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Analysis of the Concentration of Carbon Dioxide (CO_2), Ozone (O_3), Nitrogen Oxides (NO_x) and Particulate materials (PM) in the Environment in the city of Manacapuru

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Abstract— *The polluting gases carbon dioxide, ozone, nitrogen oxides and particulate materials in the environment are among the main causes of air pollution in Brazil and in the world, in the region of Manacapuru/AM, this type of pollution has been intensifying in dry periods, due to the increase of motor vehicles. The objective of this article was to analyze the concentrations of the pollutants studied and to relate to the precipitation levels, for results indicating interference with the environment on human health. The data obtained were from the Green Ocean Amazon Project (GoAmazon), where it was possible to analyze the monthly concentration of the transition period between the dry and rainy season. Through the percentage of vehicle fleet increase of the last years it was possible to analyze the impacts caused. In addition, a study of the influence of pollutants on the environment was conducted. The results showed that in the dry season the concentration levels are higher compared to the beginning of the rainy season and that what contributes to this concentration increase is the increase of vehicle fleets, causing impacts on the environment.*
Keywords— *Atmospheric pollution, Particulate material, Environment, Automobiles, polluting gases.*

I. INTRODUCTION

With the industrial revolution, emissions to the atmosphere of particulate matter generated by burning fossil fuels, biomass burning and vehicular emissions increased, thus changing their physical and chemical characteristics (DERÍSIO, 2012). These emissions bring impacts to the environment and consequently to human health, thus, the presence of polluting gases, for example, some gases, bring difficulties for the passage of oxygen in the breathing process, which can lead to death. Little is perceived what polluting gases can bring to health, but can lead to cardiovascular diseases, increase the risk of pneumonia, among other problems, so it can be perceived that it goes from simpler diseases, to more severe cases (CENZI, 2018).

High carbon dioxide (CO2) temperatures cause overheating, which result in impacts on the environment, which in their study showed reduced soil respiration rates (SILVA, 2014). What can lead to, in loss of microorganisms that act and glued to the growth of species.

Júnior, Oliveira and Andrade (2008) Ozone (O3) in relation to other air pollutants, in the ozone layer plays a different role from the lower layer of the atmosphere, in his study it was observed that at the end of weeks the concentration rate is much higher, this may occur due to the largest traffic of vehicles, and because O3 is a secondary pollutant gas, it takes place through atmospheric fusions with other gases that are emitted from mobile sources.

Nitrogen oxides (NOx) are mainly in a large amount of concentration in developed or developing regions, because they are urbanized areas, they receive a higher incidence of solar radiation (SILVA et al., 2003). When there is no presence of tree species in a balanced quantity, it happens in these ambient problems, which ends up further damaging the environment in which one lives, in addition to diseases.

The presence of particulate matter in the atmosphere has been the great cause of increased hospitalizations with

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health problems related to difficulty in breathing. The smaller particles, which measure 2.5 micrometers (μm), are considered responsible for these health problems, because they are smaller, easily enter the respiratory tract, causing diseases (SILVA et al., 2013). For Carmo et al. (2010) the concentration of particulate matter caused by fires in the Amazon has a direct influence on the increase in cases of respiratory diseases, as analyses were made where days with higher material concentration result particulate matter, there were also the days with the highest occurrences in hospitals of people with respiratory diseases.

Isaksson (2010) believes that air pollution can cause stress in terrestrial animals, because just like humans and vegetation, they are living beings and have the breathing process. And through its results, it was able to obtain data that proves that animals exposed to a higher concentration of pollutant strain has a greater stress than animals living in a balanced environment. While Ribeiro (2011) raises the question that the fusion of secondary pollutants causes acid rains, responsible for the deterioration of civil construction materials and historical monuments of cities. It may seem that this problem is not due to pollution, but when it is analyzed that acid rains occur due to air pollution, it can be understood that pollutants are the major causes, where it has been noted, that the main organic compounds volatile (VOC's) are emitted by burning fuels.

The presence of particulate materials in the atmosphere is worrisome when there is concentration at a given point. For Stern (2015) the chemical composition of aerosols in the Amazon is 78% organic, that is, it is the one that prevails, but this occurs in the dry season, which is when concentrations tend to increase. Particles differ both in size and in their chemical composition. And depending on their chemical composition, these particles may become larger over time (SANTOS et al., 2016).

According to Signoretti (2008), vehicular fleets reach 10% of global CO2 emissions. Dutra (2018) believes that chemical fusions among pollutants have become more dangerous due to high consumption. And that these emissions from motor vehicles add up largely to the changes caused in the environment over time.

The present work is based on data taken from the Green Ocean Amazon (GoAmazon) project where it was possible to perceive the increase in concentrations of air pollution in periods of drought in the years 2014 and 2015. GoAmazon is a program that aims to analyze the interactions between the environment and air pollution, showing how the dispersion of pollutants can significantly impact the environment in which one lives. The project was through the installation of experimental sites, located in the city of Manaus and Manacapuru, observing very specific characteristics of these two locations (COSTA, 2015).

The studied area is located in experimental sites in the city of Manacapuru in the state of Amazonas. In the years in which data were collected, the periods chosen were the transition between the dry and rainy period, which contributed to increased concentrations of pollutants in the atmosphere, as well as the increase in the flow of motor vehicles. In order to this problem, it is necessary to analyze the consequences of pollution in the city of Manacapuru/AM.

II. METHODOLOGY

The study was carried out in the city of Manacapuru located in the state of Amazonas whose coordinates are: LATITUDE 03º 17' 69" and LONGITUDE 60º 37' 14" (Figure 1) with an area of 7,329,234 km² and has 96,236 inhabitants according to IBGE/2018.

According to Silva, Freitas and Franco (2007) the climate of this region is called an equatorial climate, (tropical rainy and humid), this is because it is a region that is close to the equator. Having average temperatures ranging from 24 °C to 34 °C. Some data used were collected through the Green Ocean Amazon (GoAmazon) project, the collection was carried out in Manacapuru in the period 2014 and 2015, in which it aimed to develop research related to forest dynamics and its interaction with the Atmosphere.

The study was divided into three parts: i) The analysis of the variation in monthly concentration of pollutants and precipitation variation; ii) Comparison of the fleet of motor vehicles with the beginning year (2014) of the GoAmazon project and the most recent year (2018) made available by the IBGE website and, iii) Study of the influence of pollutants on the environment.

The data variation of the monthly concentration of pollutants were obtained through the GoAmazon project, where in 2014 and 2015, variations in concentrations of air pollutants that cause impacts to the environment were analyzed and computed. The data was organized into a table, using the excel tool as the basis for creating cells with the values of the concentration variation of CO_2, O_3, NOx, Precipitation, MP_1, MP_2, MP_5 e MP_{10}.

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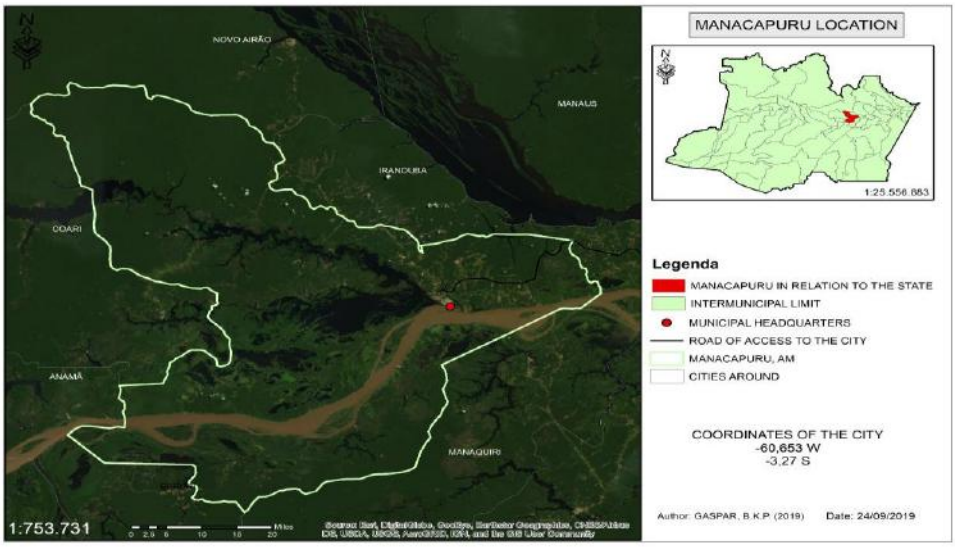

Fig.1 – Manacapuru Location.

From the collection of existing data, also through the excel tool, it was possible to compare fleets of manacapuru motor vehicles in 2014 and 2018, available on the IBGE website. With these data, the percentage of the increase in vehicular fleets in recent years (Table 1) was reached, resulting in studies of possible damage that can cause to the environment.

Table 1 – Comparative of vehicle fleets 2014 x 2018

Comparative of vehicle fleets 2014 x 2018				
	Year of 2014		**Year of 2018**	**Growth in %**
Automobile	2.377	Automóvel	2.778	16,87
Truck	354	Caminhão	392	10,73
Pickup Truck	940	Caminhonete	1.136	20,85
Pickup	293	Camioneta	303	3,41
Microbus	79	Micro-ônibus	88	11,39
Motorcycle	6.302	Motocicleta	7.977	26,58
Motor scooter	2.450	Motoneta	3.214	31,18
Total	**12.795**	**Total**	**15.888**	**24,17**

III. RESULTS

In this section, the results of the analysis of the concentration of pollutants in the city of Manacapuru/AM will be presented in 2014 and 2015. The analysis period is based on the transition period between the dry and rainy season, showing the impact on the environment and human health by increasing the concentration of pollutants by vehicular fleets.

Variability of the concentration of polluting gases CO_2, O_3, NO_x, PM_1, PM_2, PM_5, PM_{10} and precipitation in the transition period between the dry and rainy season

Figure 2 shows the levels of pollutant concentration in August, both for CO_2 and O_3. The results show that the concentrations are quite high, because the month of August, is the month where the dry season begins and begins to intensify. In September, October and November CO_2 levels fluctuate, but still continue to have high levels, so it is months where a higher temperature is found. The increase in atmospheric CO_2 can have impacts on plant species, as their concentration can lead to, in the loss of nutrients from foliage. This can be demonstrated in Bordignon (2016), where the author performs analyses on soybean leaves, showing high levels of CO_2 concentration and temperature, it was observed that CO_2 lowered the capacity that Nitrogen (N) exerts on plants, which are responsible for for its growth.

The concentration data were obtained through the

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GoAmazon project database, where it was not possible to analyze O3 in September, October and November, in return it was possible to analyze the month of December that in relation to co2 levels that fell , O3 levels were quite high, because December is when the transition from dry season to rainy season occurs, that is, what explains this high level of concentration is thermal inversion, which causes the pollutant to be trapped in the cold air layer , and thus preventing the exchange between cold air and hot air and polluting circulates. In addition, the weak local winds interfere with the dispersion of pollutants.

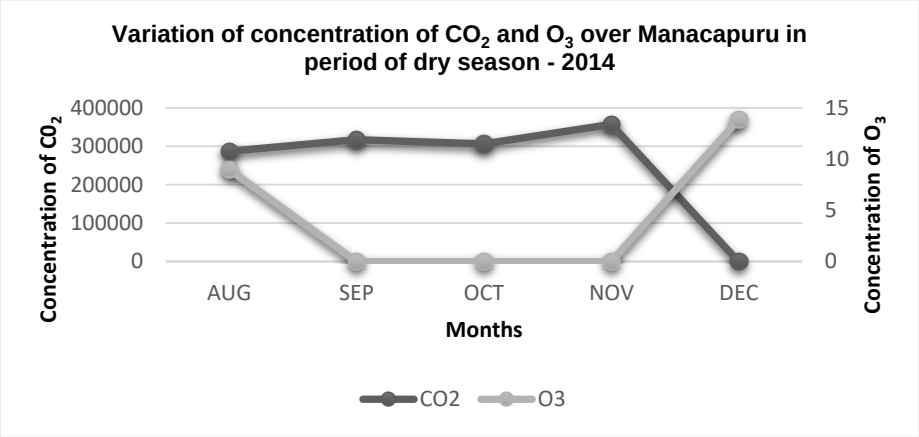

Fig.2 – Variation of concentration of CO_2 and O_3 over Manacapuru in months of august, october, november and december of 2014, period of dry season.

The variation in the concentration of CO_2 and O_3 shown in Figure 3, in 2015, an inverse behavior in the concentration of pollutants, from September to November the concentration of CO_2 is high, while the concentration of O_3 showed a lower concentration. Furthermore, the concentration of O_3 in 2015 showed higher values than 2014. To high concentrations of O_3 present in the troposphere are harmful both to the environment and humans, this due to being a secondary pollutant, generated from CO_2 oxidation solar radiation. In Dutra, Fioravante and Ferreira (2009) the study showed that the amount of O_3 found in the atmosphere is related to the increase in vehicular fleets.

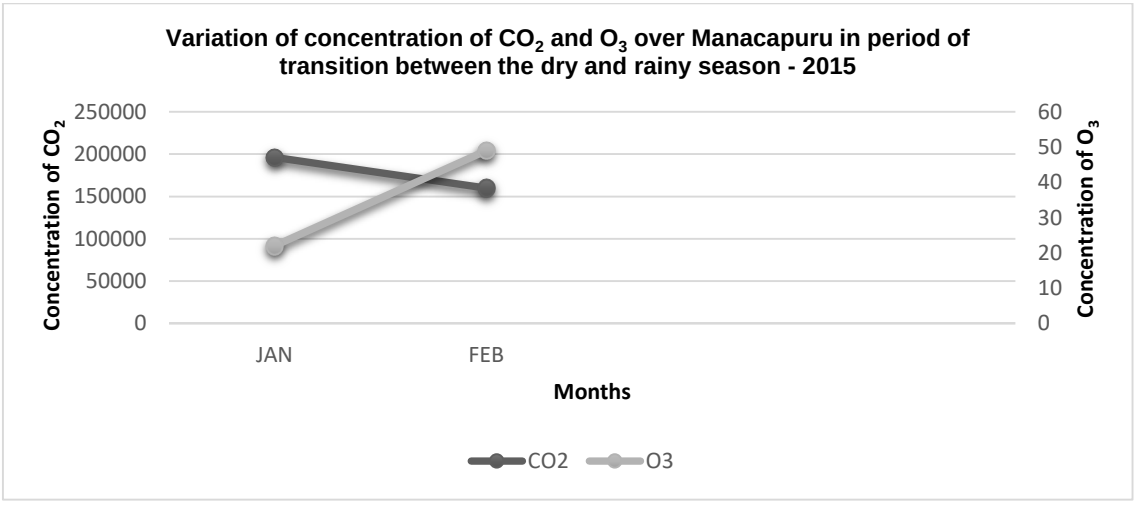

Fig.3 – Variation of concentration of CO_2 and O_3 over Manacapuru in months of january and February of 2015, transition between the dry and rainy season.

Nitrogen oxides (NO_x) are part of the group of nitrogen compounds, naturally formed in the atmosphere, through natural rays and actions that happen in the soil, but when they come from human actions they can generate greater amounts that are harmful. These anthropic actions that cause it are burning fuels, high temperature of polluting sources,

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being fixed or mobile (CÓNSUL et al., 2004). It is noted in Figure 4 that during the months of October and December there were no records of precipitation. On the other hand, during November accumulated precipitation showed high values, while NOX concentrations were lower. Thus, at the beginning of the rainy dry season, they increased considerably in September and fluctuated in October, November and December.

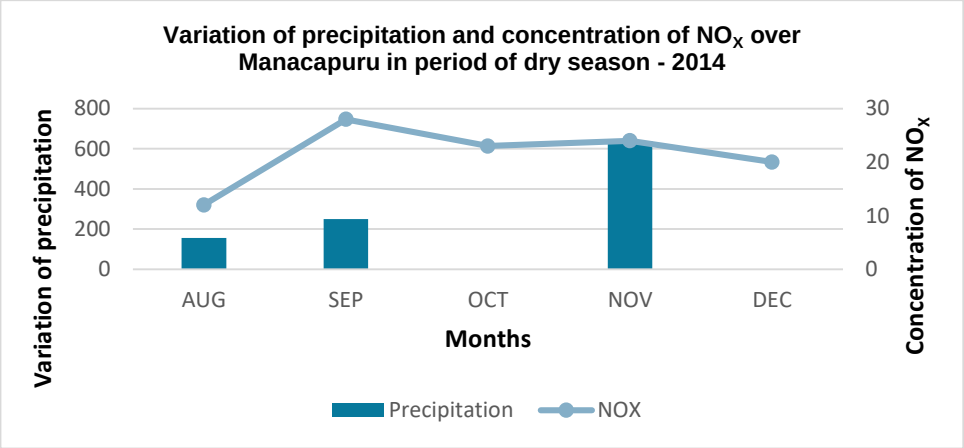

Fig.4 – Variation of precipitation and concentration of NO_X over Manacapuru in months of august, september, october and december of 2014.

Similar to the previous figure, Figure 5 also showed the absence of information in January. On the other hand, in February it was verified that accumulated precipitation had a significant increase compared to the period 2014. Nevertheless, the NOx concentration remained almost the same as that of the dry season. However, Martins (2006) showed that NOx is one of the main pollutants assist in the emergence of tropospheric O3. These are pollutants generated from the burning of fuels, and does not depend on the speed of the vehicle, but on the other hand, the important variables are the time of existence of a vehicle, distance traveled, wind directions, among other factors.

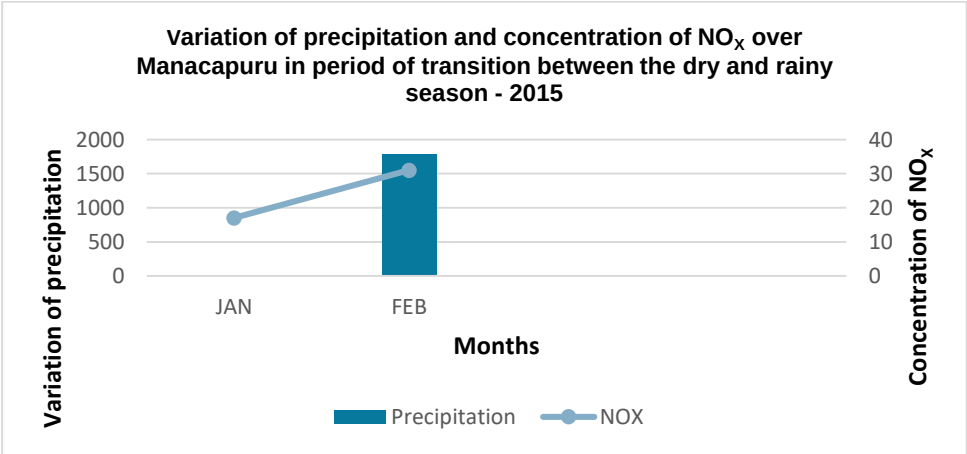

Fig.5 – Variation of precipitation and concentration of NO_X over Manacapuru in months of January and February of 2015.

In 2014, particulate materials known as PM_1, PM_5 e PM_{10}, respectively breathable particle, thick and inhaleable particle. Fornaro (2017) shows that inhaled particles are particulate materials (thin + thick) or $PM_{2,5}$ + $PM_{2,5\text{-}10}$ that result in PM_{10}, that manage to be smaller than a hair and a grain of sand, which make them highly dangerous, while the PM_1 are breathable particles that do not pose risk to the health of the environment.

While thick particles (PM_1) and inaltable (PM_{10}), continuous behavior during the months analyzed, the PM_5 shows rapid growth during December, presenting the highest levels of concentration. The inhaled particles (PM_{10}) have

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higher values than the concentration of PM1 present in the atmosphere, which can be explained to the dry period, due to the low accumulated precipitation. Presenting an analysis on the behavior of particulate matter in Manaus/AM, Dutra (2018) showed that particulate matter moves from the urban area towards the Amazon River. Thus, it is remarkable that the high concentration of this pollutant can come from in most vehicular fleets is more numerous in the capital, transporting the pollutant to neighboring cities.

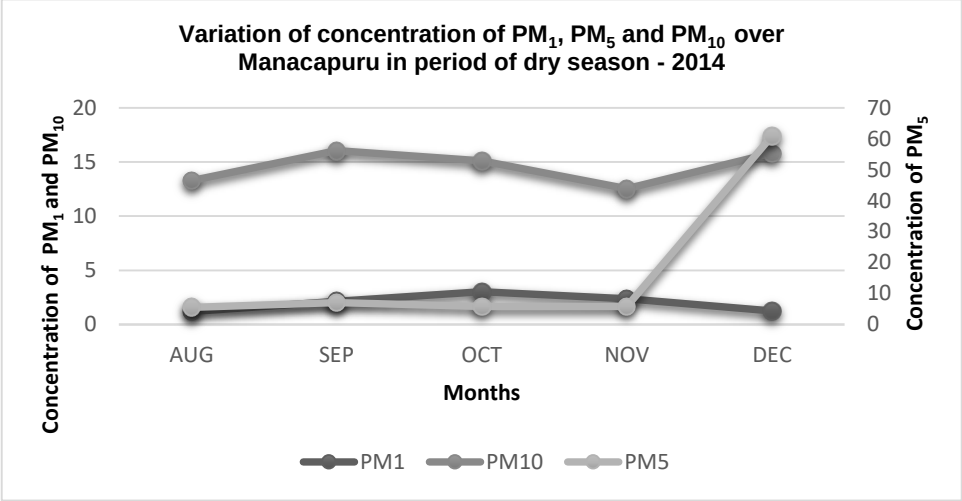

Fig.6: Variation of concentration of MP_1, MP_5 and MP_{10} in months of august, september, october, november and December of 2014.

Impact caused by increased vehicular fleets on the environment

Figure 7 shows the comparison of the vehicular rate in 2014 and 2018, showing a growth in the fleet of motor vehicles. There is a clear growth of the vehicular fleet from 2014 to 2018, after all it is 4 years from one year to another, the percentage growth totaled 24.17 % a value that may seem small, but for an average-small town of only 96,236 inhabitants, can result in large environmental impacts on the environment and society.

Dutra (2018) in his research on emissions of polluting gases, showed that there is the possibility of polluting gases dispersing in opposite directions. This may explain, because some concentrations do not reach emergency levels, as this occurs when there is a very high concentration level of a given pollutant.

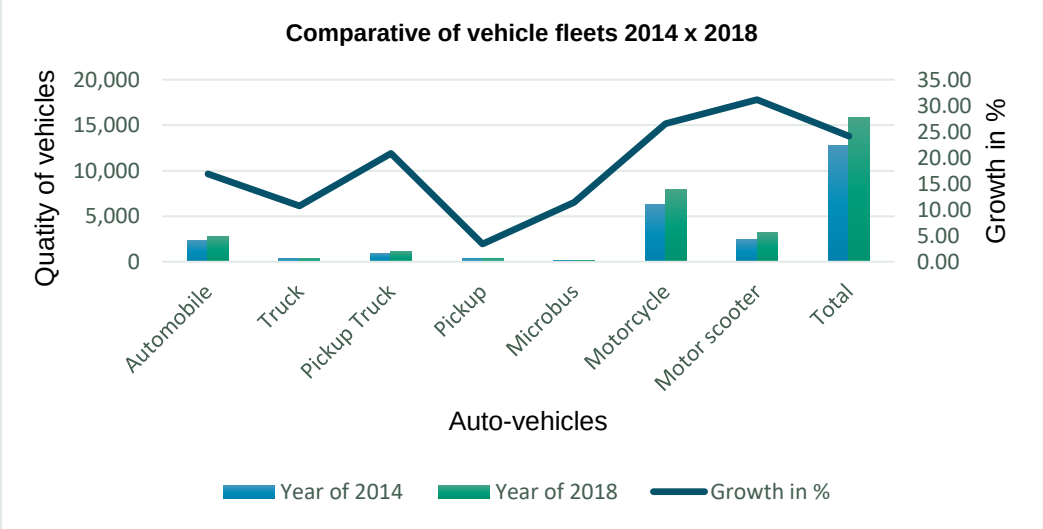

Fig.8: Comparison of vehicle fleet growth in 2014 and 2018.

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Impacts on the Environment

According to RESOLUTION CONAMA No. 491/2018 it is necessary to have an air quality control indicating management, which aims to establish amounts of air pollutants generated, to provide better quality of life to humans, thus avoiding the increase in the rate of diseases and mortality in Brazil. Thus, brazil's standards are divided into two categories: Intermediate quality standards (PI) and final air quality standards (PF) (CONAMA, 2018). It is possible to see the cause of small particles of pollutants through details that go unnoticed, such as the color change of a plant, yellowish or whitish spots, plant wear for no apparent reason, or as if they were burned.

It is very common to find them in this situation, especially those in urban cities. Plants absorb gases through their pores that are in the surface part of the leaves, so they are more prone to impacts of gas toxicity. According to Pedroso (2007) there are three pollutants present in the troposphere that can be considered the most dangerous for vegetation, which are so2, NOx and O3. Because they cause reactions that not only affect leaves, but also roots, soils and water resources. In addition, NOX and O3 gases, in contact with vegetation cause the formation of acid rains, changes in operation and weakening of agriculture.

He also believes that stress and accumulation of pollutants can occur through breathing, that is, some animals end up becoming weakened and over time mortality increases. Due to air pollution, some animals end up making a change in their natural habitat. In the case of the state of Amazonas, industries are close to green areas, depending on the climate of the place dust particles can become quite harmful to both human, plant and animal health.

Air pollutants cause damage to materials, being can corrode metals, darken them, wear historical monuments, car paintings, among other things like damaging civilian buildings. According to Kucera and Fitz (1995) damage to materials are the main caused by air pollution and that soon appear, weakening the structure of buildings. And they claim that in addition to SO_2, NOx and O_3 also contribute greatly to the acceleration of the deterioration process and not only to the external area of buildings, but also to the internal area, harming even electronics.

Currently, health problems due to air pollution have only grown in urban cities, over time air quality control has also progressed, but the more urbanized cities become, the more population growth increases, this indicates increased pollution which can lead to uncontrollable air quality.

IV. FINAL CONSIDERATIONS

Through the analyses presented, it was observed that the variability of the concentration of pollutants in the dry period is directly related to the high levels of CONCENTRATIONs of CO2, O3, NOx and PM and during the period when the rainy season begins, these pollutants disperse, resulting in low concentration levels. In addition, it is noticeable that in the period when there are higher concentrations of pollutant particles, rainfall levels are much lower, thus being inversely proportional phenomena, because when the atmosphere is clean, precipitation levels may be higher, when there are many particles of pollutants levels decrease, this is not to say that there is no rain, but rather that the rains are less recurrent, the raindrops are smaller and more acidic, becoming harmful to the environment.

Although this article is limited to the analysis of concentrations of pollutants in 2014 and 2015, it was observed that the increase in vehicular fleets in recent years can lead to higher concentrations of pollutants, that is, the tendency is that over time, with the development of the city of Manacapuru/AM, if there is no air quality control, environmental impacts and human health can become increasingly harmful.

With the study of influence of pollutants on the environment and health it was possible to pay attention to the various risks caused to the ecosystem, such as the weakening of vegetation, causing changes in its breathing process, which results in its nutritional loss and even diversity, causing negative effects also to fauna, because for the most part and diversity, they are found in forests, the loss of their environment results in loss of living beings that need the natural cycle of life. Polluting gases do not interfere only in human health, but in living beings in general, everything that has life is affected, the big difference is that in humans this can be noticed more easily, because they present respiratory diseases, cardiovascular diseases , allergies and other diseases linked to the respiratory system.

Finally, with the analysis of the data obtained in this article, it was possible to make a study with knowledge in the area of environmental engineering, of the impact caused by air pollution. It was concluded that high concentrations of pollutants and the increase in vehicular fleet over time contribute to various environmental impacts caused by air pollution and, among these impacts are acid rain, temperature rise, loss of environmental services and loss of diversity.

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