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RESEARCH ARTICLE

INFLUENCE OF ROAD TRAFFIC ON AIR QUALITY ASSOCIATED WITH INHALABLE FINE PARTICLES IN THE CITY OF LUANDA

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Abstract

This article aimed to evaluate the influence of traffic on air quality related to fine particles in the city of Luanda. For this purpose, a Thermo particle analyzer model ADR-1200S was installed on Avenida 21 de Janeiro, at the entrance of the Faculty of Engineering, for continuous measurement of fine particle concentrations in the air over 68 days. The results of this monitoring, which took place in 2014, were compared with those of a similar monitoring carried out in 2009, observing a coincidence of the days with the highest concentrations (Tuesdays and Thursdays) in both years. It was concluded that traffic has a decisive influence on the concentration of suspended PM2.5 in Luanda's atmosphere. Despite the decrease in PM2.5 concentrations from 2009 to 2014, particle concentrations in Luanda's atmosphere are still considered high, thus posing a risk to public health, and therefore additional measures are necessary

Introduction:-

According to the World Health Organization (WHO), more than 2 million premature deaths are annually attributed to the effects of air pollution (outdoor and indoor); half of these deaths occur in developing countries (Alvim-Ferraz; Pereira &Slezakova, 2009)."Previous and recent studies point to the inhalable fraction of suspended particles (PM – Particulate Matter) as having the most significant effects in terms of the impact of air pollutants on health (Padilha et al., 2026; Lisboa, 2011; Alvim-Ferraz; Pereira &Slezakova, 2009); exposure, whether acute or chronic, can lead to a wide variety of effects ranging from simple respiratory irritation to premature death" (Eliton&Alves, 2011; Kelesoglu, 2008).Various physiological tests demonstrate a relationship between particle size and their penetration into the human respiratory system (Galleto, 2025); only particles smaller than 10 µm are inhalable (PM_{10}), with the lower respiratory tract being affected only by particles smaller than 2-3 µm (Padilha et al., 2026; Soares, 2025; Maurício, 2009).

PM_{10} are referred to as the inhalable fraction and particles smaller than 2.5 µm ($PM_{2.5}$) as the fine fraction (Galleto, 2025; Soares, 2025); an increase in their concentrations is associated with effects that cause negative health impacts and the consequent emergence of various diseases, namely cardiopulmonary diseases and lung cancer, increasing

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morbidity and mortality rates (Padilha et al., 2026; Bonifácio, 2024; Mota, 2021).In urban atmospheres, various emitting sources contribute to the increase in particle concentration in the air (Freitas&Solci, 2009), with motor vehicles being one of the most relevant (Souza & Miranda, 2017; Maurício, 2009; Brito, 2005).In Luanda, particle emission is associated with the construction of large buildings, resuspension on unpaved roads in some peripheral neighborhoods, and different types of industries. However, it is road traffic that accounts for the largest amount of particle emissions (Lisboa, 2011; Gonçalves, 2011).

The number of vehicles circulating in the city of Luanda has increased significantly in recent years, both in terms of private transport vehicles and fleets of trucks and buses from state and private companies. However, this increase has not been matched by an adequate expansion of road infrastructure. This situation causes major congestion on the roads, especially in the city's urban center, forcing vehicles to move at reduced speeds on the few existing roads, thus there is no proportionality between the increase in circulating vehicles and greater population mobility. Simultaneously, fuel consumption (gasoline and diesel) has increased, reaching very high levels, which is evident in the long lines of vehicles at fuel supply pumps.Despite the long time elapsed since this study was conducted, due to road traffic conditions in the city of Luanda, this study is highly relevant with regard to particulate matter monitoring. Studies on air quality have been carried out in these and other areas of high interest in the city, which makes these studies, considered in this article, pilot projects for the initiation of further studies.As described above, in Luanda road traffic is particularly intense and disorderly, so the quantity of particles emitted may imply environmental concentrations incompatible with the preservation of health and the environment (Padilha et al., 2026; Souza & Miranda, 2017; Maurício, 2009). However, knowledge is still very incipient, making it urgent to continue evaluating the evolution of $PM_{2,5}$ concentrations, as these have the most severe health effects.

Objectives:-

To evaluate the influence of traffic on the concentration of fine inhalable particles in the city of Luanda;
To determine, with the aid of monitoring equipment, the hourly average concentrations of particles on Avenida 21 de Janeiro;
To compare particle concentrations with the traffic profile, based on hourly averages throughout the day and on daily averages throughout the week;
To compare $PM_{2,5}$ concentrations with the air quality standards for the protection of human health defined by the World Health Organization, the European Union and Portugal (Directive 2008/50/EC and Decree-Law No. 102/2010), the United States of America (USEPA), and South Africa (DEAT).

Materials and Methods:-

Study location

In order to better compare the results obtained with those from other previously conducted studies (Lisboa, 2011; Gonçalves, 2011), so as to accurately analyze the evolution of air pollution in Luanda, the monitoring equipment was installed in the same location as the previous studies: Avenida 21 de Janeiro, at the entrance of the Faculty of Engineering. Another relevant reason that led to the choice of this location was the guarantee of equipment safety. The avenue in question is a road with heavy vehicular and pedestrian traffic. Figure 1 showsAvenida 21 de Janeiro where the air sample collection took place.

Figure 1:
Avenida 21 de Janeiro (red line) [19].

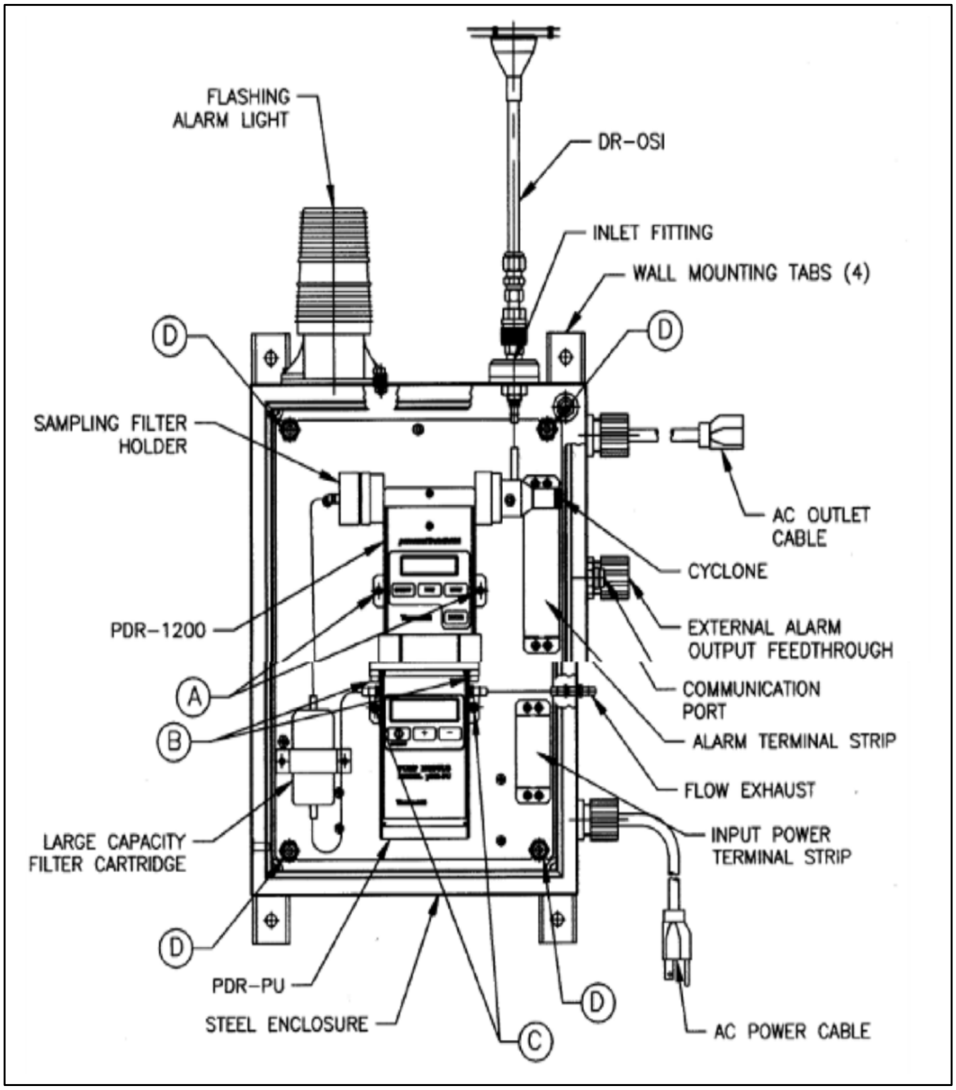
Source: Google earth (2015)

Monitoring
To achieve the objectives set out in this study, $PM_{2,5}$ concentrations were monitored. For this purpose, a Thermo particle sampler model ADR-1200_S, shown in Figure 2, was installed at the monitoring site for continuous monitoring of particle concentrations in the air.

Thermo Particle Sampler Model ADR-1200 S
"The Thermo particle sampler model ADR-1200S is a complete monitoring system designed to make continuous measurements of air particle concentrations corresponding to aerodynamic diameter sizes between 1 µm and 10 µm.Its weatherproof housing allows safe and effective operation under any weather conditions. It performs continuous monitoring with real-time data transmission to a central station and/or to an internal data logging unit.This unit is incorporated into the system, whereas for data transmission a separate modem or telemetry equipment (used to transmit data remotely) is required.The equipment monitor shows real-time concentrations, average and maximum readings. This model allows accurate monitoring over long periods of time of very low particle concentrations, on the order of 1 µg/m³" (Viegas; Gonçalves; Tatiana, 2013).

Sampler Components
As already mentioned, the ADR-1200S equipment consists of modules housed in a weatherproof enclosure: pDR-1200: monitoring unit, pDR-PU: pump module, pDR-BP: rechargeable battery module, pDR-AC: power supply/charger, pDR-RA: alarm unit, DR-OSI: sampling input.The combination of modules forms a continuous monitoring system, without interruption or power supply failure (pDR-AC) for up to 36 hours. At the alarm output, the ADR-1200S (on the external upper part of the housing) displays a flashing red light that automatically triggers its alarm system whenever the measured particle concentration exceeds the limit level selected by the operator. This alarm signal can be seen from a considerable distance (Instruction manual P/N 1000341-00, 2004).

Figure 2:
Schematic of the ADR-1200 S particle analyzer provided by the equipment manufacturer



Source: Instruction manual P/N 1000341-00, 2004

In addition to allowing continuous real-time measurement, the ADR-1200S allows the collection of particles on a filter for gravimetric or chemical analysis. Figure 3 illustrates the installation and collection of a filter, which will later be sent to the laboratory for evaluation of the concentration of fine inhalable particles in subsequent studies.In the work carried out, the filter was changed after 15 days of monitoring, in compliance with the guidelines contained in the instruction manual of the equipment used to measure $PM_{2,5}$ concentrations throughout the air quality monitoring period (Instruction manual P/N 1000341-00, 2004).

Figura 3:
Installation and collection of a filter: a) installation; b) collection after 15 days of monitoring; c) filter with deposited particles.

a) b) c)

Source: Makonga & Lito, 2026

The instantaneous concentration measurements are stored in the memory of the Personal/Data Ram at time intervals chosen by the user. In order to ensure uninterrupted long-term operation of the equipment, it is equipped with a rechargeable battery. The measured data, stored in the Personal/Data Ram, are subsequently downloaded to a computer for further processing.

Monitoring planning
The equipment was configured for continuous measurement of $PM_{2,5}$ concentration, with a flow rate of 1.5 L/min selected on the pump unit, and with an average time of one hour for data storage (1-hour averages). The duration of each monitoring run averaged 15 days without interruption, with 5 runs carried out starting from June 17, 2014 (more than 1875 hours of monitoring).At the end of each experiment, the stored data were collected to a computer; for this purpose, the computer (with specific software installed) was connected to the monitoring equipment. The data were collected in raw form, subsequently undergoing appropriate statistical treatment. In order to maintain the same operating conditions, the afternoon period was established for the data collection and run start-up process; data collections as well as run start-ups were all carried out at the monitoring site.

In order to compare the results obtained in this work with previous studies, data processing was essentially based on the calculation of arithmetic means (hourly and daily) and standard deviation, understood as the measure of dispersion or variability of the data for hourly and daily averages.The daily averages of the measured concentrations were compared with the respective standards defined by WHO and USEPA for the protection of human health.

Results and Discussion:-

As mentioned in the methodology, it was possible to measure fine particle concentrations, whose hourly averages were stored in the system memory and subsequently downloaded to a computer through the continuous particle monitoring system installed on Avenida 21 de Janeiro at the entrance of the Faculty of Engineering (Central Pavilions) of AgostinhoNeto University (UAN) in Luanda.The records of hourly average $PM_{2,5}$ concentrations stored in the system during the 68-day monitoring campaign (from June 17 to September 16, 2014) were downloaded to the computer and are archived on a CD attached to this dissertation.The results of the hourly averages of these measurements are presented in Figures 4, 5, and 6 of this article.

Figure 4:
Hourly average $PM_{2,5}$ concentrations from Monday

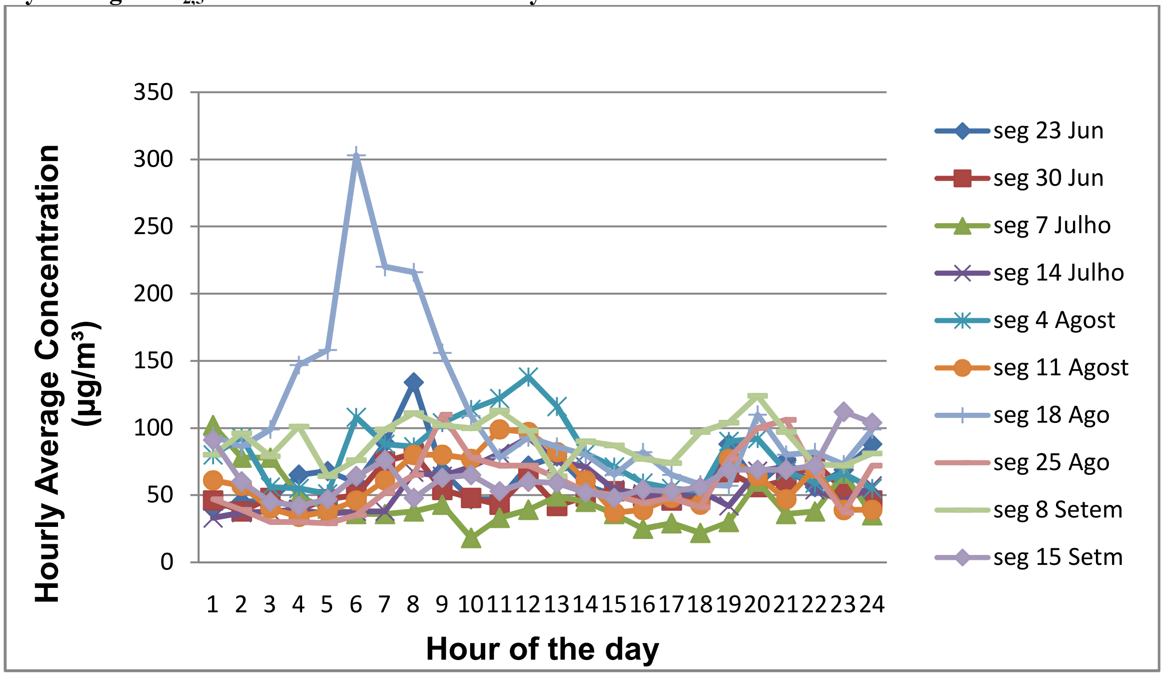
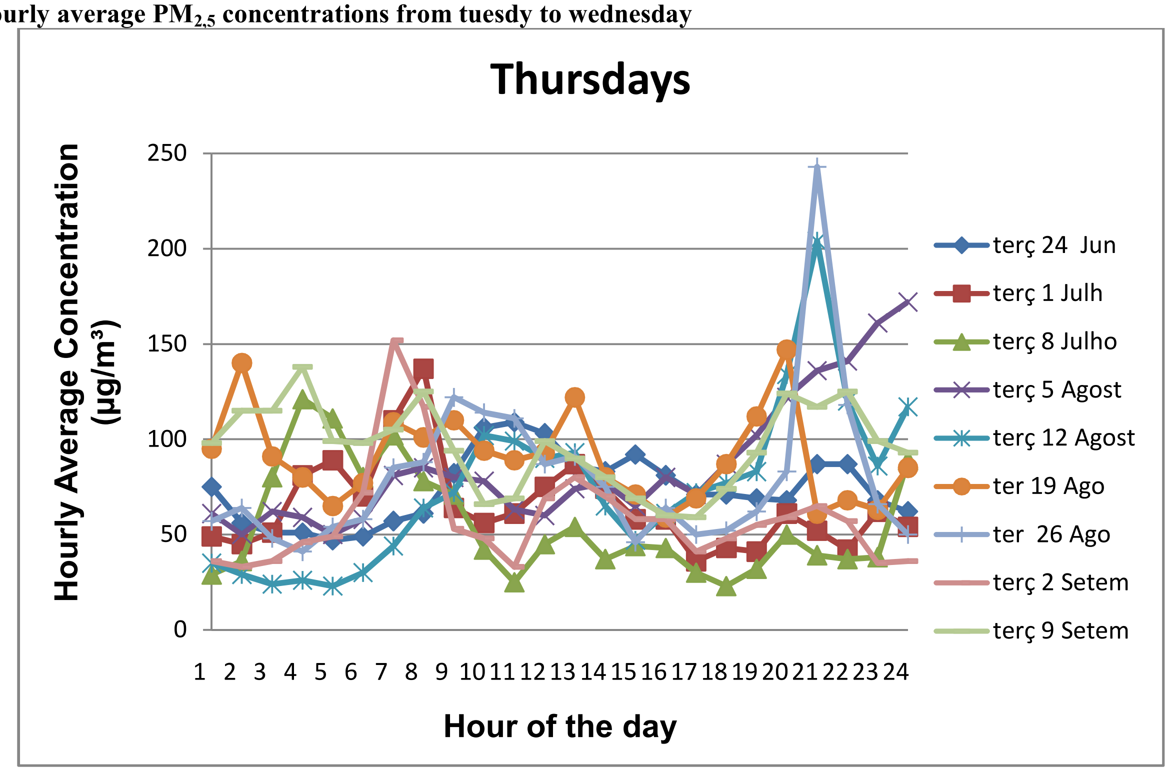
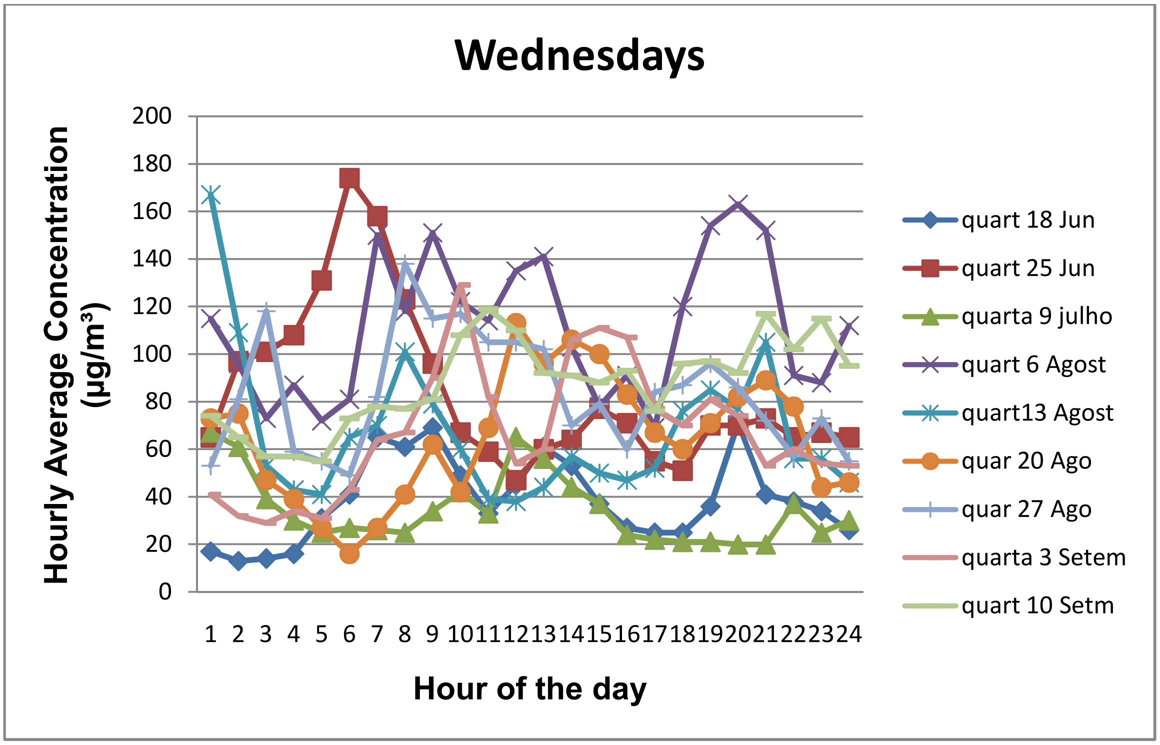


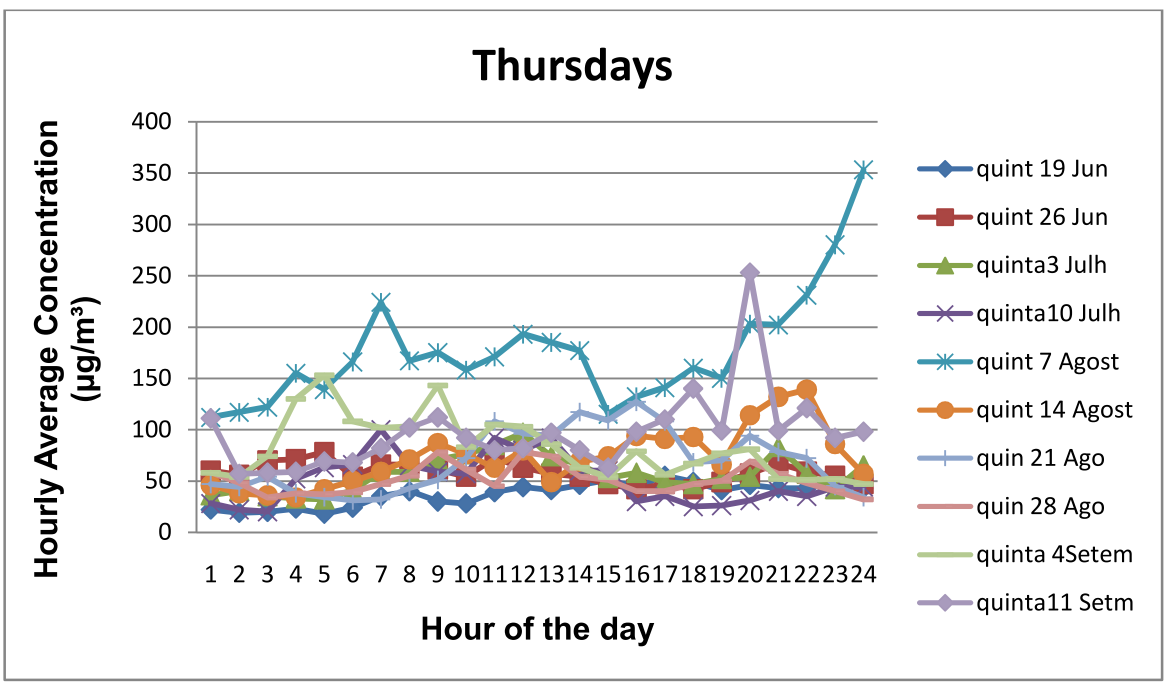
Figure 5:
Hourly average $PM_{2,5}$ concentrations from tuesdy to wednesday

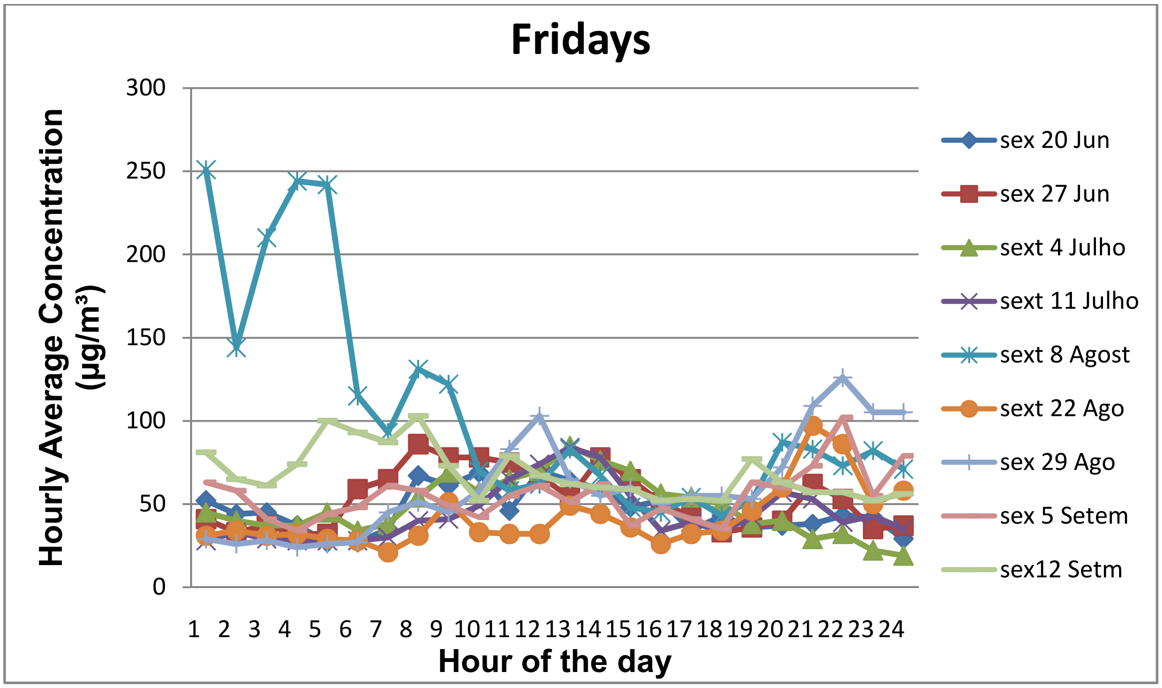




Source: Makonga & Lito, 2026

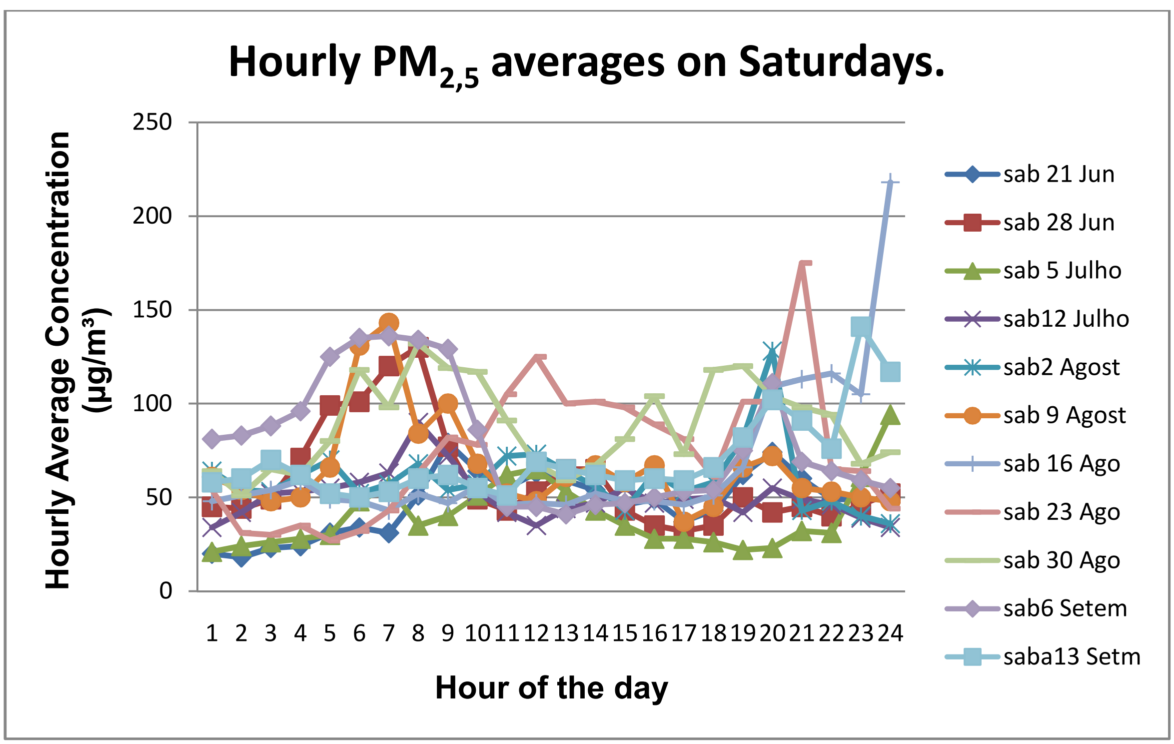
Figure 6:
Hourly average $PM_{2,5}$ concentrations from Thursday to Saturday.





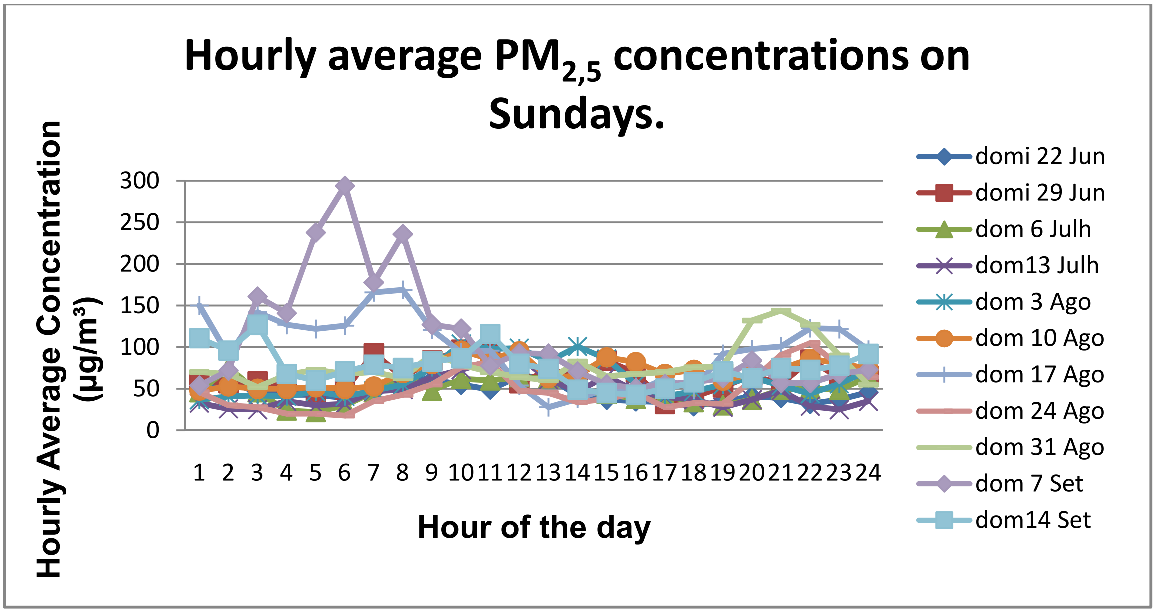
Source: Makonga&Lito

Figure 7:
Hourly average $PM_{2,5}$ concentrations from Saturday.



Source: Makonga&Lito

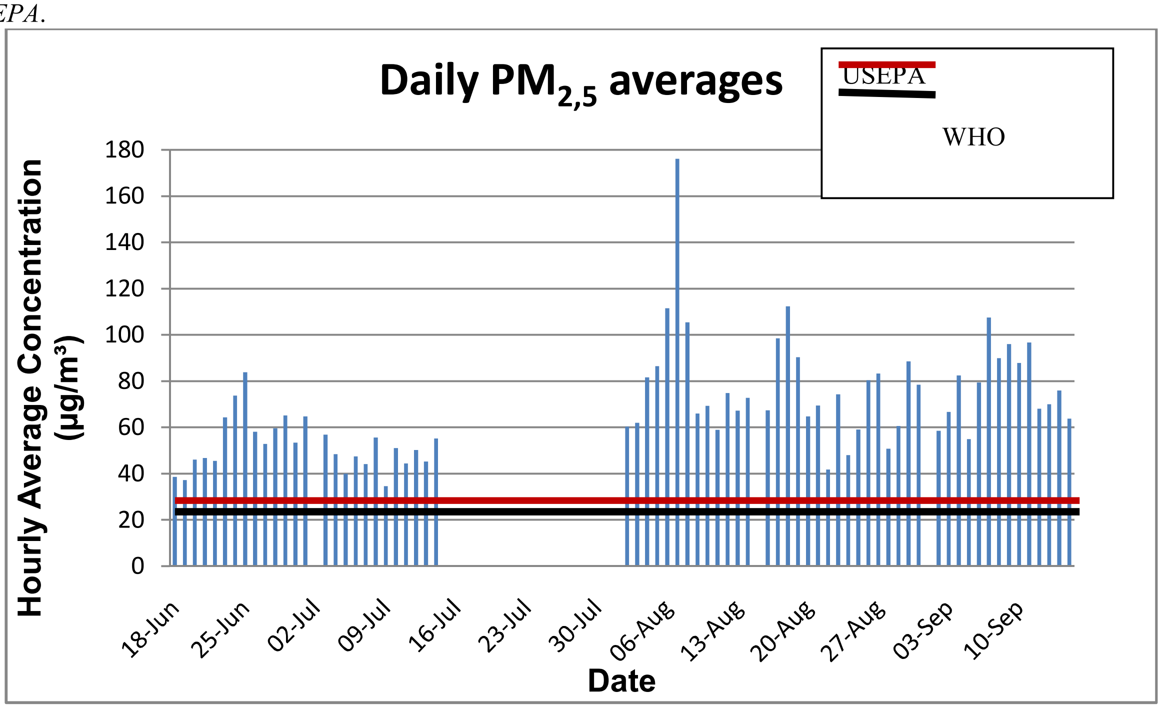
Figure 8:
Hourly average $PM_{2,5}$ concentrations on Sundays.



Source: Makonga & Lito

Figure 7 shows some data gaps, the largest corresponding to the period from July 13 to August 1, which corresponded to the equipment maintenance period.

Figure 9:
Comparison of daily $PM_{2,5}$ averages in Luanda with the human health protection standards established by *WHO* and *USEPA*.



Source: Makonga & Lito, 2026

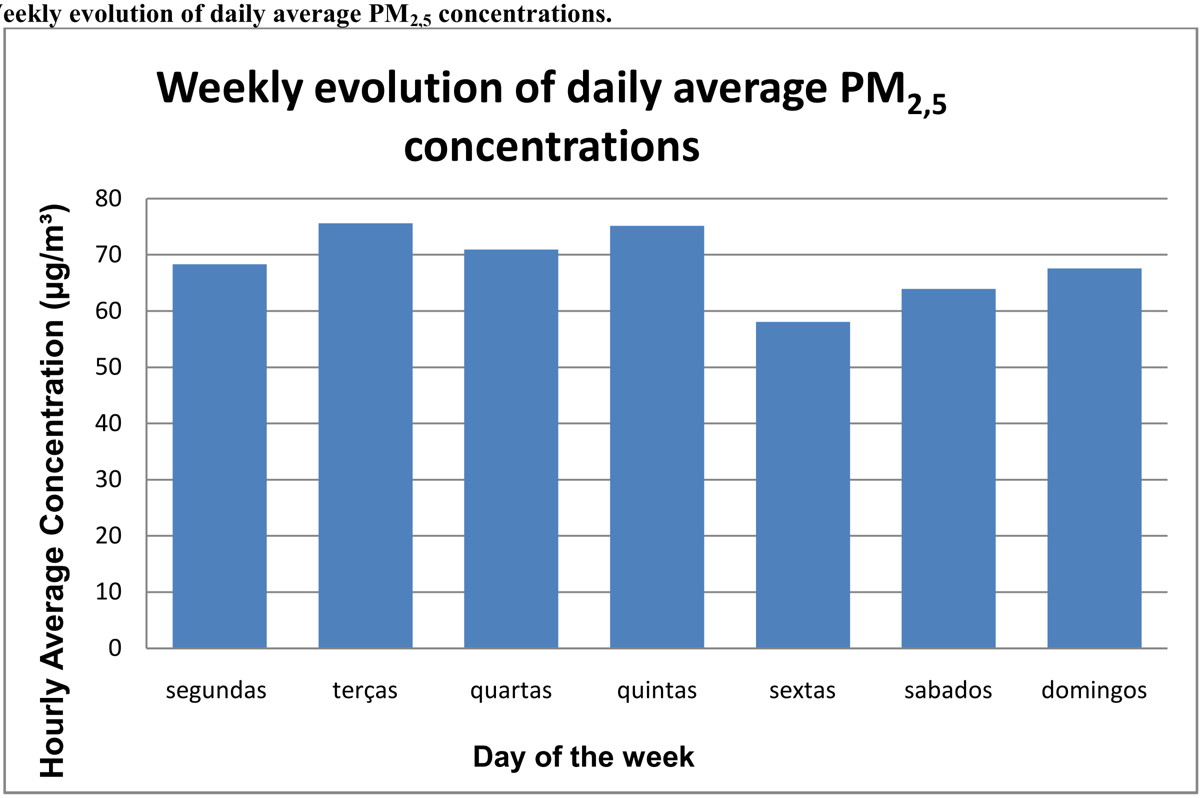
The daily average concentrations vary from day to day, being lowest between June 18 and 22 (38.7 µg/m³ and 37.3 µg/m³ on days 18 and 19, respectively). In the following days, a clear increase in concentration is observed.To protect human health, the World Health Organization (WHO) established a maximum value of 25 µg/m³ for the daily average as a standard. The United States Environmental Protection Agency (USEPA) sets a value of 35 µg/m³ for the same standard. It is with these daily average standards that the results obtained in Luanda, on Avenida 21 de Janeiro, will be compared.

Calculating the daily average concentration values is necessary because the air quality criteria legislated for $PM_{2,5}$ are established based on daily average concentrations (Freitas&Solci, 2009; Maurício, 2009). However, the research showed that during the 68 days of monitoring, the daily average concentrations were always above 25 µg/m³ (EC, 2005; EU, 2004). Particle concentrations above 35 µg/m³ and 40 µg/m³ were recorded in 98.5% and 95.6% of the monitored days, respectively. Above 50, 60, 80, and 100 µg/m³ were recorded in 80.9%, 58.8%, 22.1%, and 5.9% of the measurements, respectively. August 7 had the highest daily average: 176 µg/m³.Based on the above, it was verified that throughout the monitoring period, $PM_{2,5}$ concentrations exceeded WHO standards for the protection of human health. Regarding USEPA standards, only on July 9, which had an average of 34.6 µg/m³, did $PM_{2,5}$ concentrations fall below the limit value (EC, 2005; EU, 2004).

Analyzing the figures above, the daily average concentration of 50 µg/m³ was exceeded 55 times in a monitoring period of 68 days; it should be noted that this is the limit that cannot be exceeded more than 35 times per year for PM_{10} concentrations (EC, 2005; EU, 2004), a pollutant for which the margin of tolerance is much greater. The fact that the recommended standards are breached by such a wide margin indicates a strong risk of exposure to $PM_{2,5}$ (Nóbrega& Pessoa, 2013; Secuma, 2012), especially for the population of Luanda that frequents the studied area.

Figure 8 shows the weekly evolution of the average concentrations of fine inhalable particles on Avenida 21 de Janeiro.

Figure 10:
Weekly evolution of daily average $PM_{2,5}$ concentrations.



Source: Makonga e Lito, 2026

In Figure 8, it can be observed that the highest averages correspond to the first days of the week. However, the results obtained seem to reflect the popular knowledge of Luanda residents, who point to Tuesdays and Thursdays as the days of the week with the most congested traffic.

Table 1 shows a summary of the average values of daily average particle concentrations and the corresponding standard deviation for each average.

Table 1:

Average values of daily average particle concentrations in the air (µg/m³) and the corresponding standard deviation for each average.

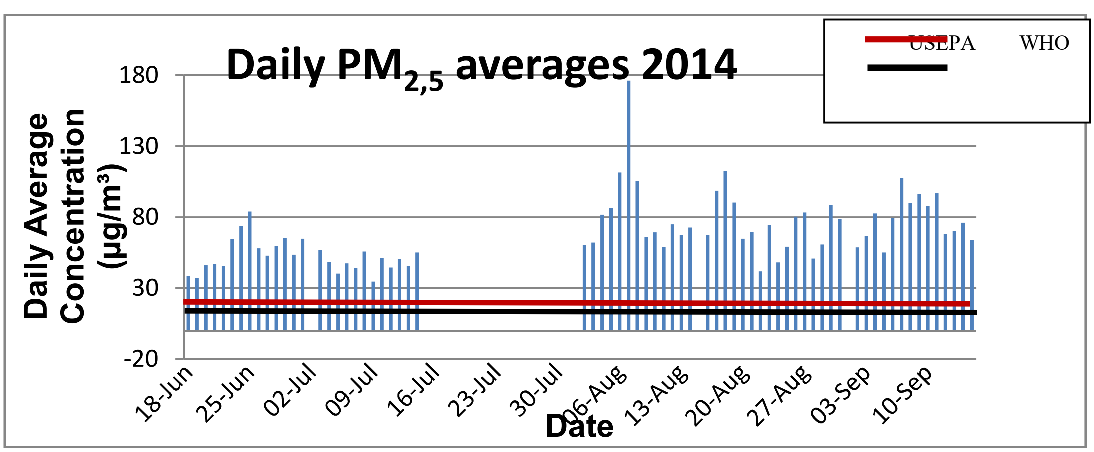
Days of the Week	**Average values of daily average particle concentrations in the air over the week (µg/m³) and standard deviations associated with each average.**	
	Average $PM_{2,5}$ concentrations during the monitoring period (µg/m³)	Standard Deviation
Mondays	68,29	20,46
Tuesdays	75,62	14,05
Wednesdays	70,95	24,18
Thursdays	75,17	39,43
Fridays	58,07	19,60
Saturdays	63,91	14,45
Sundays	67,56	31,31

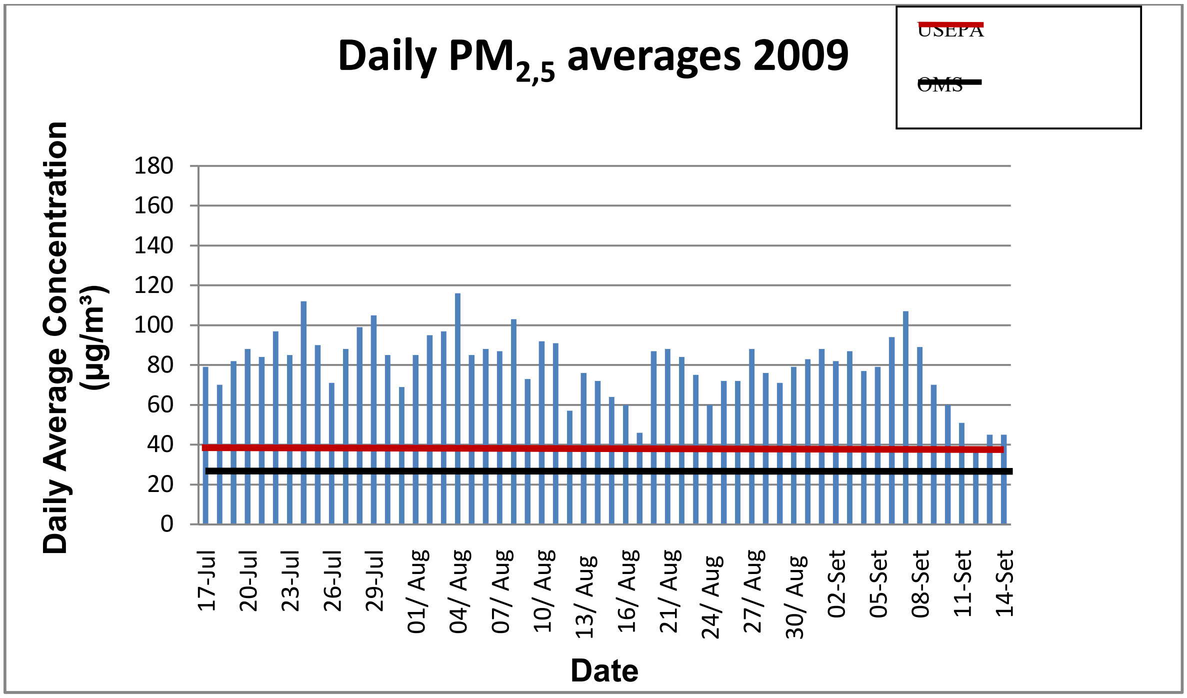
Source: Makonga e Lito, 2026

From this table it can be concluded that the degree of variation of the average values was lowest for Tuesdays at about 14.05, followed by Saturdays at about 14.45, while the days of the week with the largest standard deviation were Thursdays at about 39.43, followed by Sundays at 31.31.In Figure 9, daily average concentrations monitored in 2014 (a) are compared with those monitored in 2009 (b). For these two periods, Table 2 compares: the overall daily average, the maximum and minimum values, and the percentages of daily averages above 25, 35, 50, and 100 µg/m³; this table also indicates the monitoring periods and the number of days monitored

Figure 11:

Comparison of daily average $PM_{2.5}$ concentrations monitored in 2014 (a) with those monitored in 2009 (b). The standards for public health protection defined by WHO and USEPA are indicated.





Source: Makonga & Lito, 2026

Below, Table 2 compares the daily average concentrations monitored in 2009 with those monitored in 2014 (µg/m³).

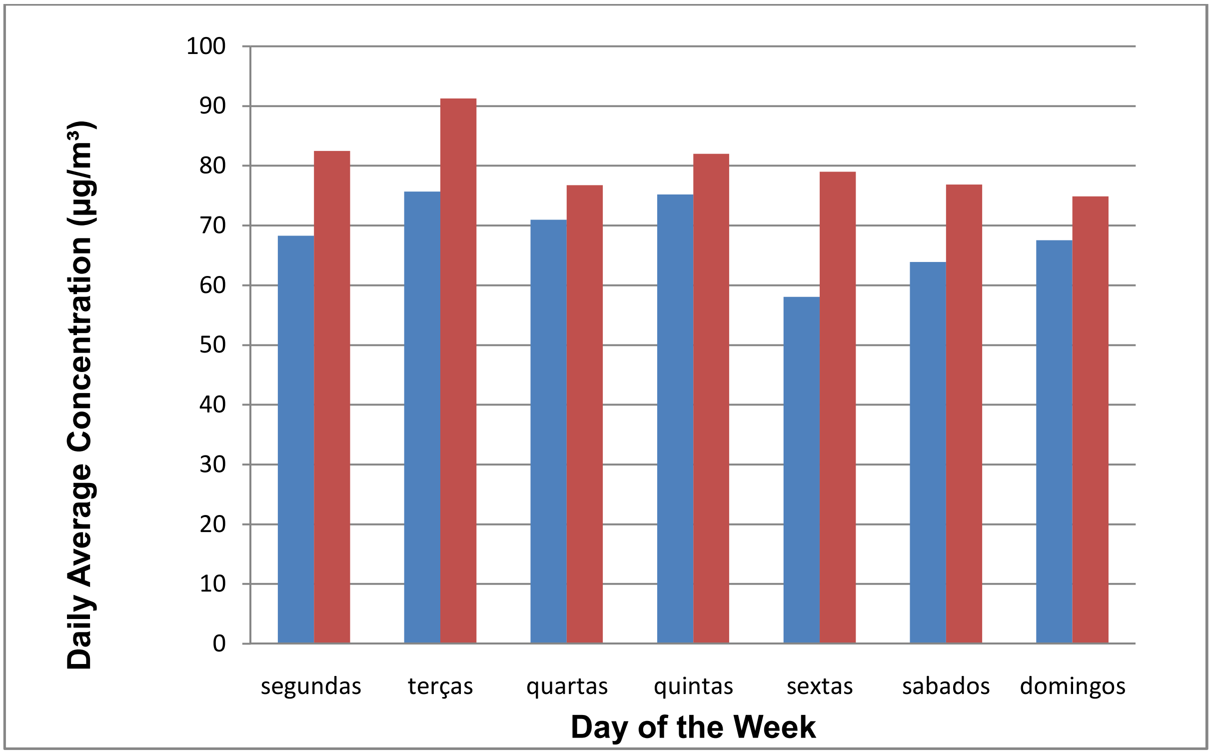
Table 2:
Comparison of daily average concentrations monitored in 2009 with those monitored in 2014 (µg/m³): global average, maximum, minimum, and percentage of days above 25, 35, 50, and 100 µg/m³.

		2014	2009
Monitoring periods		18-Jun a 15-Sept	17-Jul a 14-Sept
Number of monitored days		68	58
Global daily average		68,4	79,9
Maximum daily average		176	116
Minimum daily average		34,6	39
Percentage of days above	25	100	100
	35	98,5	100
	50	80,9	93,1
	100	5,9	8,6

Source: Makonga&Lito, 2026

Figure 10 compares the weekly evolution of daily average concentrations.

Figure 12:
Comparison of the weekly evolution of daily average $PM_{2.5}$ concentrations in 2014 with those in 2009.



Source: Makonga & Lito, 2026

As in 2014, it was observed in 2009 that the highest averages corresponded to the first days of the week. The 2014 results confirm those of 2009: Thursdays have the highest average concentrations. Regarding the lowest concentration, there is no coincidence: in 2014 it occurred on Friday, while in 2009 it occurred on Sunday. As previously mentioned, conclusions regarding the weekly evolution of daily average concentrations cannot be generalized with certainty, considering the relatively short monitoring period on which they are based. Therefore, one could not expect the 2014 conclusions to strictly replicate those of 2009. However, the coincidence of the days with the highest concentrations (Thursdays) is noteworthy; this fact confirms the relevance of the popular knowledge of Luanda residents, who consider these to be the days of the week with the most congested traffic.

The results shown in Figure 10 confirm that concentrations in 2014 were lower than those in 2009, which was consistently observed for all days of the week. The decrease in $PM_{2.5}$ concentration on Avenida 21 de Janeiro in Luanda can be explained by the following facts:

- Complete rehabilitation of this urban space;
- Increased traffic flow;
- Decrease in the average age of circulating vehicles.

These observations allow us to conclude that traffic has a decisive influence on the concentration of suspended $PM_{2.5}$ in Luanda's atmosphere.Despite the observed decrease in concentrations, the very high concentrations of suspended $PM_{2,5}$ still present in Luanda's atmosphere indicate a high risk to the health of its inhabitants, and therefore additional measures are absolutely necessary.

Conclusions:-

Generally, the first hours of the day presented considerably high values; these average values increased in the early morning hours, reaching a maximum between 8:00 and 12:00, decreasing from 14:00 to 18:00, and then increasing again.The variability of concentrations is strongly associated with the variability in traffic intensity, and the influence of meteorological conditions that condition pollutant dispersion, namely wind direction and speed, is also significant.Daily averages were always above 25 µg/m³ and rarely below 40 µg/m³, but often exceeded 50 and 60 µg/m³, repeatedly reaching 80 µg/m³ and even 100 µg/m³. August 7 had the highest daily average: 176.2 µg/m³. Hourly averages during the early morning hours were generally higher in 2014, sometimes exceeding the values observed during the day. This fact is fundamentally due to the current preferential schedule for truck traffic during that period.

WHO standards were not met on any of the monitored days; the more permissive USEPA standards were only marginally met on one of the monitored days.The daily average concentration of 50 µg/m³ was exceeded 55 times in a monitoring period of 68 days; it is emphasized that this is the limit that cannot be exceeded more than 35 times per year for PM_{10} concentrations, a pollutant for which the margin of tolerance is much larger.The highest averages correspond to the first days of the week. Tuesday and Thursday have the highest average concentrations, reflecting the popular knowledge of Luanda residents, who point to Tuesdays and Thursdays as the days of the week with the most congested traffic.A direct comparison of these studies with those conducted in the subsequent ten years is not made solely because those studies were not specific to PM2.5 and the equipment was no longer available; in other words, the equipment used in later research was not the same as that used in the years described in the methodology of this article.

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