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Atmospheric Pollution and Meteorological Parameters in the City of Cuiabá-MT

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Abstract: In the last decades, Cuiabá experienced a strong population growth and also an intense increase in the number of vehicles. Thus, concentrations of particulate matter have exceeded the tolerable limits indicated by the World Health Organization. This article studies the correlations between meteorological data, Air Temperature, Relative Humidity, Wind Speed, and concentrations of pollutants atmospheric, MP (Particulate Material smaller than 2.5 μm of diameter) and Carbon Monoxide. The study shows that the air quality in Cuiabá is inadequate and correlates with the meteorological variables and the traffic of vehicles in the city. The MP concentration is intense traffic MP = 94.93 $\mu g.m^{-3}$ and moderate traffic MP = 57.56 $\mu g.m^{-3}$. With this, there is a need to redefine the planning and execution of public policies that minimize these negative impacts.

Key words: pollutants atmospheric, variables meteorological, correlations

1. Introduction

In the last decades, air quality has deteriorated in large urban centers and mobile sources are mainly responsible for this degradation [1]. Cuiabá is a city that is located in the geodesic center of Latin America and experienced a great population growth from little more than 45,000 inhabitants in 1960 to more than 540,000 in 2010, an approximate growth of 1077%. The vehicle fleet in Cuiabá followed and even surpassed this growth, from 145,473 in 2005 to 381,369 in 2015. These indicators show a marked growth of the city in the last decades, and together, the change in the composition of urban geometry and quality of life of the citizens who live in it. In this scenario, it is relevant to study the meteorological variables and their various interfaces in the urban context, in the perspective that the transformation of the city changes the meteorological variables and these affect the microclimates, and these, in turn, the quality of life and the comfort environmental of people living in the urban environment.

The meteorological variables in their various correlations affect, and are affected by the urban environment. An important current of research on the urban environment is the understanding of the possible correlations between meteorological variables, such as wind speed, air temperature, relative humidity, solar radiation, precipitation, among others and the

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concentration of particulate matter and polluting gases. The wind velocity can affect the dispersion processes, removal mechanisms and chemical formation of the atmosphere [2]. The various microclimates of a city are a crucial factor in understanding the dispersion or concentration of atmospheric pollutants [3]. The understanding of the relationships between the meteorological variables and the atmospheric pollution has been the object of several studies: Mendonça and Castelhano (2016) [3], Derísio (2012) [4], Akpinar et al. (2009) [5], Galindo et al. (2011) [2], Luvsan et al. (2012) [6], among several others.

Numerous studies indicate that concentrations of air pollutants correlate with meteorological variables, such as when investigating the microclimates of a city with its various of air temperature, surface temperature, rainfall, wind speed, solar radiation, not considering atmospheric pollutants, the results and conclusions may be limited. There is an interdependence between the Meteorological Variables and the Concentrations of the Atmospheric Pollutants. The particulate material has an inverse relationship with the wind speed [2]. The concentration of sulfur dioxide has an inverse correlation with air temperature and wind speed and direct relation with the relative humidity of the air [6]. A study of Mendez and Castelo (2016) [3] showed small coefficients of correlation between amount of particulate matter and temperature, relative humidity and rainfall, values of R less than 10%, some close to zero. Other studies reach viable correlation factors. The correlation coefficients between the concentration of sulfur dioxide and the variables: wind speed, relative humidity and temperature ranged from 0.53 to 0.84, in the city of Ulaanbaatar, Mongolia [6].

The State of Mato Grosso, Brazil, through the State Department of the Environment, does not have equipment to measure concentrations of atmospheric pollutants at the research site. The results available and disseminated by the authorities are obtained through the application of models and are not measured directly. The theme is relevant because it has a direct impact on the city as it affects the quality of citizens' lives.

The general objective of this paper is to present the values of the meteorological variables and the concentrations of carbon monoxide and particulate matter and their possible correlations.

2. Material and Methods

The data were obtained in the city of Cuiabá, Capital of the State of Mato Grosso and Geodesic Center of Latin America Fig. 1, having an area of 3,224.68 km^2, being divided into 254.57 km^2 (7.89%) of area urban area and 2,970.11 km^2 (92.1%) of rural areas [7]. The data collection period was from 01/10 to 12/12/2017. The values referring to air quality, carbon monoxide concentration (CO) and particulate matter ($MP_{2.5}$) were extracted from daily bulletins issued by the Environment Department of the State of Mato Grosso (SEMA-MT) available on the institutional website[1]. The meteorological variables: Air Temperature (T), Relative Humidity (UR) and Wind Speed (V) were taken from INMET (National Institute of Meteorology), referring to the Cuiabá A-901 Automatic Station, located in the coordinates: latitude -15.559295 and longitude -56.062951. The data were extracted from the institutional site[2].

The city of Cuiabá has a population of 590,118, estimated in 2017 on a consultation made in December 2017 on the IBGE institutional site, Brazilian Institute of Geography and Statistics[3] and a fleet of 381,369 vehicles, including the light and heavy, information obtained from the Ministry of Cities, National Transit Department - DENATRAN, in the institutional site[4].

The location of Cuiabá in the center of the country, agricultural expansion to the north-central and the migration process generated a great urban expansion of the city, from 45,875 inhabitants in 1960 to 590,118 inhabitants in 2017 (Statistical Yearbook of Cuiabá, Volume IV, 2012 and www.ibge.gov.br). This growth

[1] http://www.sema.mt.gov.br.
[2] http://www.inmet.gov.br.
[3] http://www.ibge.gov.br.
[4] http://www.cidades.gov.br.

implies a series of factors, among which the growth in the vehicle fleet and the expansion of the built area of the municipality.

The weather station, A901, is located in the urban perimeter of the city next to Avenue Rubens de Mendonça, the city's urban structural corridor, which contains a high flow of motor vehicles daily (Fig. 1).

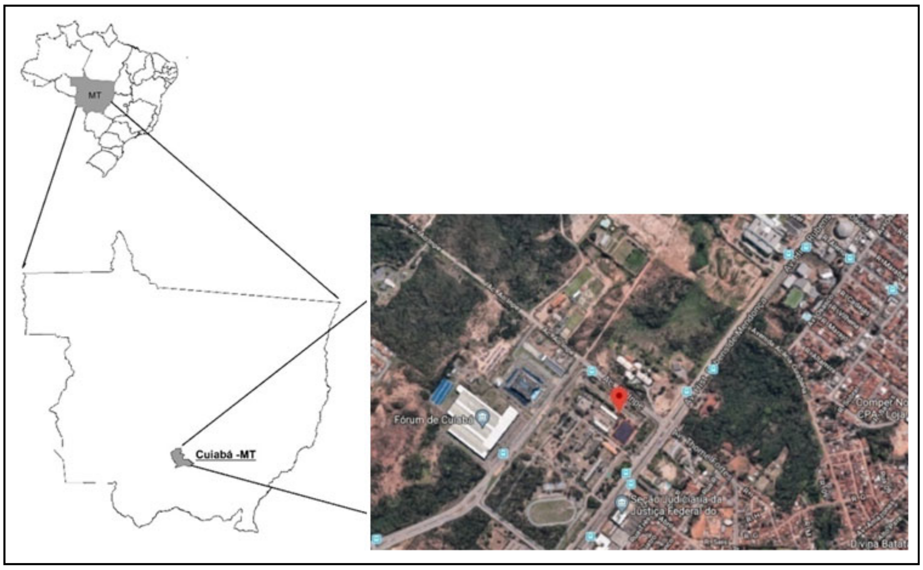

Fig. 1 Location: Cuiabá, State of Mato Grosso, Cuiabá Automatic Station - A901. Coordinates: latitude - 15.559295 and longitude - 56.062951.

3. Statistical Analysis

During the period of data collection, from 10/01/2017 to 12/12/2017, a set of values of the variables: $MP_{2,5}$, CO, T, UR and V were collected. Data were submitted to descriptive statistics and verification of possible outliers, in the IBM software SPSS 23.0, simply referred to as software, following the text. Five outliers were detected, which were removed from the database, and 50 data sets were maintained for statistical analysis. Normality and homoscedasticity tests were performed using the Kolmogorov-Smirnov test, with the Lilliefors test, and the Levene test. The variables T and UR adhered to normality, while the others did not present a normal distribution. In order to enable parametric tests, the logarithmic conversion of the variables into the neperian base was performed [8, 9] and re-made the tests. With the conversion, all the variables adhered to normality: T and UR of direct form, and, MP, CO and V in logarithmic form. These variables were respectively named LnMP, LnCO and LnV.

The descriptive statistics of the variables MP, CO, T, UR and V were used to calculate the mean values and the respective standard deviations. The variables were submitted to regression and curve adjustment to verify the possible correlation coefficients. Afterwards, the data was separated into two groups: Group 1, obtained for weekends and holidays, and Group 2, weekdays, in which traffic congestion may occur (Source: Urban Mobility Secretariat of Cuiabá). In the parametric tests, the t-test for independent samples was used to compare the means, and the non-parametric Mann-Whitney U test was used to compare the medians.

4. Results and Discussions

4.1 Meteorological Variables and Air Quality

The values of the variable T (Air Temperature) oscillated between 22.1°C and 35.4°C (Fig. 2). The descriptive statistics expressed as mean air temperature values 27.42°C with standard deviation of 2.96°C (Table 1). The same statistic results in a UR (relative air humidity) ranging from 33% to 88%, presenting an average value of 68.95% with a standard deviation of 14.64%. The descriptive data of temperature and relative humidity of the air have an association already demonstrated in other studies, confirming the inverse relationship between relative humidity and air temperature, ie, temperature increase corresponds to the reduction of relative humidity and vice versa. The values correspond to the transition from the dry period to the wet period.

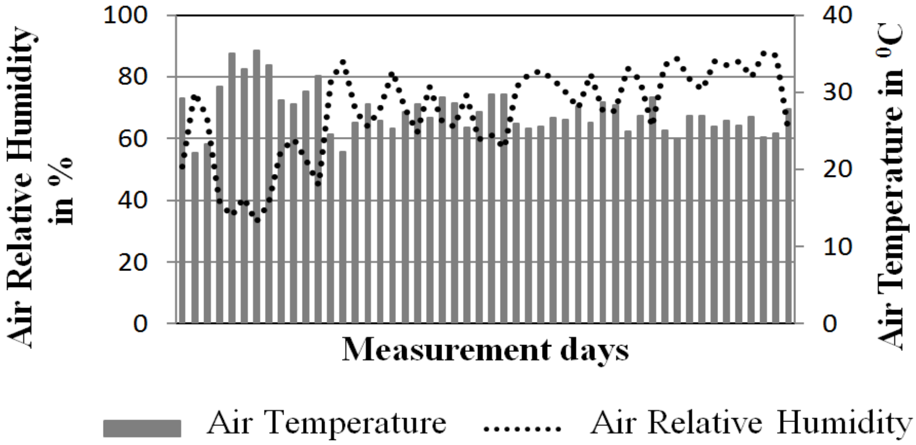

Fig. 2 Air Temperature and Air Relative Humidity, from 10/01/2017 to 12/12/2017.

Table 1 Descriptive statistics of CO and MP concentration, air temperature, air relative humidity and wind speed between 10/01/2017 and 12/12/2017.

Variables		Data	
Nomenclature	Unity	Values	standard deviation
CO	ppm	0.387	0.093
PAR	$\mu g m^{-3}$	91.51	52.26
T	℃	27.42	2.96
UR	%	68.95	14.64
V	ms^{-1}	1.84	0.66

The wind speed varied during this period from 0.7 $m.s^{-1}$ and 3.9 $m.s^{-1}$. The MP values ranged from 33 to 210 $ug.m^{-3}$ (Fig. 3), the statistic presented a mean value of 91.91 $ug.m^{-3}$ with a standard deviation of 52.56 $ug.m^{-3}$ (Table 1). The same figure and table show the concentrations of carbon monoxide (CO) that varied between 0.22 and 0.53 ppm, the statistic presented a mean value of 0.387 ppm with standard deviation of 0.093 ppm.

The bulletins issued by SEMA-MT, from 10/01/2017 to 12/12/2017, classify air quality as inadequate. Particulate matter concentration values far exceed the concentration of 25 ugm^{-3}, a tolerable limit set by the World Health Organization, to that atmospheric pollution does not harm the health of the population. Values above this limit can affect the health of the population, causing respiratory and cardiovascular diseases [10].

The value of the concentration of particulate matter, in some days, extrapolates by more than ten times the established limit, generating implications regarding the quality of life and health of the population. As for the carbon monoxide concentration, the values comply with the limits established by CONAMA (Brazilian National Environment Council, Brazil) 003/1990, whose limit value is 6 ppm.The figures indicate that there is an inadequate air quality in Cuiabá, this can be indirectly justified when there are changes in urban aspects, such as a constant growth rate in the number of vehicles, an approximate increase of 162% between 2005 and 2015, and the intensification of vehicle traffic. These considerations point out that the air pollution of Cuiabá has to be studied and treated as public policy, in its causes and consequences.

The variables that did not violate normality and homoscedasticity were T and the UR presenting p-value lower than 5%, the other variables violated these assumptions. The logarithmic transformation of the variables on the neperian basis was done to make the assumptions of adherence to normality and homoscedasticity viable [9]. After the logarithmic transformation in the neperian base, the variables, MP, CO and V, met the required assumptions. The variables were respectively written in logarithmic form and denoted by LnMP, LnCO and LnV.

4.2 Correlations between Meteorological Variables and Pollutant Concentrations

The non-violation of the parametric statistical application requirements made it possible to use the regression for curve estimation through the software to survey the correlations between the meteorological variables (T, UR, Ln (V)) and those representing air quality Ln (MP) and Ln (CO).

The tests did not identify correlations with statistical significance between the variables:

Ln (MP), T and UR. On the other hand, there is a correlation, with statistical significance, of the variable Ln (MP) with the variables Ln(V) and Ln (CO).

The correlation between Ln (MP) and Ln (V) had the best fit in the exponential model, presenting a correlation coefficient R = -0.371 (Fig. 4).

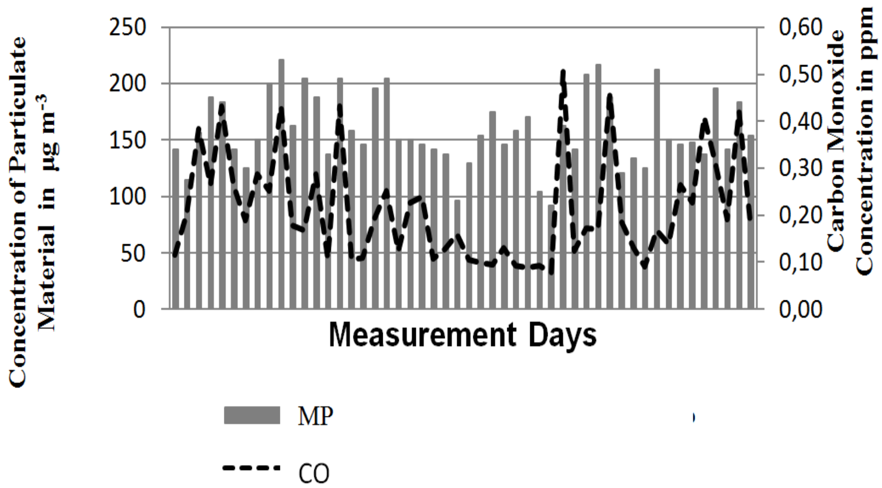

Fig. 3 Concentrations of particulate material and carbon monoxide in the period from 10/01/2017 to 12/12/2017.

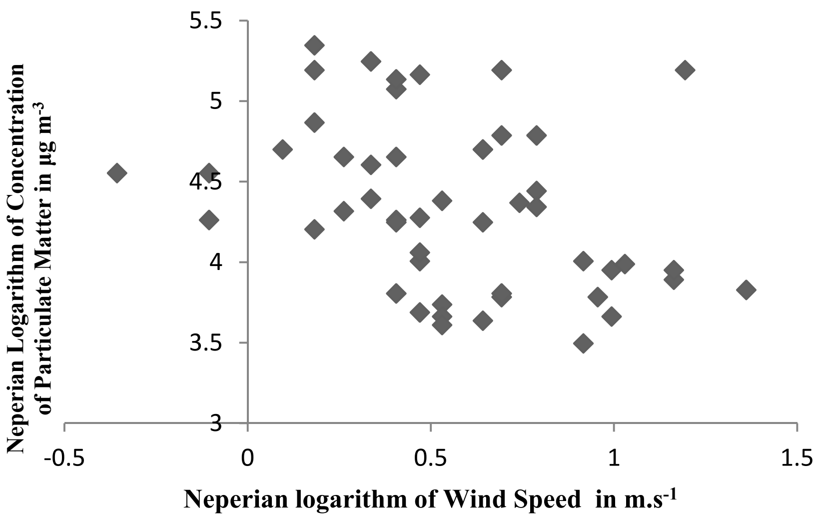

Fig. 4 Correlation chart between the neperian logarithm of the particulate material concentration and the neperian logarithm of the wind speed from 10/01/2017 to 12/12/2017. R = -0.371.

Despite the limitations of the research, regarding the data collection and the data composition itself, a negative correlation between the particulate matter concentration and the wind speed was identified. The increase in wind speed acts as an element of dispersion of atmospheric pollutants reducing local air pollution. Similar correlation was obtained in the survey conducted in a Mongolian city [6]. The application of the regression to the curve estimation, using the software, to collect correlations between the variable on the logarithmic basis, Ln (CO), with respect to the variables T, UR and Ln (V), no correlation with statistical significance was identified between the variables Ln (CO), T and UR. On the other hand, there is a correlation, with statistical significance, of the variable Ln (CO) with the variables Ln (V) and Ln (MP).

The correlation between Ln (MP) and Ln (CO) was better fitted to the linear model with correlation coefficient R = 0.455 (Fig. 5).

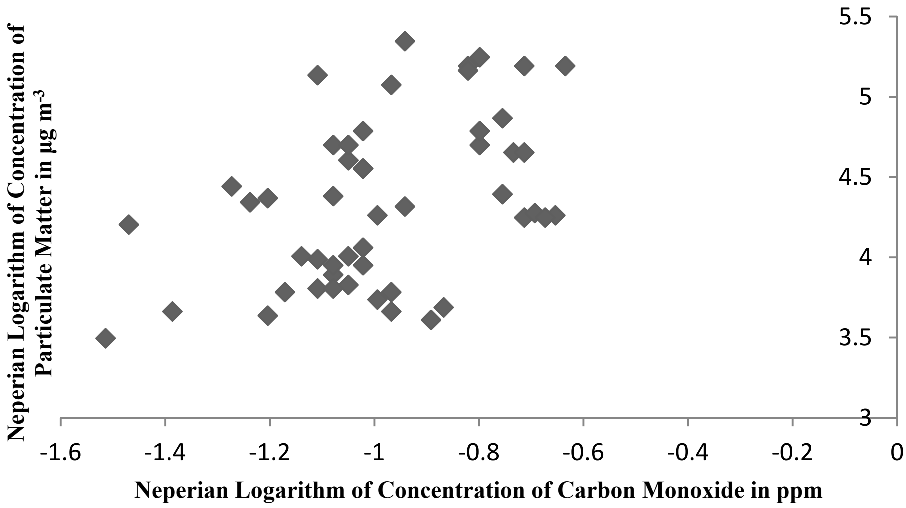

Fig. 5 Correlation chart between the neperian logarithm of the particulate material concentration and the neperian logarithm of the carbon monoxide concentration from 10/01/2017 to 12/12/2017. R = 0.455.

Despite the limitations, the assertions regarding the interdependence of meteorological variables and atmospheric pollutants concentrations are feasible:

a) The increase in wind speed reduces the concentration of MP pollutant in the study area;

b) There is a direct relationship between the quantities transformed into logarithmic bases that represent concentrations of Particulate Material and Carbon Monoxide. This correlation may be an indication that air pollution in Cuiabá correlates with mobile sources of pollution.

During the period of data collection, the air quality was classified as inadequate by the Environmental Secretariat of the State of Mato Grosso/Brazil (SEMA-MT/BRASIL), especially since the concentrations of particulate matter ($MP_{2.5}$) exceeded the limits indicated by the World Health Organization [11], whose tolerable value is 25 μgm^{-3}.

The attempt to identify the causes of the possible differences was made by comparing the concentrations of MP and CO of two groups according to the days of observation:

a) Group 01: Sundays, Saturdays and Holidays — Moderate traffic;

b) Group 02: Other days (normal working days) — Intense traffic.

The descriptive statistics of the two groups is presented in Table 2. The comparison of the two groups:

a) Group 01: Data obtained on Saturdays, Sundays and holidays. In these days, there is a reduction in vehicle traffic;

Table 2 Descriptive statistics for T, UR, V, MP and CO. Groups 1 and 2.

Variables		Vehicle Traffic	
Nomenclature	Unity	Intense	Moderate
T	ºC	27.83±0.48	26.04±0.61
UR	%	67.20±2.33	76.11±4.04
V	$m.s^{-1}$	1.80±0.10	2.11±0.25
PAR	μgm^{-3}	94.93±7.86	57.56±5.35
CO	ppm	0.382±0.012	0.376±0.023

b) Group 02: Data obtained on normal working days, from Monday to Friday, which is not a public holiday.

The verification of possible differences between groups was done by applying the t test to independent samples for those variables that adhered to normality.The only variables that showed difference of means between groups 01 and 02, with statistical significance, was the concentration of particulate material expressed in the logarithmic form of neperian base. This result allows the inference that the concentration of particulate matter is different when comparing the days of intense traffic and moderate traffic of vehicles in the area studied.

The occurrence of averages difference only for the variable related to the concentration of particulate material minimizes the interference of the other variables and accentuates the inference that the difference detected may be associated to the characteristic of the vehicle traffic. To strengthen the analysis of the data in the identification of possible differences, between groups 01 and 02, the non-parametric statistic was applied through the Mann-Whitney U-Test.

The only variable that presented difference in medians between groups 01 and 02, with statistical significance, was the concentration of particulate matter (MP), confirming the inference that the concentration of particulate matter is different when the days of intense traffic are compared of moderate traffic of vehicles.

5. Conclusion

Air quality during the study period was found to be inadequate because concentrations of particulate matter reached values above the limits indicated by the World Health Organization. Data analysis shows that there is a correlation between the meteorological variables and the air quality expressed by the statistically significant correlation of wind velocity with concentrations of particulate matter and carbon monoxide, the two inverse correlations with R respectively, equal to -0.37 and -0.28. Wind acts as a dispersion factor for local pollution, reducing the concentration of air pollutants in the city. The concentrations of particulate material and carbon monoxide presented a direct correlation, with R = 0.455. This result, associated with the comparisons between days of intense traffic and moderate traffic, is an indication that the reduction in air quality may be associated with intense vehicular traffic.

The results of the study show that there is a correlation between atmospheric parameters and air quality and that traffic interferes with the concentration of particulate matter (MP): intense traffic MP = 94.93 $\mu g.m^{-3}$ and moderate traffic MP = 57.56 $\mu g.m^{-3}$.

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