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# Estimating the Role of Roadside Vegetation in Reducing Particulate Matter Pollution in the Karkh District of Baghdad City

**Ammar A. F. AlObaidi[1*] and Ibrahim M. A. Al-Salman[2]**
[1,2]Department of Biology, College of Education for Pure Sciences (Ibn-Al-Haitham), University of Baghdad, Baghdad, Iraq
*Corresponding Author.

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## Abstract

Baghdad is considered one of the most crowded cities, and it is the location of all government institutions, making it a destination for people from all other provinces. This results in increased traffic density, which in turn leads to increased emissions that contribute to air pollution in the form of gases and particulate matter. This study was conducted from July to December 2022 in the Karkh district of the city, where the Salahuddin highway was divided into five sites based on the presence or absence of plant barriers on either side of the road. $PM_{10}$ and $PM_{2.5}$ pollutant concentrations and climatic factors were measured at each site during morning and afternoon peak hours. The study found that concentrations exceeded local and global standards at all sites by several times, posing a real health and environmental risk in the city's atmosphere. The highest concentrations were found at site (E), followed by sites (A) and (D), which were all devoid of plant barriers except for scattered trees. The lowest concentrations were recorded at sites (B) and (C), which contained plant barriers on either side of the road and in median barriers. Although these plant barriers and median barriers did not meet the best standards, they contributed to reducing particulate pollutants by a good percentage compared to the first three sites. Climate factors played a role during the study period, which extended during the summer and winter seasons. Heat and wind speed had a negative correlation with $PM_{10}$ and $PM_{2.5}$ concentrations, while relative humidity had a positive correlation. Therefore, from what has been presented, it is necessary to increase the use of public transportation buses for their role in reducing the number of private cars on the street and to focus on planting plants and trees on the sides and in the middle of roads for their role in reducing air and visual pollution and providing natural shade for pedestrians and vehicles.

**Keywords:** Air pollution, Particles pollutants, Plant barriers, Vegetation cover, Hedges, Green infrastructure, Urban, Plant fences.

## 1. Introduction

Air pollution is considered one of the most pressing issues discussed in the world today, posing threats to all forms of life due to the enormous challenges associated with it. Particulate matter, also known as airborne particles, atmospheric particulate matter, or PM, or suspended particulate matter (SPM), are microscopic solid or liquid particles suspended in the air.

The term particulate matter generally refers to a mixture of particles and air, not just the particles themselves [1]. Sources of particulate matter can be of natural or human origin [2,3], in addition to being directly inhaled, which affects the climate and rainfall and has a negative impact on human health.The types of particles in the atmosphere include suspended particulate matter, thoracic particles, and respirable particles [4]. Inhalable coarse particles, called $PM_{10}$, are coarse particles with a diameter of 10 micrometers (µm) or less; fine particles, called $PM_{2.5}$, have a diameter of 2.5 micrometers or less; ultrafine particles have a diameter of 100 nanometers or less; and soot particles [5].The International Agency for Research on Cancer (IARC) and the World Health Organization classified airborne particles as Group 1 carcinogens [6]. Particulate matter is the most harmful form of air pollution, especially ultrafine particles, due to their ability to penetrate deeply into the lungs and brain through the bloodstream and cause health problems such as heart disease, lung disease, and premature death [7]. Global exposure to $PM_{2.5}$ contributed to 4.1 million deaths from heart disease, stroke, lung cancer, chronic lung disease, and respiratory infections in 2016 [8].Some particles occur naturally, such as those originating from volcanoes, dust storms, forest fires, grasslands, living plants, and sea spray. However, others can result from human activities, such as burning fossil fuels [9] and construction (building renovation or demolition, roadworks, diesel exhaust from heavy equipment, and emissions from building material production) [10,11], carpentry and glass recycling, agricultural activities [12], power generation stations, road dust from tires and road wear [13,14,15], and various industrial processes such as mining, smelting, and oil refining also generate significant amounts of particles. Microplastics are also gaining attention as a type of airborne particle [16]. Currently, human-made particulate matter accounts for about 10% of the total mass of airborne particulate matter in the atmosphere [17].There is a general agreement that increasing green spaces and expanding tree planting operations are considered among the best treatments [18, 19], and that trees and shrubs are among the best ways to achieve green cities.Researchers also indicate that plant barriers can significantly reduce levels of fine particles and toxic gases emitted from traffic on the sides of roads [20, 21]. Other studies have found that plant barriers can reduce the accumulation of chemicals in the soil adjacent to roads [22] by absorbing and storing them in the green parts of the barriers [23-25].Furthermore, plant barriers can reduce the accumulation of chemicals in the air surrounding the road by filtering fine particles and toxic gases through their leaves and branches [26-28]. Green road boundaries also help to reduce air temperatures in the summer and decrease the amount of dust and noise generated by traffic [29,30].Green urban infrastructure can be implemented as a measure to combat negative air pollution and control air pollution in cities through limited modifications to the built environment [31].Therefore, this study was designed to determine the level of performance and compatibility of green barriers and green infrastructure on the Salahuddin Highway located in the Karkh district of Baghdad City with international standards and their efficiency in reducing levels of fine air pollutants on the road sides.

## 2. Study Area

The study area is on the Karkh side of Baghdad, Iraq's capital, which is bordered on the eastern side by the Tigris River and is astronomically located between latitude (33) north, longitude (44) east, as shown in **Figure 1**.

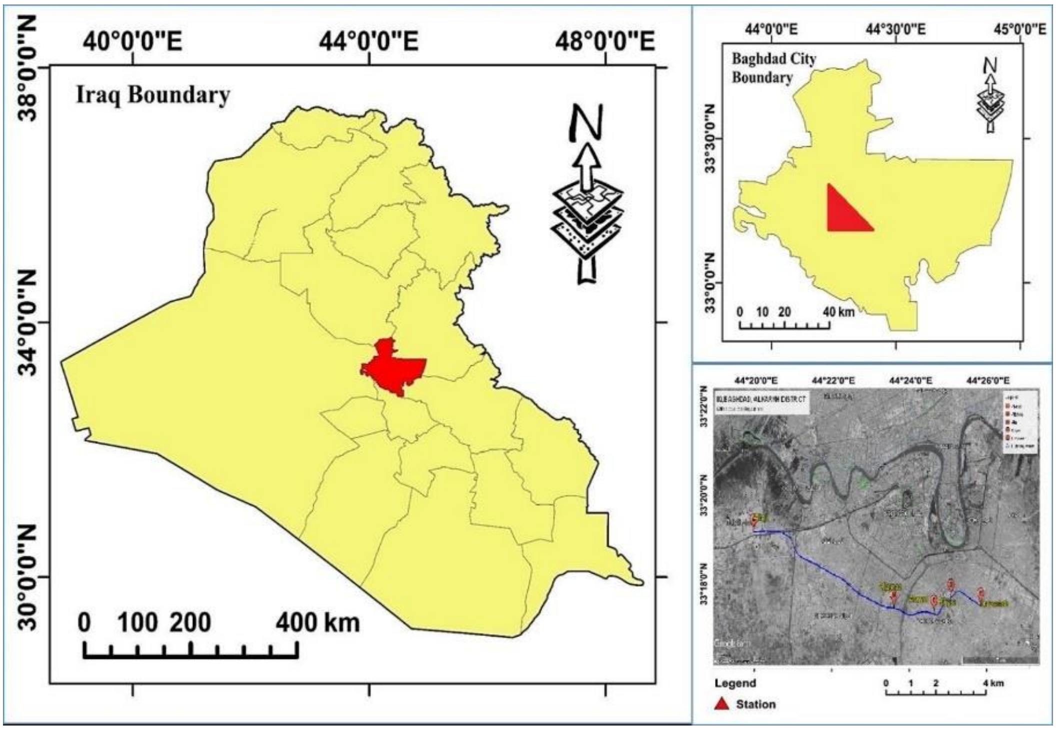


**Figure 1.** Study Area, Baghdad city, Iraq.

### 2.1. Study area locations

The study area was divided into five sites where the highway passes and included the following areas:(A) Taji area, (B) Aljamaa district,(C) Alaamil district,(D) Al-Bayaa garage, and(E) Darwish intersection, distributed over a distance of about 22 km, as shown in **Figure 2** and **Table 1**. Where the division depended on the presence and absence of plant fences on both sides of the road and the middle islands, and whether the site is residential or non-residential near or far from the road, as shown in the satellite image of these sites from (1-5).

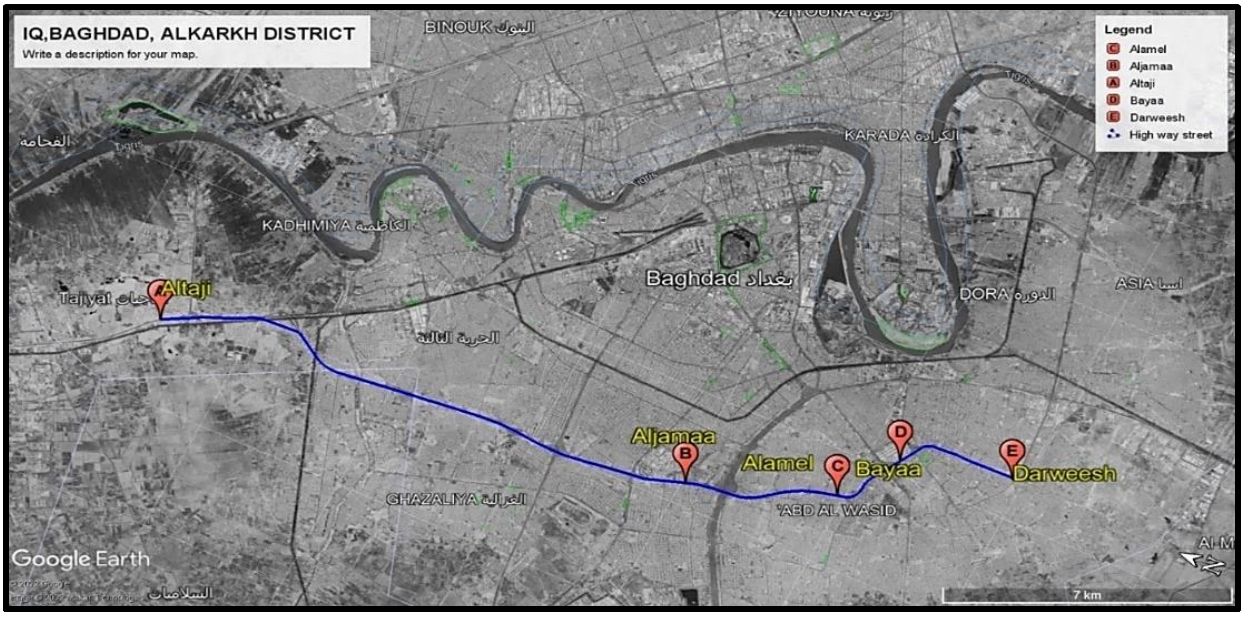


**Figure 2.** Study sites within the Karkh side - Baghdad Governorate. Source: (Google Earth**)**


**Satellite image 1.** Location of (A) Taji area


**Satellite image 2.** Location (B) Aljamaa district


**Satellite image 3.** Location (C) Al-Aamil District


**Satellite image 4.** Location (D) Al-Bayaa Garage


**Satellite image 5.** Location (E) Darwish Intersectio

**Table 1.** Locations and their coordinates.

| No. | Site Name | North Coordinate | East Coordinate |
|---|---|---|---|
| 1 | Site (A) Altaji | 33°25'09.7"N | 44°17'27.1"E |
| 2 | Site (B) Aljamaa district | 33°17'57.6"N | 44°18'25.2"E |
| 3 | Site (C) Alaamil district | 33°16'05.9"N | 44°19'15.6"E |
| 4 | Site (D) Albayaa Garage | 33°15'35.3"N | 44°20'15.1"E |
| 5 | Site (E) Darwish intersection | 33°14'09.3"N | 44°20'42.0"E |

## 3. Materials and Methods

After determining the coordinates of each site, the center point of each site was chosen for measurement within each site. Portable measuring devices were used to measure the concentration of Particulate Matter ($PM_{10}$, $PM_{2.5}$) in the atmosphere of the study area using the device Air Quality Detector (Temtop LKC-1000s+). The devices were installed at a height of one and a half meters above the ground to avoid dust flying due to wind movement, and the measurement was made in the direction of the prevailing winds in the region during the implementation of the experiments, as stated in [32]**.** The samples were taken simultaneously for a period of exposure (one hour) and at a rate of four readings per month for each site (two readings during the morning peak and two readings during the afternoon peak interchangeably between sites). The rates of the four readings for each site were taken for six months during the summer and winter (July, August, September, October, November, and December) of 2022. Some basic atmospheric factors affecting the distribution of the particles targeted in the study were also measured, represented by temperature, relative humidity, and wind speed, as well as the number of passing vehicles during the measurement process.

## 4. Results and Discussion

Current study according to **Table 2** and **Figure 3**, showed that spatial variation in concentrations, where the highest concentrations of $PM_{10}$ were recorded at site (E), Al-Darwish intersection, ranging from (255.50-73.87) µg/m³ with a mean value of (151.53±71.29) µg/m³, followed by site (A), Al-Taji, ranging from (197.50-43.07) µg/m³ with a mean value of (110.84±65.56) µg/m³, then site (D), Al-Bayaa Garage, ranging from (170.50-33.75) µg/m³ with a mean value of (97.34±48.49) µg/m³. Concentrations and mean values were close to each other at sites (C), Al-Aamil district, ranging from (141.20-33.00) µg/m³ with a mean value of (77.34±37.53) µg/m³, and site (B), Al-Jamaa district, ranging from (129.82-35.37) µg/m³ with a mean value of (86.50±30.82) µg/m³.

**Table 2.** The average of $PM_{2.5}$, $PM_{10}$ and metrological factors (wind speed, temperature and RH) in sites of study compared with WHO standards.

| Sites | $PM_{10}$ µg/m3 | $PM_{2.5}$ µg/m3 | Temp C° Average | RH % Average | Wind Sp. Km/h | cars per Hour |
|---|---|---|---|---|---|---|
| Site (A) Altaji | 86.5 | 71.1 | 45.7 | 18.0 | 12.6 | 4782 |
| | 98.0 | 45.8 | 43.0 | 21.7 | 5.0 | 5548 |
| | 54.9 | 33.4 | 41.4 | 20.4 | 3.7 | 5700 |
| | 43.1 | 26.0 | 29.6 | 33.3 | 5.9 | 5889 |
| | 185.1 | 116.6 | 20.5 | 49.0 | 4.2 | 6525 |
| | 197.5 | 117.5 | 16.0 | 46.3 | 2.3 | 6538 |
| Site (B) Hay-Aljamaa | 35.4 | 33.6 | 46.1 | 19.0 | 6.6 | 8064 |
| | 98.3 | 43.1 | 40.1 | 24.7 | 3.3 | 8050 |
| | 82.6 | 56.2 | 42.0 | 18.0 | 3.7 | 8669 |
| | 79.2 | 49.3 | 30.4 | 32.5 | 2.1 | 8700 |
| | 129.8 | 80.6 | 22.5 | 43.0 | 4.6 | 10050 |
| | 93.8 | 60.8 | 18.5 | 44.8 | 3.5 | 11325 |
| Site (C) Hay-Alaamil | 33.0 | 30.5 | 48.2 | 17.4 | 8.0 | 4175 |
| | 90.0 | 40.6 | 42.5 | 21.7 | 5.7 | 4313 |
| | 49.5 | 34.2 | 41.0 | 17.0 | 5.4 | 3903 |
| | 69.9 | 43.7 | 31.8 | 33.3 | 4.3 | 5025 |
| | 141.2 | 88.1 | 23.0 | 44.3 | 1.9 | 5625 |
| | 80.5 | 50.8 | 18.4 | 45.0 | 2.4 | 5356 |
| Site (D) Albayaa Garage | 33.8 | 30.8 | 45.5 | 17.4 | 7.5 | 6222 |
| | 93.8 | 43.4 | 45.4 | 18.9 | 5.7 | 5785 |
| | 71.5 | 46.6 | 43.0 | 15.9 | 4.9 | 6938 |
| | 80.1 | 50.1 | 31.7 | 30.5 | 5.4 | 7935 |
| | 170.5 | 104.0 | 23.3 | 39.5 | 1.8 | 7350 |
| | 134.5 | 83.8 | 19.0 | 42.5 | 2.8 | 6425 |
| Site (E) Darwish intersection | 73.9 | 70.6 | 46.1 | 17.3 | 7.7 | 4200 |
| | 141.3 | 66.5 | 44.1 | 19.5 | 3.8 | 4705 |
| | 91.1 | 59.0 | 42.4 | 16.4 | 4.9 | 6620 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 130.0 | 76.1 | 30.6 | 32.3 | 5.7 | 5910 |
| | 255.5 | 162.2 | 22.0 | 40.8 | 3.4 | 6250 |
| | 217.5 | 133.0 | 17.8 | 46.3 | 5.7 | 5888 |
| EPA level | 150<br>24-hour | 35<br>24-hour | | | | |
| Iraqi National Limits | 50<br>1-hour | 10<br>1-hour | | | | |

As for the $PM_{2.5}$ concentrations, they also showed spatial variation, where the highest concentrations were recorded at site (E), Al-Darwish intersection, ranging from (162.21-59.02) µg/m³ with a mean value of (94.57±42.45) µg/m³, followed by site (A), Al-Taji, ranging from (117.50-26.02) µg/m³ with a mean value of (68.38 ±40.67) µg/m³, then site (D), Al-Bayaa Garage, ranging from (103.97-30.75) µg/m³ with a mean value of (59.74 ±27.96) µg/m³. Concentrations and mean values were also close to each other at sites (C), Al-Aamil district, ranging from (88.12-30.50) µg/m³ with a mean value of (47.97±20.92) µg/m³, and site (B), Al-Jamaa district, ranging from (80.57-33.62) µg/m³ with a mean value of (53.92 ±16.20) µg/m³, as shown in **Table 2** and **Figure 4**.

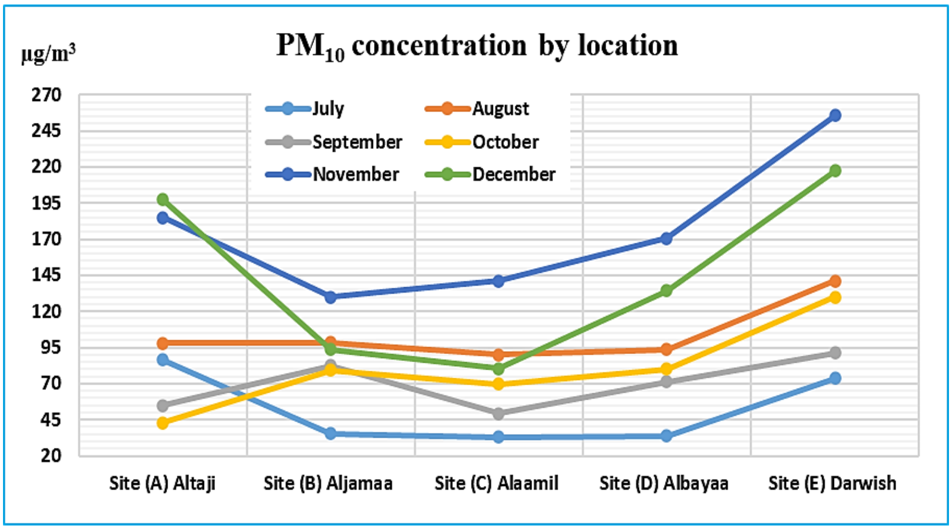


**Figure 3.** Average $PM_{10}$ concentrations by study sites

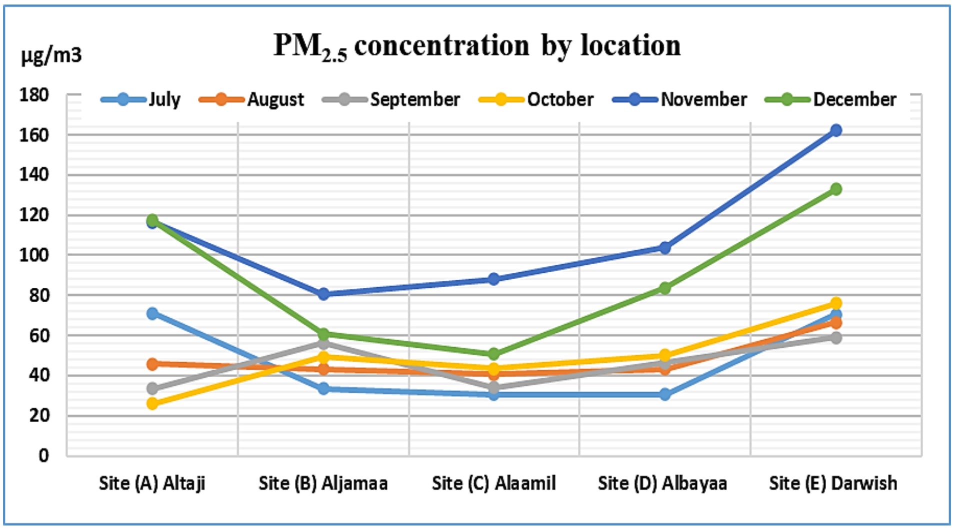


**Figure 4.** Average $PM_{2.5}$ concentrations by study sites.

It is evident that all sites have significantly exceeded both national and global air quality standards, as the recorded concentrations of $PM_{2.5}$ particulate matter were 2.5 times higher than the local limits at the lowest recorded concentration and up to 16.2 times higher at the highest recorded concentration. Similarly, $PM_{10}$ particulate matter concentrations were 1.5 times higher than the local limits at the lowest recorded concentration and up to 5.1 times higher at the highest recorded concentration.

The most dangerous and highest concentrations were recorded at site (D) Al-Darwish intersection, followed by sites (A) Taji and (D) Al-Bayaa garage, during all months of the study, due to the continuous traffic congestion during morning and evening peaks. However, the highest percentage was at the site (D) Al-Darwish intersection, due to the emissions from vehicles and trucks during the combustion process in engines. The rates of fine particle emissions vary between different vehicles and the quantity of emissions increases when speeds are high or when old, environmentally unfriendly vehicles are used, in addition to the absence of plant barriers, hedges, and vegetation cover in general at the sites. This makes these sites seriously polluted, which in turn increases the risk of respiratory and cardiovascular diseases [33], dermatological diseases, eye irritation, and allergies [34,35]. This also affects pedestrians and cyclists [36] as well as residents of homes located near the street, especially since the homes are only a few meters away from the pollution center on site (E).This is consistent with numerous academic studies that have examined the relationship between traffic congestion and levels of $PM_{2.5}$ and $PM_{10}$ in the air, [37,38] and also with [39].Upon examining the lowest concentrations, it becomes clear that they were found in locations (B) Al-Jamaa district and (C) Al-Aamil district. It is likely that this decrease was due to the presence of vegetation and plant cover in these locations, with the latter having the lowest concentrations in most months. It is possible that the presence of trees and shrubs in rows, despite their irregularity, played a major role in reducing fine pollutants. Despite the high numbers of passing cars, especially in location (B) Al-Jamaa district, where the highest number of vehicles was recorded during the study period, as shown in **Table 2**. This is consistent with the findings of [40], where vegetation was found to play a role in dispersion, deposition, and modification processes. It also aligns with the study conducted by [41] and [42], where their research found that plants and trees along roadsides can reduce the concentration of fine particles in the air by absorbing and depositing them. Similarly, [43] found that vegetation plays a role in reducing the amount of particulate matter in the air.When presenting the results of both types of particulate matter, $PM_{10}$ and $PM_{2.5}$, according to the months of the six-month study, there is a clear variation. The lowest concentrations were recorded in the first months of the study and then began to increase, reaching their peak in the last months. It is also likely that the increase can be attributed to the number of vehicles that increased in the last two months of the study, which coincided with the start of the academic year. This is shown in **Figures 5** and **6**.

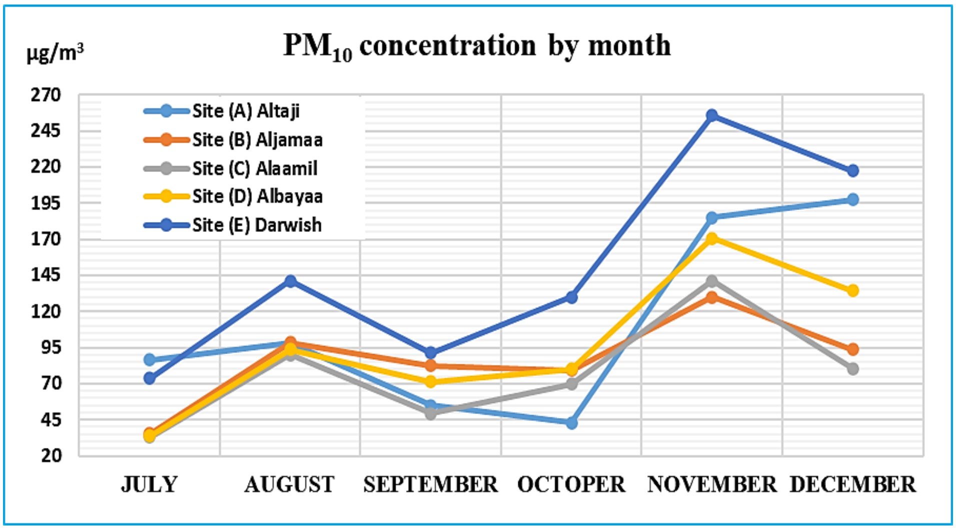


**Figure 5.** Average $PM_{10}$ concentrations by study months.

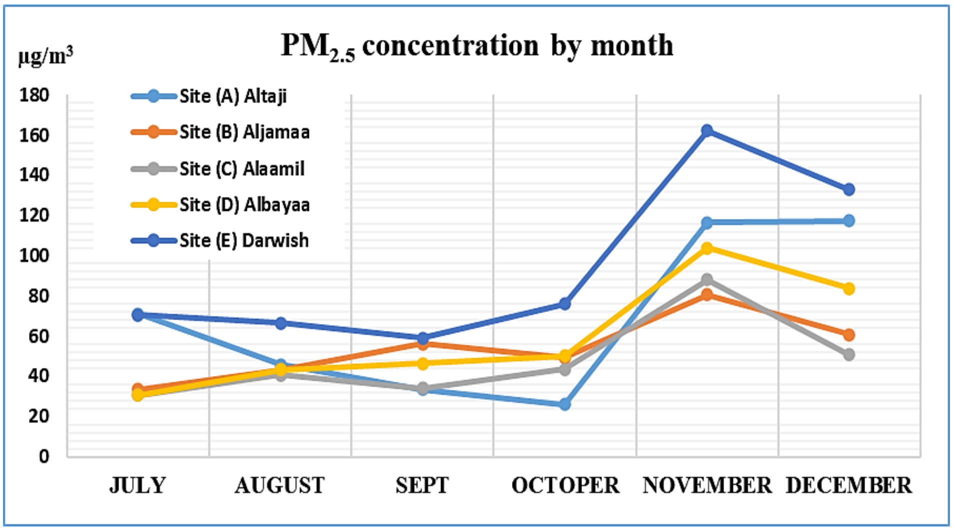


**Figure 6.** Average $PM_{2.5}$ concentrations by study months.

The study found that there was a negative correlation between temperature and wind speed and the concentrations of $PM_{2.5}$ and $PM_{10}$, due to temperature influencing the processes of formation and breakdown of particulate pollutants. At high temperatures, the increase in temperature can lead to the decomposition of organic and chemical particulate matter, resulting in increased emissions of particulate pollutants. Conversely, at low temperatures, particulate pollutants may accumulate and freeze, leading to an increase in their concentration in the air.The lowest concentrations of fine particulate matter were recorded when the temperature ranged between 48.2°C and 40.1°C, while the highest concentrations were recorded at temperatures ranging from 16°C to 23°C, as shown in **Table 2**.As for the relative humidity, there was a positive correlation with the concentrations of $PM_{2.5}$ and $PM_{10}$, because the larger particles are formed in the air due to the agglomeration of suspended particles in moisture, leading to an increase in air particulate concentrations. Additionally, a decrease in air movement and natural circulation of airborne particles is observed under high humidity conditions, which increases the likelihood of their accumulation and concentration in confined areas. The lowest concentrations of fine particulate matter were recorded when the relative humidity ranged from 21.7% to 15.9%, while the highest concentrations were recorded at relative humidity levels ranging from 49% to 40.75%, as shown in **Table 2** and **Figures 7** and **8.**And this is consistent with many studies that have pointed to this type of relationship. For example, in the studies [44-46], as well as the researchers [47], who studied the effect of temperature and relative humidity on the concentration of particulate matter $PM_{10}$ in an urban area during the winter. They found a negative correlation between temperature and $PM_{10}$ co

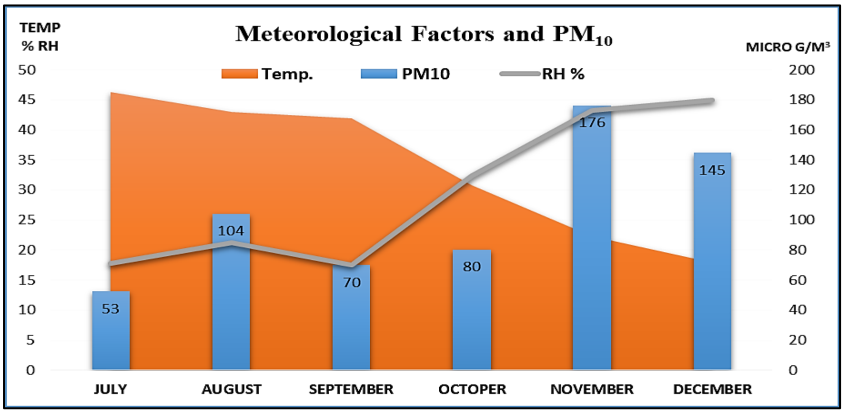


**Figure 7.** Correlation between $PM_{10}$ and Meteorological factors.

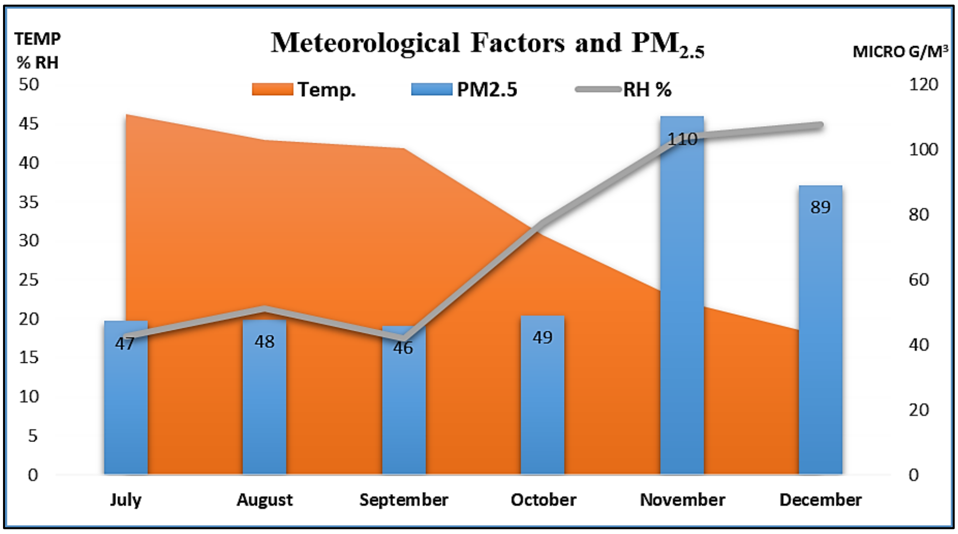


**Figure 8.** Correlation between $PM_{2.5}$ and Meteorological factors.

From the perspective of the effect of wind speed in urban areas and its relationship with fine particulate matter $PM_{2.5}$ and $PM_{10}$ pollutants, the study found a negative relationship between them due to wind speed affects the movement of particulate matter in the air. When wind speed is low, it accelerates the accumulation of particulate matter in confined areas such as residential neighborhoods or valleys, increasing the exposure of residents to particulate pollutants. On the other hand, when wind speed is high, it disperses particulate matter and carries it away from residential areas. This is consistent with the study by [48-50] and the researchers [51], whose results showed an inverse relationship between wind speed and particulate matter concentration in cities. The concentration of particles increased on days when wind speed was low, as shown in **Figures 9** and **10**.

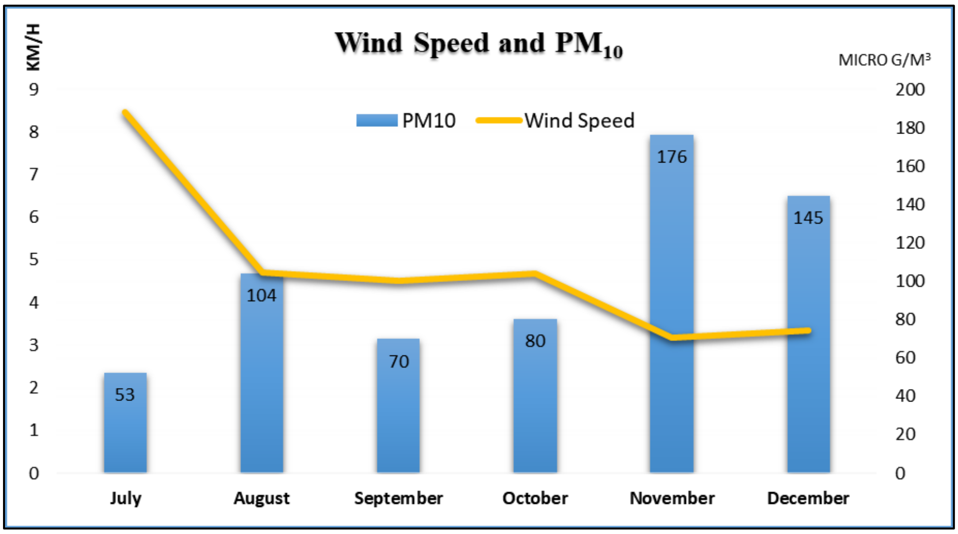


**Figure 9.** Correlation between $PM_{10}$ and wind speed.

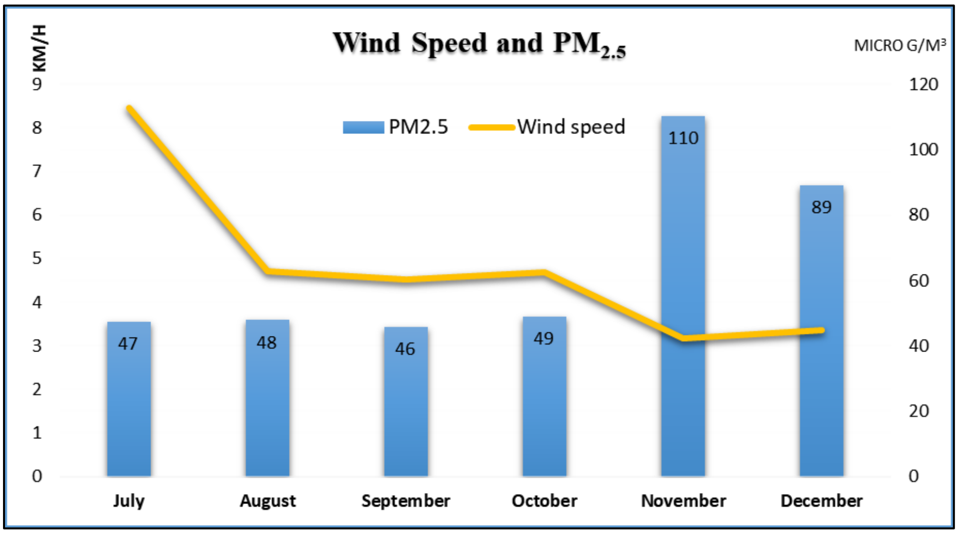


**Figure 10.** Correlation between $PM_{2.5}$ and wind speed.

The statistical analysis in the **Table 3** confirms what was mentioned above about the relationship between climatic factors and particulate matter.

**Table 3.** Correlation coefficient between meteorological factors and particles

| | $PM_{2.5}$ | $PM_{10}$ | Temp C° | RH % | Wind Sp. | cars |
|---|---|---|---|---|---|---|
| $PM_{2.5}$ | 1 | | | | | |
| $PM_{10}$ | 0.958781 | 1 | | | | |
| Temp C° | -0.6585 | -0.66165 | 1 | | | |
| RH % | 0.658192 | 0.665392 | -0.98024 | 1 | | |
| Wind Sp. | -0.26855 | -0.39284 | 0.589546 | -0.54583 | 1 | |
| cars | 0.080847 | 0.083553 | -0.35487 | 0.330588 | -0.36491 | 1 |

## 5. Conclusion

The influence of the presence of plant fences on the composition, shape, and density was evident in the values and rates of particles studied when comparing sites B and C with the rest of the sites.

The concentration of particles and pollutants was above the limits allowed by the global and local limits, and their values varied during the months of the year and the study sites. This variation was related to meteorological factors and traffic density (transportation density).

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**Conflict of Interest**

The authors declare that they have no conflicts of interest.

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