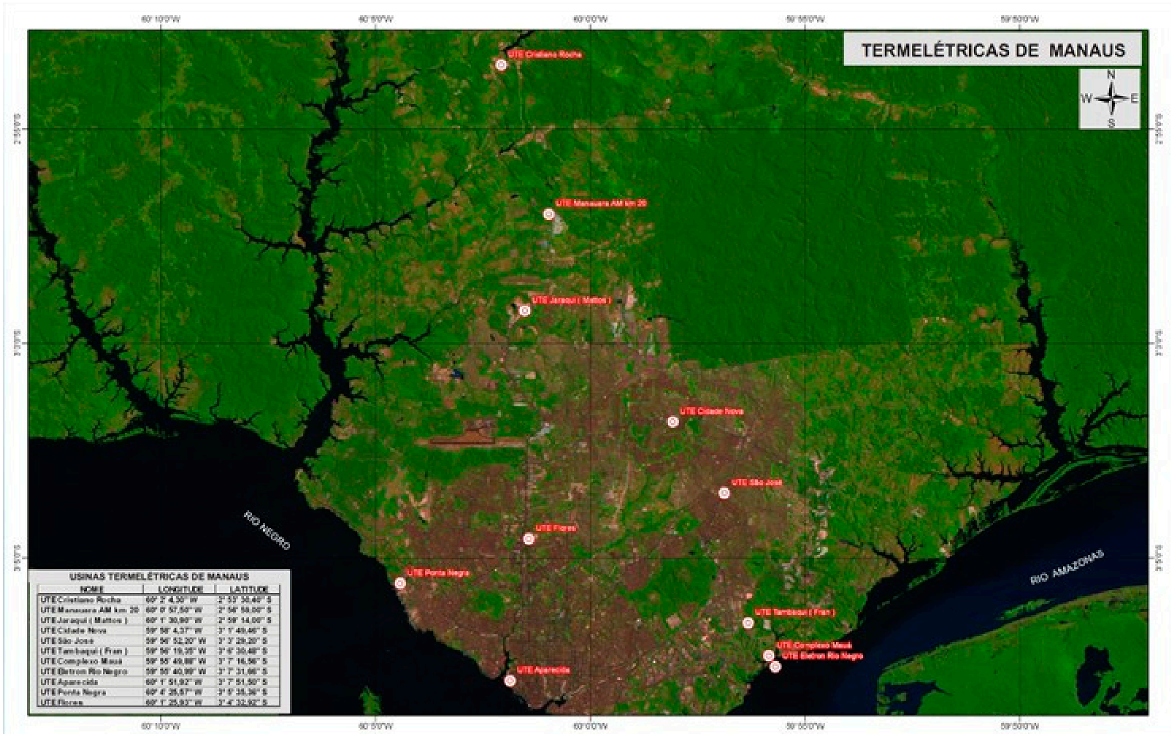

Figure 1. Location of UTE's in the city of Manaus/AM. Source: [13].

Rapid growth has also been observed with regard to the number of vehicles in the city of Manaus. According to data provided by the Ministry of Cities, National Traffic Department (DENATRAN), Manaus has 705,296 motor vehicles, and difficult conditions of transit (slow moving traffic, paving, and other problems) associated with pollutant emissions and the noise can produced [14] may be responsible for the deterioration of air quality in the city (Table 2).

The transport sector's role in increasing emissions has been extensively reported worldwide. In the countries of the European Community, transport contributes 75% of all carbon monoxide (CO), 40% of hydrocarbons (HC), and 48% of nitrogen oxides (NOx) [15]. In the United States, the main source of CO is transport, despite reductions in emissions that have occurred since 1970 owing to increasingly stringent standards of emission control and improvements in energy efficiency [16].

Table 2. Data concerning the vehicle fleet in Manaus. Source: [17].

Type	2010	2012	2013
Automobile	246,265	285,796	309,162
Truck	14,314	15,990	16,406
Truck-tractor	1902	2348	2540
Van	48,537	58,977	83,700
Pickup-truck	18,367	21,607	23,166
Minibus	2280	2777	2894
Motorcycle	80,333	104,819	119,763
Motor-scooter	8269	10,320	11,821
Bus	5626	7307	7714
Trailer	1642	1848	1836
Semi-trailer	9618	10,861	11,236
Tractor wheels	48	50	58
Tricycle	90	342	571
Utility	2269	3473	4078
Other	60	65	67
Total	439,620	526,580	595,012

In Brazil, the situation is broadly similar, justifying concerns relating to air quality. The traffic congestion occurring in virtually all capitals is responsible for 90% of CO, 80 to 90% of emissions of NOx and hydrocarbons, and a considerable portion of particles that constitute a threat to human health [18].

Consequently, the issue of transportation and the environment is a paradoxical one. On one hand, increasing the number of vehicles meets the growing demand for mobility; on the other hand, the effects are significant for society. Hence, transport plays a fundamental role in the lives of city dwellers and is a major environmental concern because in coming decades, transport is expected to remain a significant contributor to air pollution, especially in more populous cities.

Converging factors, such as the deployment of car factories and the construction of highways, led to an increase in oil demand. As a result, the consumption of fuels increased, increasing emissions and impacts on environment and society that are difficult to measure [8].

Undeniably, there has been major technological development of engines and fuels, resulting in significant reductions in emissions of some pollutants. Notwithstanding, factors such as the growth of vehicular fleets, traffic jams, and increases in distances traveled contribute to significant emission increases. Moreover, one should take into account the fact that, although vehicle pollutants can be formed in combustion processes, the production of pollutants per unit of burned fuel is higher in vehicle engines [19].

There are several factors that produce this effect, including no permanent combustion, insufficient fuel atomization, and the engine cooling system that prevents the oxidizing mix from burning equally. Overtaking, stopped traffic, conversions, vehicle speed, and other typical traffic events also have significant impacts on fuel consumption and emissions, caused by changes in operating motor vehicles [19].

Despite the fact that the State of Amazonas represents the largest isolated energy system, its capital, Manaus, does not have an environmental management policy directed at monitoring and supervising air quality. The number of thermoelectric plants and motor vehicles is increasing within its territory, mainly within the state's capital; consequently, the city needs to adapt to the increase in fuel and energy consumption.

Some developed areas such as the United States and Western Europe, have made significant progress in relation to the control of air pollutants. These advances have been globally important; however, poor air quality continues to affect many people in developing countries. This situation is caused by rapid population growth combined with growing energy demand, weak standards for pollution control, dirty fuels, and inefficient technologies. Some governments have begun to address this problem, but very strict measures are needed to reduce the serious impacts of air pollution on public health worldwide [20].

Currently, some consequences are already notable in the atmosphere of Manaus as a result of increased emissions of pollutants. These include smog, which is probably due to the high turnover of cars, abundant sunlight, and frequent temperature inversions [21].

Nevertheless, very little is known about the effects of urban development on the quality of air that local people breathe. This is because the immensity of the Amazon rainforest conveys the idea of infinity of natural resources. It follows that, having abundance of exaggerated features and dimensions, as is the case of the Amazon region, conscious concern with saving nature is minimized and natural resources are used on a large scale, surpassing necessary limits [8].

Among major air pollutants, carbon monoxide is considered to be the vehicular pollutant with greatest influence on the loss of quality of atmospheric air. Its emissions are related to incomplete combustion, both in mobile sources and in stationary sources. The effects caused by the exposure to the pollutant are associated with their affinity to hemoglobin in the blood, which is greater than that of hemoglobin with oxygen, potentially leading to death by asphyxiation.

Nitrogen oxides also play an important role in atmospheric chemistry. These pollutants are not required to be present in fuel composition in order to be formed, with formation occurring naturally during all processes of combustion. These gases form when fuel is burned at high temperatures, mainly from motor vehicle exhaust and stationary sources. Nitrogen dioxide is a strong oxidizing agent that reacts in air to form corrosive nitric acid as well as organic nitrates and other toxic secondary pollutants, which can attack the outer layer of the material of the monuments of the works of art [22]. It also plays a major role in atmospheric reactions by producing ground-level ozone (or smog) [23].

Nitrogen oxides may be involved in a series of reactions commonly associated with the occurrence of peak ozone that produces photochemical smog, reducing visibility. In urbanized areas, one of the obvious effects caused by burning fossil fuels is the occurrence of smog. It is a photochemical phenomenon characterized by the formation of a kind of fog composed of pollution, water vapor, and other chemical compounds [7].

In Manaus, the consequences of these factors added to forest fires in the dry season, result in an environment with a high level of pollution and serious health problems caused by changes in air quality. Currently, some consequences are already evident in the atmosphere of Manaus due to the increase in pollutant emissions. This is the case with *smog*, probably due to high turnover of automobiles, abundant sunlight and frequent thermal inversions.

According to Kuhn et al. [21], the main contribution in the urban pollutant plume in Manaus was attributed to the city's thermal power plant complex. Strong evidence has shown that there are significant amounts of ozone from this source, as well as the relationship between the concentrations of nitrogen dioxide found in the site studied and the activities related to the intense vehicular traffic, which may directly influence the formation of photochemical *smog* in this region.

Figure 2 shows a photochemical *smog* in the city of Manaus, the visible differences of this environment in the comparison of the images: (a) photographic record of an avenue in humid season of the year; and, (b) photographic record of the same avenue in dry period of the year. The dry period occurs between the months of July to December; the humid period occurs in the months January to June.

This phenomenon is unlike events recorded in other countries, such as in many American cities where haze occurs during wet conditions. The American environmental agency, the EPA, has announced a major effort to improve air quality in national parks and wilderness areas [23].

(a) (b)

Figure 2. Photographic record of Efigênio Sales Avenue, Coroado/Manaus (2014). (**a**) In the humid period; (**b**) In the dry period.

On the contrary, in the Amazon, the atmosphere undergoes great changes during the dry season due to emissions of trace gases and aerosol particles from pasture and forest. The intense deforestation activity and the consequent emission of gases and particles from fires during the dry season have important implications at local, regional and global levels [24]. In Manaus the rains wash the particles, providing a better air quality.

The yellow color in the atmosphere of a city enveloped by smog is due to the presence of nitrogen dioxide, because this gas absorbs some visible light near the limit of violet and, therefore, solar light transmitted through the fog appears yellow.

The consequences of NO_2 atmospheric emissions are diverse, because they cause several harmful effects, direct or indirect, on the health and well-being of humans, fauna and flora, materials, soils, and water bodies. The degree and extent of these effects depends on the scale of these emissions. They can occur at local and regional levels owing to the short residence time of NO_2. Local impacts are limited to the vicinity of sources. Regional impacts comprise a much larger radius of hundreds of kilometers.

According to Kun et al. [21], the main contributors to urban air pollution in the plume of Manaus were the complexes of power plants in the city. Strong evidence showed that there are significant amounts of ozone derived from this source, potentially directly influencing the formation of photochemical smog in the region. The study recorded a rate of ozone in the order of 15 ppb/h within the plume of pollutants.

In the Amazon, there is no air quality monitoring network, the vehicle fleet is increasing exponentially, and the electric sector is made up of 80% thermal generation. These facts motivated this work, which presents the partial results of a survey on air quality carried out by the research group of the Interdisciplinary Center for Energy and Environment (NIEMA) at the Federal University of Amazonas. The study analyzed CO and NO_2 emissions in an urban area of the city of Manaus, using different methodologies.

2. Materials and Methods

As the impact of human activities is increasing on a global scale, the need to recognize and deal with the health risks associated with air pollution has become increasingly urgent [25]. Accordingly, emission monitoring has been adopted as a tool for the management of air pollution, aiming to eliminate or reduce pollutants to acceptable levels.

However, despite the efforts that have been made to clean up the atmosphere, pollution remains a major problem, posing a continuous health risk. Population growth, coupled with an increase in the number of circulating vehicles, traffic conditions, and characteristics of vehicular fuel pollutants, are factors that create a worrying scenario in relation to air quality. This research was conducted by researchers from NIEMA in the context of two research projects supported by National Council for Scientific and Technological Development (CNPq).

2.1. Emissions Monitoring

There are two main types of monitoring: Monitoring emissions directly at the source, and air quality monitoring. In the first type, the concentration of pollutants released into the atmosphere by ducts and chimneys (CME, or Maximum Concentration of Issue) is measured. Conversely, monitoring of air quality deals with the measurement of emissions scattered into ambient air (CMI, or Maximum Concentration Immersion). Both are important because they are chemically related, depicting the pathways that pollutants follow in atmospheric air, dragged by winds, washed by rainfall, or transformed by chemical reactions and solar energy [6].

The weather conditions affect the quality of air, phenomena such as the dispersion and removal of pollutants are closely related to climatic factors, weather conditions, topography, and the use and occupation. For this reason the study of atmospheric chemistry involves knowledge of these conditions, for environmental vitality of any region depends on the ability to exchange energy and matter without accelerating the entropy processes [26].

In this study the variations of meteorological parameters were recorded and considered in the analysis of the measurements. Figure 3 shows the data considered during the study period.

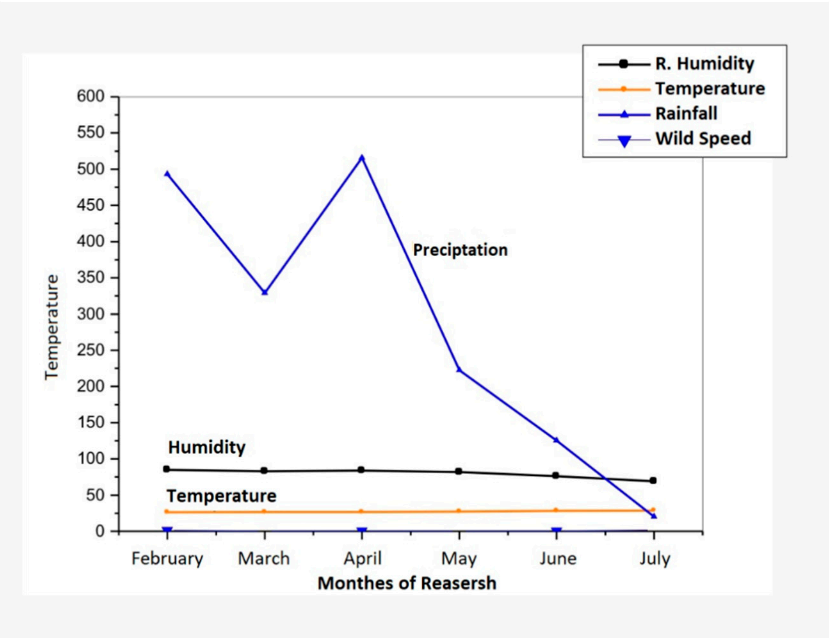

Figure 3. Simultaneous variation of meteorological parameters.

Air quality can be measured using passive or active monitors. Passive samplers are well known because the molecules of the gas of interest are absorbed in the atmosphere by diffusion and/or molecular permeation. These methods were initially used for monitoring indoor environments but are today occasionally used to monitor gases and vapors at low outdoor concentrations [27].

Two sampling sites (passive and active) were installed in a space belonging to the Ministry of Agriculture, Livestock and Supply (MAPA) at a location with coordinates 03°02′36″ S and 60°04′28″ W (Figure 4). This particular location was selected owing to its situation in a neighborhood of busy avenues, where it is consequently influenced by both mobile and urban sources. The two points were located in parallel. Direct monitoring of vehicular sources was conducted at a distance of 3 m from the samplers [27].

Figure 4. Image of passive and active sample mesh.

2.2. Data Stratification

The sample was made up of vehicles manufactured between 1982 and 2013, as shown Table 3.

Data collection took place through stratified sampling. Strata have been classified as follows: Light vehicles, heavy vehicles (trucks and buses), and motorcycles, with the total size of 262 vehicles. The strata are detailed in Table 3. In this sample we selected one hundred and seventy light vehicles, sixty seven motorcycles, eight trucks, eight buses and eight minibus.

According to the type of vehicles, the sample was stratified as follows: Two hundred and eleven vehicles powered by gasoline, twenty one vehicles running on ethanol and 30 Diesel.

Table 3. Year of Manufacture.

Year	N°. of Vehicles	Year	N°. of Vehicles	Year	N°. of Vehicles
1985	2	2000	5	2007	15
1987	2	2001	4	2008	26
1990	2	2002	2	2009	22
1995	2	2003	2	2010	44
1996	2	2004	11	2011	44
1998	2	2005	14	2012	34
1999	2	2006	18	2013	3

2.3. Passive Monitoring

Concentrations of NO_2 were provided by passive analyzers. The methodology adopted was described by Ugucione et al. [28], and consisted of the use of passive samplers installed three meters above the ground on a stand with eight samplers; three of these samplers were used as blank and remained sealed during sampling.

Passive monitoring took place over three months; subsequently, chemical analysis was performed in the laboratory of environmental analytical chemistry of the National Institute of Amazon Research (INPA), employing a molecular UV-Vis spectrophotometer with absorbance at a wavelength of 540 nm. The calibration curve was prepared for each analysis using the standard solution of sodium nitrite.

The concentration of NO_2 was calculated using the first integration of Fick's Law [29]. The Figure 5 shows the image of the measurement sites and the Figure 6 is the photographic record of one of the installed passive analysers.

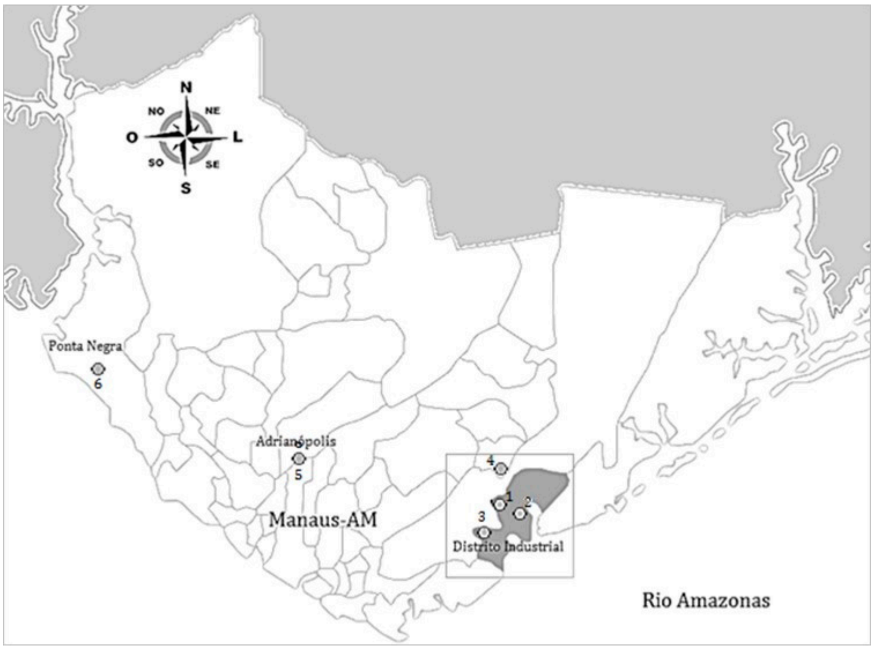

Figure 5. Map of the passive sampling mesh.

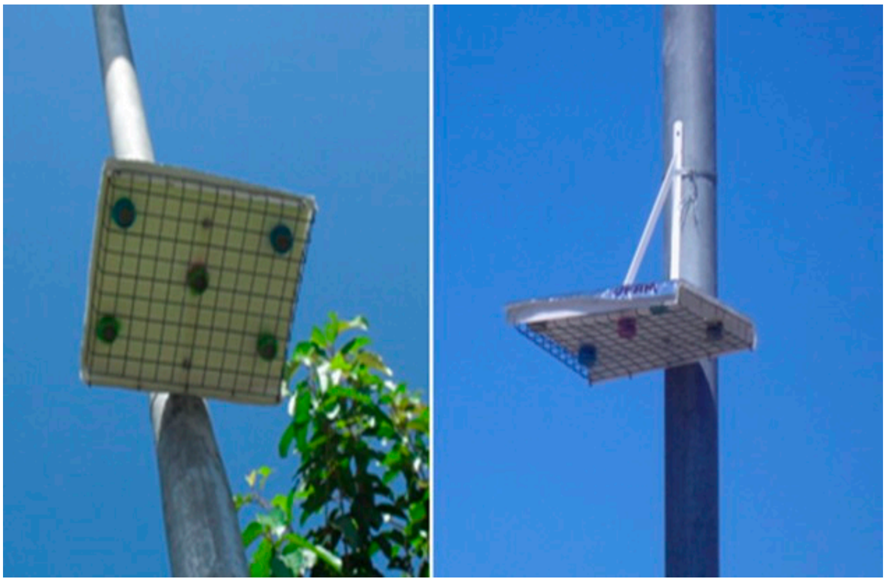

Figure 6. Support with samplers installed at the study site.

2.4. Automatic Monitoring

In addition, an air quality monitoring station, installed a few meters away from the point of passive samplers (Figure 7), provided data on the carbon monoxide concentrations. The Model 48I CO Analyzer from Thermo Scientific was used, with this being widespread and tested throughout the world by environmental agencies.

Figure 7. Air Quality Monitoring Station installed.

2.5. Vehicular Source Monitoring

The instrument of measurement used for vehicular sources was the exhaust gas analyzer for engines, BRIDGE MODEL 900403. This analyzer uses a proven methodology for the measurement of gases, NDIR (Non Dispersive Infra-Red) for the gases CO, HC, and CO_2, and electrochemical sensors for measuring O_2 and NOx. The collection of data for vehicular sources was carried out for three consecutive days during November 2012. This study made use only of data for CO and NO_2. The Figure 8 shows photographic records of the measurements made.

Figure 8. Measurement in vehicular sources.

3. Results and Discussion

Direct NO_2 emissions from vehicular sources were grouped according to the corresponding year of manufacture of each vehicle. The results indicate that average NO_2 concentration was 89.01 ppm (Figure 9).

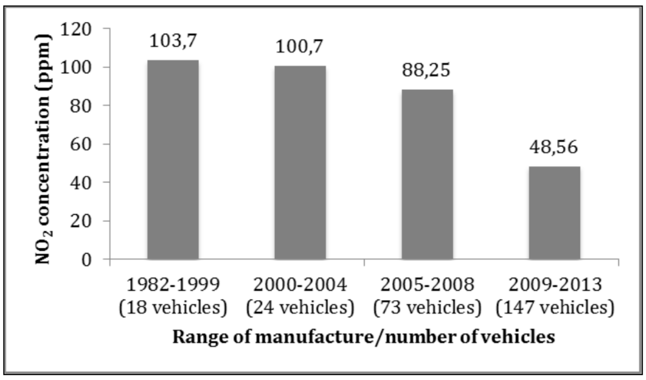

Figure 9. Emission of NO_2 according to the year of manufacture of the vehicle.

It was also evident that older vehicles are the largest emitters, because the largest quantity of emissions corresponds to a smaller number of old vehicles, while a large number of new vehicles have lower emissions.

According to CONAMA Resolution 418, the maximum exhaust emission of CO was fixed at 0.3% (3000 ppm). Dependent on vehicle type, it was observed that measured values were above legal limits. The findings also showed that motorbikes have average CO emissions much greater than those of other types of vehicles. The lack of space for installation of efficient equipment such as filters, for example, seems to be one of the difficulties faced in making this means of transport more ecologically friendly (Table 4).

Table 4. CO average emissions according to vehicle type obtained by the research sample.

Vehicle Type	CO (%)
Light Vehicle	0.61 (6100 ppm)
Motorcycles	12.64 (126,400 ppm)
Trucks	0.71 (7100 ppm)
Bus/Minibus	0.75 (7500 ppm)

In 2009, PROMOT (Program for Control of Air Pollution by Motorcycles and Similar Vehicles) imposed fairly strict restrictions on the emission of pollutants, but these were restricted only to new motorcycles.

It was found that gasoline is the largest emitter of CO (Table 5). Owing to the large number of gasoline-powered vehicles, high concentrations of carbon monoxide are generally found in cities, mainly in areas of large moving vehicles.

Table 5. Average emissions according to fuel type obtained by the research sample.

Fuel Type	CO (%)	NOx (ppm)
Gasoline	1.95 (19,500 ppm)	82.2
Ethanol	1.521 (15,210 ppm)	113.93
Diesel	0.94 (9400 ppm)	34.03

It also became evident that ethanol-fueled vehicles emit more nitrogen oxides than diesel and gasoline-powered ones. Measures have been taken for stationary vehicles and those at average acceleration that facilitate an increase in evaporation losses. With the vehicle stationary and the engine running, the conditions under which measurements were conducted, CO emissions are higher. This is because, at the beginning of the combustion process, the fuel quantity in the mix (fuel × air) is greater, resulting in inefficiency of combustion and in the formation of CO in large quantities. This fact confirms that traffic congestion conditions are decisive for pollutant emissions.

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In addition to measuring the exhaust gases of vehicles, the automatic monitoring station provided data on the atmospheric concentration of CO. The verification of these results showed that the levels of carbon monoxide vary over time, being lower during morning hours and higher during periods of intense traffic movement. Hourly average emissions of carbon monoxide provided by the monitoring station during the first three days of sampling are shown in Figure 10.

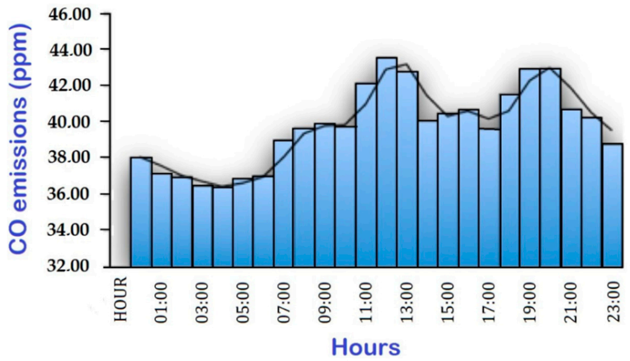

Figure 10. Information from the emission of CO by hours of the day. Source: Research NIEMA. Note: Measurements of NO_2 in atmospheric air were performed with passive analyzers, installed a short distance from the site of vehicular source monitoring. Results obtained at this sampling point during the month in which the survey was conducted were as follows: Sample 1: 0.117 ppm; Sample 2: 0.153 ppm; Sample 3: 0.118 ppm; Sample 4: 0.135 ppm; Sample 5: 0.174 ppm.

The Brazilian legal standard (CONAMA 03) defines the maximum NO_2 limit as being 0.170 ppm, which was exceeded only in one sample. However, the World Health Organization reduces this limit to 0.100 ppm. This standard was exceeded at all sampling points [30].

4. Conclusions

The aim of this study was to quantify emissions of nitrogen oxides and carbon monoxide in vehicle exhaust gases in an urban area. In recent decades, as a consequence of the development process and of limited investment in public transport, the choice of individual means of transport has been responsible for most of the impact on air quality. Saturated urban roads and the idling of vehicle engines result in incomplete combustion of fuel, resulting in substances that are not fully oxidized, such as carbon monoxide and unburned combustible material (HC).

Even if we discard the utopian theories of sustainable development, the increasing number of automotive vehicles seems to make sustainability almost a chimera. Considering population growth and heavy reliance on cars, there are no doubts about the urgency of finding energy alternatives to ensure the possibility of a reasonably sustained system.

This problem is tending toward becoming chronic. The analysis developed here highlights the fact that sustainable development goals are unattainable in the face of breakneck-speed economic growth and social and regional differences, creating dangerous imbalances for future generations. The results from these mismatches are evident, demanding that we reflect on the growing use of energy, increased greenhouse emissions, and investments in public transport, not to mention the need to look at each region with a different perspective, seeking in diversity the solutions for equality.

In Manaus, there more than two million people and almost 500,000 vehicles circling the city. That means a motorization of 4 people per vehicle. By analyzing these facts and the data presented in this study about pollution, we conclude that the city of Manaus is not yet one of the most polluted Brazilian cities, but that there is a problem in the making that cannot be ignored.

The results from the study suggest that gasoline-powered lightweight vehicles are the main emitters of CO and that ethanol-fueled vehicles emit more nitrogen oxides than gasoline-driven vehicles. It was also noted that the emerging segment of motorcycles, which has grown substantially, needs greater control.

In fact, pollution abatement should demand monitoring of emissions mainly from mobile sources in order to reduce impacts on the environment and on people's health. Monitoring is an important environmental management tool in the assessment of air quality, allowing the establishment of measures of prevention and control, which may suggest energy redevelopment interventions consisting of new plant and building technologies, in addition to offering subsidies for traffic.

Above all, so that public policies can be created to reduce emissions, it is important to find ways to measure actual vehicular emissions. Moreover, it is necessary that pollutant emissions are estimated with precision to ensure the appropriate implementation of environmental management policies.

The Program for Air Pollution Control by Automotive Vehicles (PROCONVE) of the Ministry of Environment, based on values measured in laboratory tests, quantified emissions in g/km. The resolution CONAMA number 415 (2009) established the PROCONVE phase L6 to control such emissions from 2013 onwards. To reduce air pollution in urban centers and save fuel, the legal norm in question lays down emission ceilings for the following pollutants from exhaust of motor vehicles.

- Carbon monoxide (1.3 g/km)
- Total hydrocarbons (THC) only for natural gas vehicles (0.3 g/km)
- Non-methane hydrocarbons (NMHC) (0.05 g/km)
- Oxides of nitrogen (NOx) (0.08 g/km)
- Aldehyde (CHO) for Otto cycle (0.02 g/km)
- Particulate matter (PM) to Diesel cycle (0.025 g/km)
- Carbon monoxide at idling to Otto cycle (0.2% in volume)

These tests do not refer to emissions of used vehicles. Moreover, even if they are conducted under strictly controlled conditions, they do not reflect the real use conditions of vehicles.

The processes of dispersion and diffusion of pollutants in air are affected by various environmental characteristics that complicate the process of measurement that is not conducted at source. Measurements taken directly at the source, i.e., at the output from vehicle exhaust, seem to better reflect actual conditions of use of the vehicle.

Many challenges must be faced by developing countries, because these countries must achieve rapid economic growth without compromising air quality. This seems to be an unattainable goal considering global limits; however, an excellent model to follow is that of the developed world, in which progress in air quality has been pursued more effectively.

Author Contributions: Conceptualization, Methodology, Investigation, E.C., I.V. and M.C.; Writing–Original Draft Preparation, E.C. and I.V.; Writing-Review & Editing, E.C. and V.M.; Supervision: E.C. and V.M.; Project Administration, E.C.

Funding: This research received funding by National Council for Scientific and Technological Development (CNPq), Agency of the Ministry of Science, Technology, Innovation and Communications (MCTIC) of the Brazilian government, grant Processes Numbers 5756602008-2 and 5529912005-8.

Acknowledgments: The authors would like to thank CNPq; Superintendence in Manaus of the Ministry of Agriculture, Livestock and Supply (MAPA); and National Institute of Amazon Research (INPA).

Conflicts of Interest: The authors declare no conflict of interest.

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