Correlation model between PM2.5 and atmospheric variables in the city of Villavicencio

Modelo de correlación entre PM 2.5 y variables atmosféricas en la ciudad de Villavicencio

Modelo de correlação entre PM 2.5 e variáveis atmosféricas na cidade de Villavicence

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Abstract

Introduction: This article is the product of the research "Monitoring and Characterization of air quality in the downtown area of Villavicencio", carried out from 2018 to 2020 in Villavicencio - Colombia.

Problem: Air quality directly impacts the health of the people who breathe it. Currently Villavicencio does not have enough monitoring stations, nor are there strategies to improve air quality.

Objective: The main objective is to collect and analyse atmospheric and air quality information, to determinate the relationship between atmospheric variables and particulate matter.

Methodology: Quantitative and experimental research in stages, a number of samples to be taken were defined and a statistical treatment was carried out. Different instruments were used to collect the variables.

Results: The linear model between particulate material and atmospheric variables was obtained. The correlation index of particulate material with atmospheric variables was determined. The results were compared with regulations in Colombia and other countries.

Conclusion: The results are within the limit allowed by national regulations. Linear models of the relationship between environmental variables and particulate matter were obtained.

Originality: There are few studies related to air quality in the region. With the results, improvement actions can be proposed to local administrations to mitigate the impact on air quality in Villavicencio.

Limitations: Sample collection time was limited, the availability of equipment in the institution where the research work originated also affected the scope of the work carried out.

Keywords: Air quality, atmospheric variables, particulate matter, PM 10, PM 2.5.

Resumen

Introducción: Este artículo es un producto del proyecto titulado "Monitoreo y caracterización de la calidad del aire en la zona centro de Villavicencio", ejecutado entre el 2018 y el 2020 en Villavicencio – Colombia.

Problema: La calidad del aire y el impacto directo en la salud de las personas que lo respiran. Actualmente Villavicencio no cuenta con suficientes estaciones de monitoreo, ni existen estrategias para mejorar la calidad del aire.

Objetivo: El objetivo principal es recolectar y analizar información atmosférica y de calidad del aire, para determinar la relación entre el material particulado y las variables atmosféricas.

Metodología: Es una investigación cuantitativa de tipo experimental desarrollada por etapas, se definió un número de muestras a recolectar y se llevó a cabo un tratamiento estadístico. Se usaron distintos equipos e instrumentos para recolectar la información.

Resultados: Se obtuvo un modelo lineal entre la concentración de material particulado y algunas variables atmosféricas, así como el índice de correlación entre ellas. Se realizó la comparación de los resultados obtenidos con normas ambientales colombianas y de otros países.

Conclusiones: Los resultados de la concentración de material particulado en el rango observado están dentro de los límites permitidos por la regulación nacional. Se obtuvo modelos lineales de la relación entre el material particulado y las variables ambientales.

Originalidad: Existen pocos estudios relacionados con la calidad del aire en la región. A partir de los resultados se pueden proponer acciones a la administración gubernamental local para mitigar el impacto de la calidad del aire en Villavicencio.

Limitaciones: El tiempo de recolección de muestras fue limitado, la disponibilidad de los equipos en la institución donde el Proyecto se originó terminó afectando el alcance del trabajo realizado.

Palabras clave: Calidad del aire, variables atmosféricas, material particulado, PM 10, PM 2.5.

Resumo

Introdução: Este artigo é produto do projeto intitulado "Monitoramento e caracterização da qualidade do ar na área central de Villavicencio", executado entre 2018 e 2020 em Villavicencio - Colômbia.

Problema: A qualidade do ar e o impacto direto na saúde das pessoas que o respiram. Atualmente Villavicencio não possui estações de monitoramento suficientes, nem existem estratégias para melhorar a qualidade do ar.

Objetivo: O objetivo principal é coletar e analisar informações atmosféricas e de qualidade do ar para determinar a relação entre material particulado e variáveis atmosféricas.

Metodologia: Trata-se de uma investigação quantitativa do tipo experimental desenvolvida em etapas, foi definido um número de amostras a serem coletadas e realizado um tratamento estatístico. Diferentes equipamentos e instrumentos foram utilizados para coletar as informações.

Resultados: Obteve-se um modelo linear entre a concentração de material particulado e algumas variáveis atmosféricas, bem como o índice de correlação entre elas. Os resultados obtidos foram comparados com os padrões ambientais colombianos e de outros países.

Conclusões: Os resultados da concentração de material particulado na faixa observada estão dentro dos limites permitidos pela regulamentação nacional. Modelos lineares da relação entre material particulado e variáveis ambientais foram obtidos.

Originalidade: Existem poucos estudos relacionados à qualidade do ar na região. Com base nos resultados, podem ser propostas ações à administração do governo local para mitigar o impacto da qualidade do ar em Villavicencio.

Limitações: O tempo de coleta das amostras foi limitado, a disponibilidade dos equipamentos na instituição de origem do Projeto acabou afetando o escopo do trabalho realizado.

Palavras-chave: Qualidade do ar, variáveis atmosféricas, material particulado, PM 10, PM 2.5.

1. INTRODUCTION

The air is a gaseous mixture composed of 78% nitrogen, 21% oxygen and 1% of gases such as carbon dioxide, ozone, argon, xenon, radon, etc. [1]. Due to continuous development in cities, its people face to different contaminants, the presence of particulate matter emitted from stationary and mobile sources such as transportation, construction, burning of waste materials, deteriorating pathways, including external factors [2] [3]. Suspended particulates (PM), defined as a mixture of chemicals and / or biological elements, such as metal salts, carbonaceous, organic volatile materials, volatile compounds (VOC), polycyclic aromatic hydrocarbons (PAHs) and endotoxins which can interact together forming other compounds [4][5].

These inhalable particles smaller than 10 micrometers (PM10 or 10 microns) but greater than 2.5 microns (PM2.5 or 2.5μm) are considered atmospheric pollutants [6] [7]. The World Health Organization (WHO) notes that air pollution is causing about one in nine deaths a year worldwide and is a major aspect in respiratory and cardiovascular diseases such as strokes and heart attacks, in addition to cancer lung [8] [9]. The initiative of the Organization of the United Nations Educational, Scientific and Cultural Organization (UNESCO) and WHO encourages all countries of the world studies of air quality and public policies to generate strategies are generated and reduce this risk being living in the world, in order to improve the environment and quality of life of people [10] [2].

In Colombia, studies on air quality in different regions and in accordance come forward with the report of the state of air quality of the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM), some of the monitoring stations located in Bogotá, Medellín, Cali, Santa Marta, Ráquira, Nemocón, Sibaté, Yumbo and the mining zone of Cesar, recorded annual average concentrations that exceeded the maximum permitted levels [11][3]. This leads to a direct effect on human health and this effect increases to the extent that there is greater concentration of particulate matter, affecting health to the point of respiratory diseases lead to serious consequences for the population [11][12].

The Ministry of Environment has been proposed as the present challenge facing air pollution [13]. According to the report, a contaminant of most concern at present is the PM2.5 particulate matter whose particles are very fine and can carry hazardous material for humans, such as viruses, organic compounds, among others. Such compounds can penetrate the airways of people [11]. PM2.5 is the contaminant that is present in the Colombia, said particles are generated by heavy vehicles using diesel system, and can cause serious illness [11]. Through technical and scientific studies have found high levels of air pollution in the Valley of Aburrá (Antioquia), Yumbo (Valle del Cauca), and towns of Puente Aranda, Keneddy and Carvajal in the City of Bogotá, among others [12]. It is also important to note that these municipalities or localities are in the most extensive and overpopulated departments of Colombia. Likewise, the industrial development that these cities have had a negative impact causes generated on the environment [14][15]. It is important to indicate that the results of this research are framed within Resolution 2254 of 2017 and only for particulate material PM2.5, according to what is presented in table 1 where the range of particulate material is indicated by colors as well as the air quality index that this value represents.

Table 1. AQI Cut points

AQI Range	Color	Category	PM 2.5 (ug / m3)
0 - 50	Green	Good	0 - 12
51 - 100	Yellow	Acceptable	13 - 37
101 - 150	Orange	Harmful to sensitive groups	28 - 55
151 - 200	Red	Harmful	16 - 150
201 - 300	Purple	Very Harmful	151 -250
301 - 500	Brown	Dangerous	251 - 500

Source: [13]

Currently, it has been generating awareness of how these factors affect the health of people and has placed special emphasis on monitoring the effects of exposure to particulate matter, as well as growth of respiratory diseases. According to the analysis of the health situation in Colombia and particularly in Villavicencio, the rate of death from chronic diseases of the lower respiratory tract 2015 is 36.7% and for Meta 30.6% per hundred thousand inhabitants [16]. Taking into account the studies and dates, there is an urgent need to monitor the emission of particulate material present at specific points in the city of Villavicencio, where the population is regularly concentrated, due to economic and industrial activities in this city are made [17][18].

2. MATERIALS AND METHODS

The methodological design that is conducting this work is quantitative approach and type of research is descriptive and interactive. It is intended to measure and collect data about the contaminants present in the air Villavicencio, in order to assess quality by diagnosing PM2.5 particulate matter in the air of the area, all in accordance Colombian regulation Resolution No. 2254 of November 2017 first regulating this process [19][13].

Population and Sample

Villavicencio is rich in flora and fauna, with a warm climate that ranges between 20° and 36°, its economy depends on agriculture, livestock and mining generating development in the Orinoco Colombian, also this city can compare with other Latin American cities like Habana, where residents practice food production and cultivate gardens; Mexico City whose land promotes sustainable agriculture in rural areas and food production in the city itself; Also to Managua, a city that has been developing

horticultural practices in training centers with sustainable technologies and finally have to Quito developers urban agriculture throughout the region, one of the greenest capitals in the region [20].

Villavicencio is the capital of Meta department. In 2005, according to the census of the National Administrative Department of Statistics (DANE) has a population of 384,131, 2015 has a population of 961,334 [21][22], Demonstrating exponential growth in its population. This significantly influences the development of the city (infrastructure, access roads, and other technologies). Villavicencio economic activity is focused on the agribusiness sector, a latent example is the processing of rice seed (mills are in out of town), also carries out other economic activities such as cement processing. In recent years, it has increased the vehicles of all kinds in the city, impacting positively on the environment, so the mobility secretary had to intervene in the downtown area of the city of Villavicencio by increased automotive [23].

Sample Size

For this research, 385 measurements at 35 measurements in 11 days of September 2018. These measurements were made at the Cooperative University of Colombia, which is geo-referenced to the following coordinates were performed: Latitude 4° 6' 55.06" N, Longitude 73° 36' 34.02" O. For the calculation of the sample size, (1) was used:

$$n = \frac{z^2 pq}{e^2} \tag{1}$$

In this equation, "n" is 385 and represent the sample size, "z" is the level of confidence (1.96), "p" is positive variability (50%), "q" is the negative variability (50%), "e" is the precision or the error (5%). The sample was made up data 385, with 95% confidence, 5% error. The value of the sensor sensitivity meter particulate material is used as an error.

Techniques and Data Collection Formats

The variable for measuring or independent variable is Air Quality, which has the following dimensions: particulate matter and meteorological variables. In addition to indicators: PM2.5 particulate material, solar radiation, humidity and temperature. The technique used to gather information is observation. This observation is made by the instruments mentioned in the materials and equipment section. Regarding the

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reliability of the measurement, a checklist arises in accordance with the established protocol, with items to verify such as: calibration date, filter conditions, filter zero calibration, and meter start-up procedure and sampling time. The instrument used for data collection is an autosampler. These sampling systems allow deliver high resolution measurements, time zones managed and a single point for different contaminants such as particulate matter (PM), CO, SOx, NOx, the collected sample is analyzed in real time through processes electro-optical, infrared or ultraviolet absorption, chemiluminescence detection principles or fluorescence, allowing analyzing data from an accurate shape and preserving the quality thereof [3][24]. The data generated from the integration of the detector and light source in a given path, it is necessary to have operating procedures, instrument calibration and data handling, so that its analysis is meaningful and of great use [24].

Given the monitoring protocol and monitoring of air quality [25], Standardized in resolution 2254 of 2017 [13]. In addition to international standards such as those established by the Environmental Protection Agency US (EPA), the Official Mexican Standard for Environmental Health (NOM020SSA1) and the standards set by the European Environment Agency (EEA). It has a framework well founded and enabled validate the parameters that were measured particulate matter PM2.5 and the rate of air quality in the city of Villavicencio.

Research Phases

The study was conducted in four phases. Phase one environmental analysis and formulation of the state of the art research project was called. Phase two design and development of tools and formats for the collection of information on air quality. Phase 3, monitoring, collection, and analysis of information. Finally, the last stage diagnosis and evaluation of air quality in accordance with current regulations was called. Currently the research project is in phase 3, however, this work is the analysis of partial results of the collection of information that is being carried out until the end of 2019.

Equipment

Table 2. Equipment

Instrument	Reference	Variable
Heat stress meter	Extech HT30	Room temperature, Relative Humidity
Solar radiation meter	Dr. Meter SM206	Solar radiation
Air monitoring	Dustrak Modelo 8530	PM 10, PM 2.5, PM1.0

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To carry out the investigation and the collection of information, the equipment listed in Table 2 were used. in the same table is possible observe the references and the main characteristics, in Figure 1 you can see an image of the equipment used for the collection of data.

Figure 1. Equipment to collect data.
Source: Autors

3. RESULTS

For the statistical processing of information the Pearson correlation coefficient, which was defined as a linear trend between two variables was used. It is an independent analysis of the scale of measurements of the variables. The correlation is an index to measure the degree of dependence or relationship between two variables, as long as these are quantitative [26]. With data collected analysis linear correlation between PM2.5 particulate material and weather variables was performed; room temperature (RT), solar radiation (SR) and relative humidity (RH). Table 3 presents the correlations obtained for each of the variables described, which are 0.71, between PM2.5 and RH is between -0.64 and PM2.5 and radiation is 0,58.

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Table 3. Correlation between PM2.5 and weather variables

Variables	Correlation
PM2.5 vs RT	0.71
PM2.5 vs RH	-0.64
PM2.5 vs SR	0.58

Source: Autors

Once obtained the linear correlations, we proceeded to perform for each pair of variables graphical analysis, the results are detailed in the following figures. Figure 2 shows the distribution of data and trend line, where it is evident that by increasing the ambient temperature rises PM2.5 particulate material.

$$y = 55.783x - 1631.1 \quad (2)$$

The linear trend model variables obtained for PM2.5 and RT shown in expression (2), where "y" represents the value of PM2.5 and "x" room temperature can also be seen that this equation with slope positive, it is consistent with the result obtained for the correlation value of temperature and PM2.5.

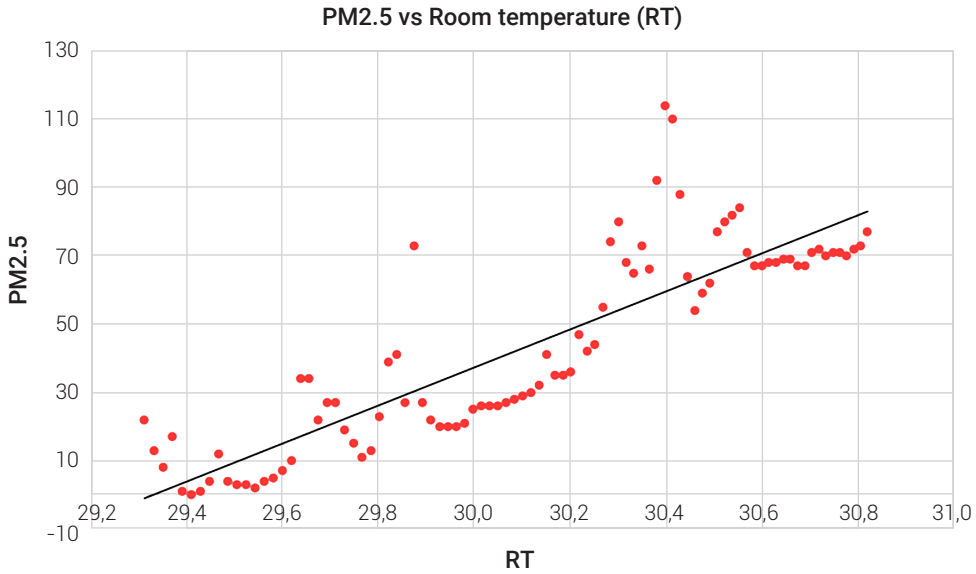

Figure 2. PM2.5 (µg/m³) vs Room temperature (°C).
Source: Autors

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Likewise, in Figure 3, it is observed that there is an inverse relationship between the PM2.5 indicator and relative humidity, demonstrating that increasing the relative humidity decreases PM2.5 particulate material in the air. The model obtained for variables PM2.5 and relative humidity shown in (3), where "y" represents the value of PM2.5 and "x" relative humidity in percent.

$$y = -11.35x - 791.19 \quad (3)$$

The negative slope of the equation (3) shows that the value obtained for the correlation between PM2.5 and humidity is valid and successful. Furthermore, Figure 4 shows that there is a direct relationship between the PM2.5 indicator and solar radiation.

$$y = 2.47x - 274.22 \quad (4)$$

The linear model obtained for variables PM2.5 and solar radiation was obtained with Equation 4, where "y" represents the value of PM2.5 and "x" the average solar radiation.

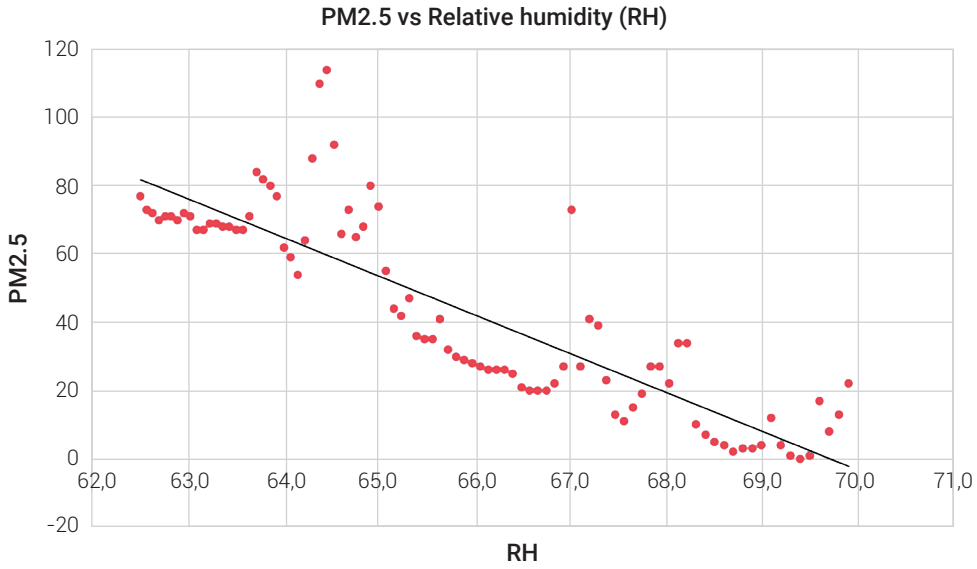

Figure 3. PM2.5 (µg /m³) vs. Relative Humidity (%)
Source: Autors

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According to the values obtained, the average solar radiation months evaluated, not exceed a value of 200W /m^2, given the weather and the place where the particulate material is measured conditions.

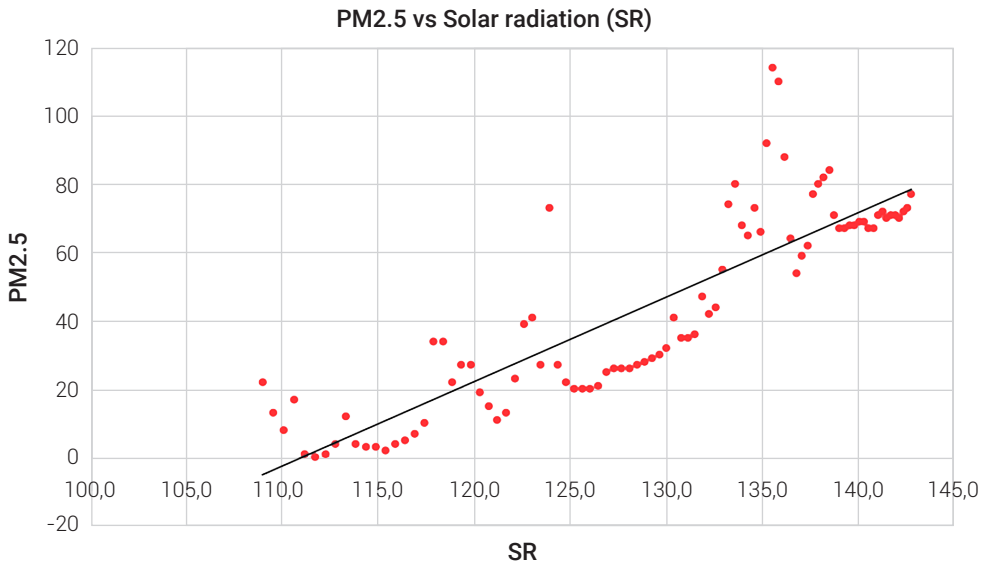

Figure 4. PM2.5 (µg/m^3) vs Solar radiation (W/m^2)
Source: Autors

4. DISCUSSION AND CONCLUSIONS

The behavior of particulate matter PM2.5 is an average result of 39.9 µg/m^3, a fact that was compared to the norm in Colombia, which is 37 µg/m^3 established by resolution 2254 of 2017, a maximum permissible value [27]. Thus it is evident that the average value obtained as a result exceed the standard 2.9 µg/m^3. It should be noted that in this area measurement period was in construction stage of the two lane road, which influenced the measurement results. The results were compared with some countries like Peru standards and Argentina, corresponding to South America. Presidential Decree No. 003-2017 of the standard in Peru, indicates that the maximum allowable value for PM2.5 is 50 µg/m^3, therefore the results match Colombia Peruvian standard [28]. As for the standard of Argentina NA-Al-00 1 -03 the allowable value for PM2.5 is 65 µg/m^3, where the results obtained in Colombia fit and remain within the range indicated in Argentina standard [29]. On the other hand the comparison was made in Central America with Mexico, according to the norm NOM-025-SSA1-2014 whose maximum allowable value for PM2.5 is 45 µg/m^3, a value that matches the information obtained in Colombia [30].

According to a study regarding the spatial PM2.5 assessment, conducted at the National Agrarian University in Lima - Peru, one can observe that the results obtained in this study were as follows: concentration range from 36.89 to 49.92 μg/m^3 and average value of 45.25 μg/m^3. This value is comparable to that obtained by the study conducted in the city of Villavicencio, which is 39.9 μg/m^3, a value that is not far to the information obtained from the National Agricultural University of Peru [31]. In Colombia there have been similar studies because of the alerts presented in major cities like Medellin. In a study of spatiotemporal characterization of pollutant PM2.5, presented by the authors [32], obtaining a power measurement that the average value for PM2.5 was 33.9 μg/m^3 value is performed within the limits permitted by Colombian law and against the result obtained in Villavicencio is only 6 μg/m^3 below the value obtained [32].

It was identified that the average daily PM2.5 particulate matter between the periods September-October 2018 is 39.99 μg/m^3, compared to Resolution No. 2254 of November 1, 2017 establishes the maximum permissible level for an exposure time 24 hours a value of 37 μg/m^3, it can be concluded that the particle concentration is greater than the maximum allowable value. Considering Article 4 of resolution No. 1 November 2254 of 2017 and the average value measured in this study, one can conclude that the rate of air quality is within a range of 0-50 identified with green shows that the state of air quality is good, indicating that air pollution is at a low risk to the health of the person. According to the linear correlation between PM2.5 and atmospheric variables, it was observed that the greater dependence is variable ambient temperature and relative humidity, ambient temperature being a variable dependent directly proportional since its value was 0,709, and however, the relative humidity is -0,639, indicating an inverse dependency. While the correlation of PM2.5 solar radiation and has a value of -0,582 with an inverse dependence. This article then substantiate the basis for possible research on air quality, including studies of mathematical prediction models, the design and implementation of embedded systems that enable the measurement of air quality as those presented in the literature review [33].

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