

Evaluation Of Particulate Matter (PM_{2.5} And PM₁₀) And Falling Dust Levels And Their Relationship To Some Climatic Factors In Selected Areas In Anbar Governorate

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Abstract:

Fine particulate matter (**PM_{2.5} and PM₁₀**) is one of the most impactful air pollutants on human health and the environment, especially in industrial areas. This study aims to assess these particles and falling dust from several selected locations in Anbar Governorate. The study relied on field readings from 21 fine particulate matter monitoring stations (**10 industrial stations, 6 residential stations, 4 commercial stations, and 1 control station**), in addition to 16 dust monitoring stations (**6 industrial stations, 6 residential stations, and 4 commercial stations**), along with measurements of some climatic factors such as temperature, relative humidity, and wind speed. Data were collected from environmental monitoring stations over a period of four months (**October, January, March, and April**) using precision instruments. The study results revealed significant variations in pollution levels at the stations selected for the study. The highest concentrations of suspended particulate matter (**PM₁₀**) were recorded at (**200, 117, and 88**) micrograms/m³ in the industrial, commercial, and residential areas, respectively. The results confirmed that all industrial stations recorded concentrations higher than the global and local permissible limits, while none of the residential stations exceeded these limits. The results indicated that PM_{2.5} recorded the highest concentrations at (**58, 42, and 32**) micrograms/m³ in the industrial, commercial, and residential areas, respectively. The industrial and commercial areas exceeded the global and national limits (**except for the commercial A10 in Haditha**), while the residential stations did not exceed these limits. The results also showed that the concentrations of particulate matter (**PM₁₀ and PM_{2.5}**) recorded at the stations selected for the study were higher when compared to the monitoring (**control**) station.

The study results also showed that the Kubisa Cement Plant recorded the highest levels of falling dust, at 834.78 g/m²/month, in April.

The study also demonstrated statistically significant correlations between some climatic factors and suspended particulate matter concentrations, with particulate matter concentrations (**PM_{2.5}, PM₁₀**) showing an inverse relationship with wind speed and temperature, and a direct relationship with relative humidity. However, no climatic factor was statistically significantly associated with falling dust.

Keywords: Air pollution, falling dust, particulate matter.

INTRODUCTION:

Air pollutants are one of the most troubling environmental problems and have attracted the attention of many researchers and specialists in this field. The problem of air pollution has escalated to become a global challenge, and it is the subject of ongoing discussions not only in international forums but also within all institutions, even among citizens, due to its close connection to human health and environmental safety (1). Falling dust and fine particulate matter (**PM₁₀, PM_{2.5}**) are the most prominent airborne pollutants, and their increased levels are associated with an imbalance in natural ecosystems in general. Their effects on human health are reflected in an increase in respiratory and heart diseases, in addition to a decrease in plant productivity and vitality through their accumulation on the surfaces of leaves (2). Their increased concentrations depend on human industrial and commercial activities and certain climatic factors that have a direct or indirect role or influence on their concentrations through the deposition or spread of these pollutants (3).

Anbar Governorate was chosen as a model for this study, given its arid, semi-desert climate and increased seasonal dust storms, in addition to its diverse activities (industrial, commercial, and residential). This makes it a model for studying the spatial and temporal variations in pollutant concentrations, contributing to a knowledge based on between pollutant concentrations and climatic

factors. This knowledge base supports environmental efforts and future studies.

Region	Station number		Station Description	Station Coordinates
	Particle Material	Falling Dust		
Industrial	A9	S7	Haditha	Lat:34.135421/Lon:42.381956
	A5	S3	Inside the Haditha refinery, at its center	Lat:34.070566/Lon:42.362305
	A6		Outside the Haditha refinery, upwind	Lat:34.072053/Lon:42.364934
	A7		Outside the Haditha refinery, downwind	Lat:34.072666/Lon:42.361507
	A12	S10	Hit	Lat:33.637440/Lon:42.826355
	A1	S1	Inside the Kabisa Cement Factory at its center	Lat:33.593121/Lon:42.504870
	A2		Outside the Kabisa cement factory, upwind	Lat:33.590463/Lon:42.504938
	A3		Outside the Kabisa cement factory, downwind	Lat:33.590411/Lon:42.504878
	A15	S13	Ramadi	Lat:33.425898/Lon:43.300157
	A18	S16	Fallujah	Lat:33.350066/Lon:43.763918
Residential	A4	S2	Residential complex in Kabisa district	Lat:34.072004/Lon:42.363832
	A8	S4	Haditha Refinery Residential Complex K3	Lat:33.647004/Lon:42.833676
	A11	S5	Haditha	Lat:34.084433/Lon:42.357677
	A14	S8	Hit	Lat:33.647004/Lon:42.833676
	A17	S11	Ramadi	Lat:33.413045/Lon:43.306224
	A20	S14	Fallujah	Lat:33.413045/Lon:43.306224
Commercial	A10	S6	Haditha	Lat:34.088314/Lon:42.366482
	A13	S9	Hit	Lat:33.638348/Lon:42.810723
	A16	S12	Ramadi	Lat:33.427396/Lon:43.317828
	A19	S15	Fallujah	Lat:33.350658/Lon:43.796191
Control	A21		Alos village	Lat:34.019511/Lon:42.410330
*Control station (A21) was selected in a rural location far from pollution sources				

Therefore, current study aims to: -

1. Analyses the concentrations of fine particulate matter (PM_{2.5}, PM₁₀), and falling dust in different areas of Anbar Governorate.
2. Determine the relationship between these concentrations and certain climatic variables, which will contribute to providing recommendations for improving air quality in the region.

Working methods

• Study Site

The study was conducted in Anbar Governorate, located in western Iraq. It has a semi-desert (dry) climate, with prevailing winds ranging from north to northwest (4).

The governorate is characterized by its diverse industrial, commercial, and residential areas. Twenty-one monitoring stations were selected for fine particle pollutants, distributed among (**10 industrial, 6 residential, 4 commercial, and 1 control station**), and 16 stations for falling dust, distributed among (**6 industrial, 6 residential, and 4 commercial**) districts of Anbar Governorate, as shown in Table No. (1).

- **Industrial Regions**

Include factories, large facilities, and industrial neighborhoods, which are often scattered randomly across a number of streets. They are home to blacksmith and carpentry workshops, as well as car repair and painting garages, which emit large quantities of smoke, a source of local environmental pollutants (**5**)

- **Commercial Regions**

Areas containing bakeries, restaurants, and parking lots are characterized by their diverse commercial activities and heavy vehicle traffic, particularly small vehicles, both private and public, which emit pollutants (**6**).

- **Residential Region**

Residential areas with high population density have been selected for stations to monitor air pollutants.

- **Research Duration**

The study spanned four months, starting in November 2024 and ending in January, March, and April 2025.

After conducting a comprehensive field study of the governorate's areas and carefully selecting the locations of monitoring stations within the study scope, various devices and equipment were used to collect pollutant data through readings, including:

- **Measuring concentrations of fine particles of various sizes.** A Chinese-made air quality detector was used to measure PM2.5 and PM10 particles in units of (**micrograms per cubic meter**).

- **Measuring Climatic Factors**

Climatic conditions and factors at the stations used for the study were measured using devices manufactured by the Chinese company Oregon, including a thermo-hygrometer, a wind speed and direction measuring device (**Anemometer**), and a temperature measurement device using an electronic thermometer.

Table No. (1) Locations and coordinates of stations selected for measuring air pollutants

- **Measuring Falling Dust**

To determine the amount of falling dust at the study site, 16 stations were selected and designated by the letter S based on their location: commercial, industrial, and residential. Their distribution is shown in **Table (1)**. Open dishes or containers (**7**) were used to collect the dust. A hollow circular cylinder, 30 cm high and 15 cm in diameter, was taken, closed at the bottom, with a wooden stand to secure it vertically. It was placed on the roofs of buildings in exposed locations, approximately one meter above the ground, to reduce the possibility of readings being affected by dust or dirt accumulating on roofs due to wind.

After installing the cylinders in the specified locations for a month, they are taken to the laboratory for the purpose of measuring the amount of falling dust. The cylinder is washed several times by adding distilled water. The water containing the dust is added to a clean, dry glass beaker of known weight, which is empty (w_1). The water is evaporated using a (**Hot Plate**) device, then it is placed in the electric oven for half an hour at a temperature of (**105**) and weighed a second time (w_2), in order to obtain the final value of the amount of falling dust in the unit (**gr/m²/month**) by applying the following equation:-

$$\text{Amount of falling dust} = (w_1 - w_2) \times 56.58 \text{ gr/m}^2/\text{month}$$

The value of 56.58 = results from calculating the base area of the cylinder ($r^2 \times \pi$) and converting the unit from cm² to m².

- **Number of recorded readings**

To ensure accurate measurements, the suspended particles and climatic factors were measured simultaneously for all stations. Three readings were recorded per week, i.e. 12 readings per month for each pollutant at each monitoring station. The average of these readings was then taken to represent the average for that month. This applies to all 21 stations and to the study period.

Statistical Analysis

Statistical analysis was conducted using SPSS (8), using a set of tests including one-way ANOVA, Turkey's pairwise differences test, Pearson correlation test, and simple linear regression test.

RESULTS AND DISCUSSION

Discussing the results is an essential step to understanding the extent to which the obtained data align with the study's hypotheses and objectives. It is also important to analyze spatial and temporal changes in air pollutant concentrations, particularly fine particulate matter (**PM10 and PM2.5**), and interpret them based on the nature of the monitoring sites, surrounding human activities, and prevailing climatic factors. This will ensure an assessment of the environmental impact in the areas selected for the study. Therefore, the results will be analyzed for each pollutant separately and classified according to industrial, commercial, and residential areas. These results will be compared with the control station (A21) and with global and national environmental standards.

1. Fine particulate matter PM10

The study results in **Table (2)** showed temporal variation between PM10 concentrations and the study months. The highest concentration was recorded in January, at (200) micrograms/m³, at site A3, Kubisa Cement Plant, downwind. This was followed by March and November, with averages of (184, 168) micrograms/m³ for the same site (**A3, Kubisa Cement Plant, downwind**). Meanwhile, (A1, Kubisa Cement Plant, downwind) recorded an average of (158) micrograms/m³ for April.

The box plot in **Figure (1)** shows the variation between the study months, as the highest median value was recorded at a concentration of (116) micrograms/m³ in January, with a range of values ranging between (77-200) micrograms/m³, while the month of April recorded a median value of (88) micrograms/m³, with a narrow range between the value that ranged between (158-59) micrograms/m³, which confirms that the difference in climatic factors between the months was reflected in the variation in the levels of particle concentrations. The stability of the atmosphere in January, with weak wind movement, led to the lack of dispersion of particles (PM10), and thus an increase in their level in the atmosphere and recording the highest concentrations for them. This is consistent with (9), which concluded that there is an inverse correlation between wind speed and particle concentration. In contrast, the month of April recorded the lowest concentration.

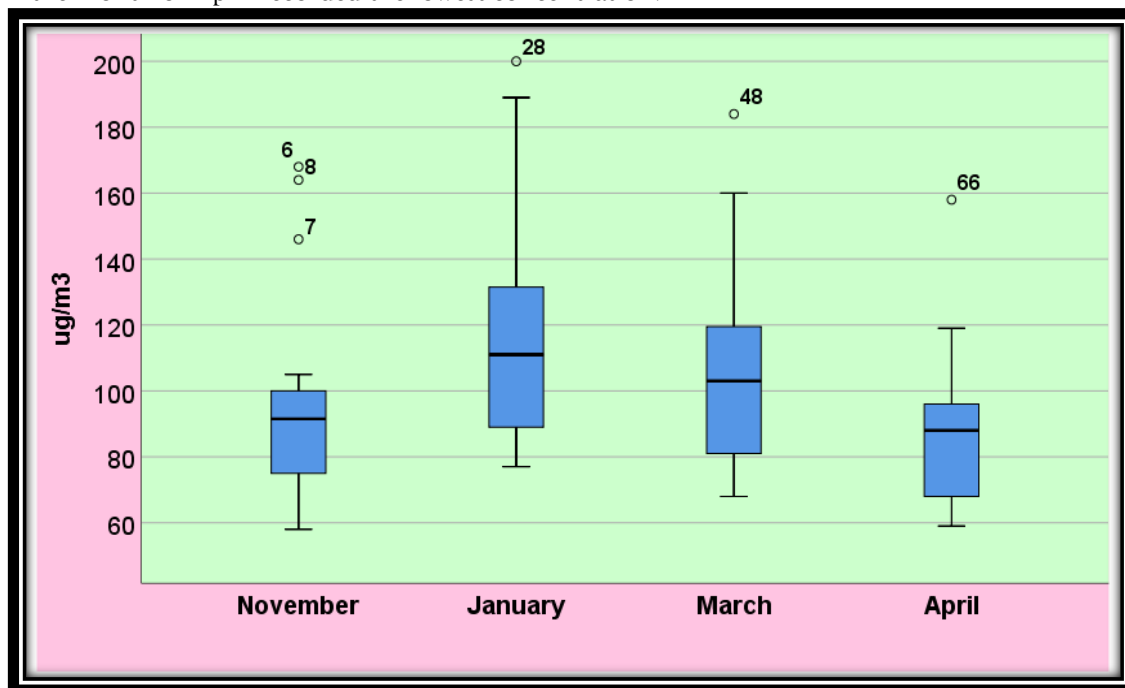


Figure (1) Analysis of differences in PM10 concentration according to the study months

Station No.	PM10 (µg/m³)					PM2.5 (µg/m³)					Falling Dust (µg/m²)				
Nov.	Jan.	Mar.	Apr.	Spatial Average	Nov.	Jan.	Mar.	Apr.	Spatial Average	Station number	Nov.	Jan.	Mar.	Apr.	
98	111	105	92	101.5	39	47	39	37	40.5	S7	23.48	18.48	34.44	30.44	
93	123	110	91	104.25	42	45	42	34	40.75	S3	23.01	24.01	37.33	29.33	
88	111	103	88	97.5	41	50	41	33	41.25	-	-	-	-	-	
96	134	121	94	111.25	40	48	44	35	41.75	-	-	-	-	-	
92	131	118	100	110.25	44	49	45	37	43.75	S10	31.01	23.01	24.31	30.31	
168	189	150	158	166.25	42	58	48	39	46.75	S1	699	516	766	834	
146	176	160	118	150	38	54	43	36	42.75	-	-	-	-	-	
164	200	184	139	171.75	47	57	51	43	49.5	-	-	-	-	-	
105	114	111	94	106	36	45	44	36	40.25	S13	21.5	26.5	32.83	37.83	
102	132	121	96	112.75	45	53	49	45	48	S16	26.33	18.33	48.86	34.86	
76	90	75	71	78	21	38	24	18	25.25	S2	23.24	15.24	24.25	28.25	
58	77	70	65	67.5	24	36	26	22	27	S4	19.61	31.61	25.69	32.69	
58	79	80	78	73.75	17	30	29	20	24	S5	17.03	23.03	17.28	20.28	
79	88	87	66	80	28	32	22	17	24.75	S8	16.88	13.88	22.5	27.5	
81	85	83	70	79.75	19	32	23	0	23.5	S11	24.73	11.73	22.6	22.6	
61	81	68	68	69.5	23	35	21	24	25.75	S14	19.24	11.24	21.13	25.13	
74	94	74	62	76	25	33	28	21	26.75	S6	22.06	10	18.35	9.35	
91	117	91	73	93	27	39	37	25	32	S9	17.39	19.39	20.39	17.39	
93	101	82	65	85.25	31	37	31	27	31.5	S12	13.19	11.19	16.22	14.22	
73	92	96	59	80	25	42	32	29	32	S15	20.88	7.88	11.37	22.37	
94	116	96	104	87	32	43	35	29	34.75	-	63.66	48.85	71.47	76.47	
51	69	104	53	55	16	23	19	17	18.75	-	-	-	-	-	
Environmental Determinant		50 µg/m³			25 µg/m³					-	-	-	-	-	
Environmental		45 µg/m³			15 µg/m³					-	-	-	-	-	
According to the Iraqi Ministry of Health and Environment (2018)									Red color indicates the Highest concentration						
Global standard according to the World Health Organization (2021)									Green color indicates the Lowest concentration						

Table (2) Concentration of suspended particles and falling dust in the selected areas during the months prepared for the study

or particulate matter (PM₁₀), increased wind speed contributed to the transport and dispersion of these particles away from their source and their non-accumulation near the ground surface (10). The results in **Table (3)** showed, through a one-way ANOVA test, the presence of clear statistically significant differences ($p = 0.021$) between the average PM₁₀ concentrations across the study months. To achieve more accurate results, pairwise comparisons between months were analyzed, and a probability value ($P < 0.05$) between the months of January and April indicated significant statistical differences between them. Meanwhile, a comparison between the months of November and January, November and March, and November and April, showed non-statistically significant values ($P > 0.05$), despite the presence of differences between the averages.

Table (3) Results of statistical analysis of the concentration of suspended particles PM₁₀ for the study areas and months

Monthly Concentration	Month	Mean	Comparison Between Two Months	Mean Difference	Std. Error	p-value
			Nov. _ Jan.	-21.450	9.829	.137
	November	94.80	Nov. _ Mar.	-10.095	9.958	.742
	January	116.25	Nov. _ Apr.	7.990	9.711	.844
	March	104.89	Jan. _ Mar.	11.355	9.958	.666
	April	86.81	Jan. _ Apr.	29.440*	9.711	.017
			Mar. _ Apr	18.085	9.841	.264
ANOVA $p = 0.021$, $F = 3.421$						
Region Concentration	Region	Mean	Comparison Between Two Regions	Mean Difference	Std. Error	p-value
	Residential	74.75	Ind. _ Com.	39.088*	6.116	.001
	Commercial	83.56	Ind. _ Res.	47.900*	7.007	.001
	Industrial	122.65	Com. _ Ind.	-8.813	7.646	.485
ANOVA $p = 0.001$, $F = 35.755$						

In contrast, **Table (2)** shows a spatial disparity between PM₁₀ concentrations across the study areas. Industrial areas recorded the highest concentration (200 micrograms/m³) at site A3 in the Kubisa Cement Plant, downwind of the site. Commercial areas followed, recording the highest concentration (117 micrograms/m³) at site A13 Hit, while residential areas at site A14 Hit recorded an average of 88 micrograms/m³. **Figure (2)** indicates a disparity between PM₁₀ concentrations. Industrial areas showed an increase in the median value and an increase in the number of values close to the upper limits resulting from the impact of industrial activities and emissions from factories or workshops with high concentrations of PM₁₀. These results are consistent with the study (11), while residential areas recorded the lowest levels due to the decrease in the median value and its proximity to the values and concentrations of the upper and lower limits resulting from the lack of industrial activities with the presence of a clear vegetation cover in them, which contributes to the process of particle deposition and recording a decrease in particle concentration (12).

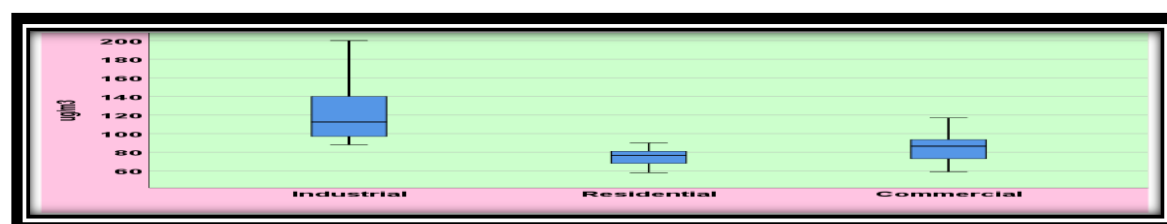


Figure (2) Analysis of differences in the concentration of suspended particulate matter PM10 according to the study areas

The results of the one-way analysis of variance (**Table (3)**) confirmed the presence of significant differences between the average concentrations of PM10 particles for the three regions, where its statistical significance was recorded ($P=0.001$), while pairwise comparisons between regions showed a probability ($P<0.05$) between (industrial-commercial, industrial-residential) with significant statistical differences, while between commercial-residential (the probability value between them was recorded ($P>0.05$)). There are no significant statistical differences between them - to confirm that industrial activities represent the most important source of raising the levels of PM10 particles (13).

Based on the results of the recorded PM10 concentration levels, it was noted in **Table (2)** that all study stations had spatial and temporal averages that exceeded the average of the control station (A21). While these stations showed variations when compared with global and national environmental standards, industrial, residential and commercial areas showed levels higher than the natural value of ($45 \text{ micrograms/m}^3$) set globally by (14), indicating increased air pollution as a result of various human activities (15). In contrast, when compared with the national limit (16) of $100 \text{ micrograms/m}^3$, it was found that all industrial stations exceeded this limit, while the commercial areas of stations (A13 Hit, A16 Ramadi) exceeded the permissible limits. The results showed that no station recorded levels exceeding the national limit in residential areas, indicating that the sources of pollution in these areas are limited. This is consistent with what was proposed by (17), that residential areas are often less exposed to direct pollutants compared to industrial and commercial areas.

2. PM2.5 particulate matter

The study results in **Table (2)** showed a temporal variation between PM2.5 particulate matter and the months of the study. In January, the highest average was recorded at ($58 \text{ micrograms/m}^3$) at station (A1, Kubisa Central Cement Plant), followed by (March, November) at ($51, 47 \text{ micrograms/m}^3$) at (A3, Kubisa Central Cement Plant), respectively. In April, the average concentration was ($45 \text{ micrograms/m}^3$) at site (A18, Fallujah Industrial District). **Figure (3)** shows a temporal variation in PM2.5 concentration. It was noted that the highest median value was recorded in January, with high concentrations of the upper and lower limits leading to the highest pollution levels. As a result of the decrease in temperatures and the lack of wind movement, this led to a recurring thermal inversion phenomenon, causing the pollutant to be trapped in the lower atmosphere (18). Meanwhile, a decrease in the median average was recorded in April, with a narrow dispersion of the upper and lower limits, indicating a decrease in pollution levels due to the gradual rise in temperatures with The increase in wind movement was reflected in a decrease in its concentrations, and this result is consistent with (19), which confirmed the existence of a negative correlation between the increase in wind speed and the concentration of PM2.5 particles.

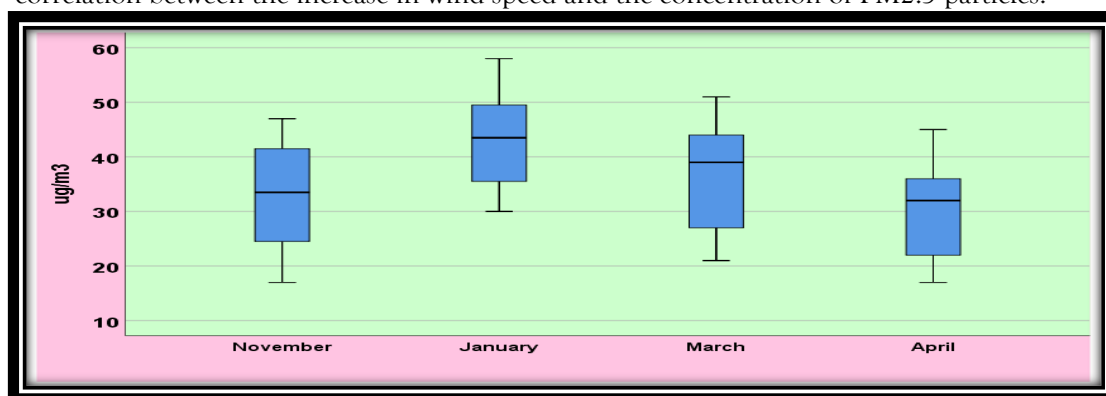


Figure (3) Analysis of differences in PM2.5 concentrations according to the study months

While the results of the analysis of the one-way analysis of variance test, **Table (4)**, confirmed the presence of significant statistical differences between the concentration of the pollutant PM2.5 and the months, as it recorded the probability value level ($P=0.001$), and the results of the pairwise comparisons test between the months of (January-April, November-January) showed the recording of a probability value ($P < 0.05$) indicating the presence of significant differences between those months and the high value of the difference for the month of January reflects the accompanying climate changes in this month (20), while

the other pairwise comparisons between the months did not record any value less than (0.05), which indicates the absence of significant differences.

Table (4) Results of statistical analysis of the concentration of suspended particles PM2.5 for the study areas and months

Monthly Concentration	Month	Mean	Comparison Between Two Months	Mean Difference	Std. Error	p-value
			Nov. _ Jan.	-10.300*	2.929	.004
	November	32.70	Nov. _ Mar.	-3.458	2.967	.650
	January	43.00	Nov. _ Apr.	2.700	2.894	.787
	March	36.16	Jan. _ Mar.	6.842	2.967	.106
	April	30.00	Jan. _ Apr.	13.000*	2.894	1.00
			Mar. _ Apr	6.158	2.932	.162
ANOVA p =0.001 , F = 7.478						
Concentration by region	Region	Mean	Comparison Between Two Regions	Mean Difference	Std. Error	p-value
	Residential	25.04	Ind. _ Com.	18.483*	1.572	.001
	Commercial	30.56	Ind. _ Res.	12.962*	1.801	.001
	Industrial	43.53	Com. _ Ind.	5.521*	1.965	.017
ANOVA p =0.001 , F=75.44						

In contrast, the results in **Table (2)** showed a spatial variation between the concentrations of suspended particles (PM2.5) and the study areas. The highest rates were recorded in industrial areas at (58) micrograms/m³ in (A3 Kubisa Cement Factory Center towards the wind), and in residential areas the highest rate was (38) micrograms/m³ at the site (A4 Kubisa Residential Complex), while in commercial areas (A19 Fallujah) it was recorded at a rate of (42) micrograms/m³.

Figure (4) shows that industrial areas recorded higher levels of PM2.5 concentration, with a median value. This increase is explained by the intensity of industrial activities that include fuel combustion and industrial dust production, especially in the Kubisa Cement Factory, which are known sources of the release of these particles into the air. These results reinforce the findings of (21), which indicate higher PM2.5 concentrations in industrial areas due to the nature of their emissions from heavy industry operations compared to other areas. In contrast, residential areas recorded lower median value concentrations, confirming that the environment of these areas is less exposed due to limited sources of emissions. This was confirmed by (22), which stated that urban areas experience lower levels due to their distance from direct industrial sources.



Figure (4) Analysis of differences in PM2.5 concentrations according to the study areas

While the results of the statistical analysis between the concentration of PM 2.5 and the study areas for the one-way analysis of variance test, **Table (4)**, showed the presence of significant differences with clear

statistical significance, as they were recorded at a value of $P = 0.001$. When conducting a binary comparison between the months (industrial-commercial, industrial-residential), their probability values showed a level of ($P < 0.05$), with statistical significance and clear significant differences, confirming that this variation between the areas is not random, but rather has a real significance.

The results showed that the concentrations of PM_{2.5} particulate matter recorded for all stations selected for the study exceeded the average of the control station (A21). While the concentrations of these stations exceeded the environmental standard of the World Health Organization, estimated at 15 micrograms/m³, and with regard to the national environmental standard, estimated at 25 micrograms/m³ by the Iraqi Ministry of Health and Environment, there was a difference between the stations, as all industrial stations recorded exceeding the permissible limit, while most commercial areas also showed exceeding this limit, except for (A10 Haditha), which recorded a concentration of (21 micrograms/m³) for the month of April, while the residential areas were the least clearly exceeding, as January recorded all exceeding the permissible national limit, and November recorded at the site (A14 Hit) and the month of March (A11 Haditha, A8 Refinery Residential Complex) concentrations of (28, 29, 26) micrograms/m³, respectively, while the rest of the stations did not exceed the permissible limit.

3. Falling Dust

When analyzing the temporal variation in **Table (3)** for the amount of falling dust during the study months, the months (November, January, March, and April) recorded the highest average concentrations (699, 516, 766, and 534.78) g/m²/month, respectively, in all months at the same station (A1, Kubisa Central Cement Plant).

Figure (5) shows a temporal representation of the amount of dust during the study months. The presence of some extreme values with high concentrations and dispersion far from their median values across the four months indicates that the average value is far from the average value.

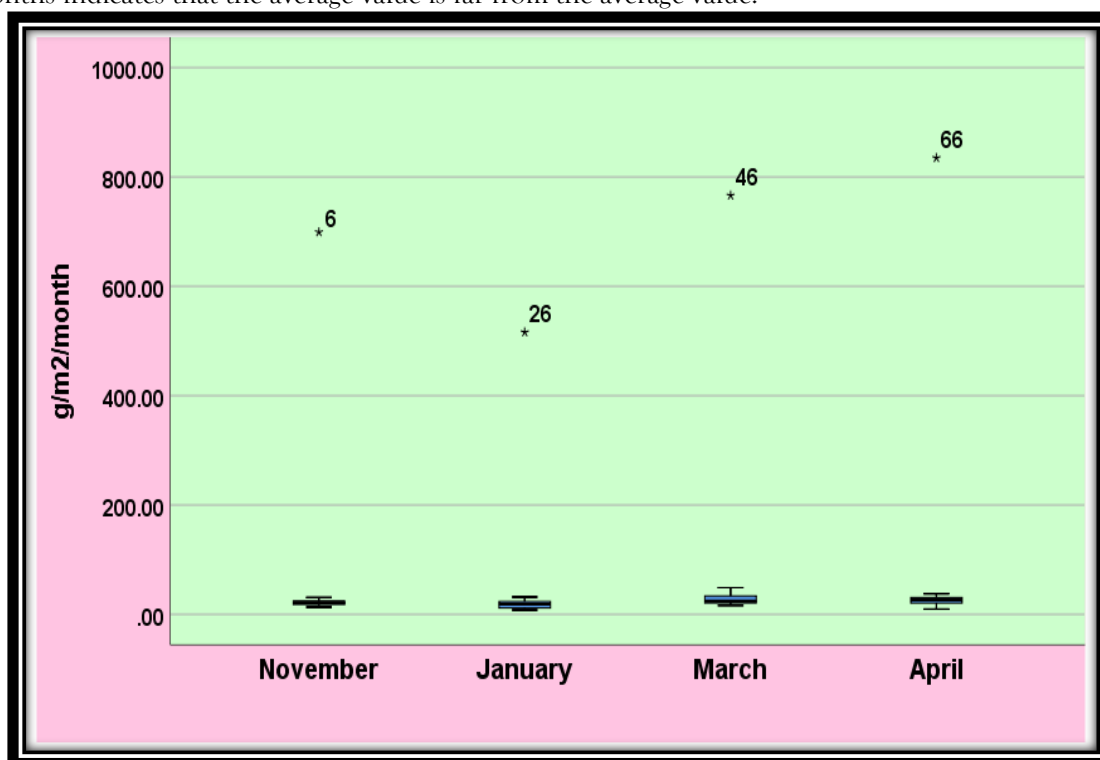


Figure (5) Analysis of the differences between falling dust according to the study months

Table (5) shows the results of the one-way analysis of variance test, which shows that the probability value in it is $P = 0.973$, which is higher than the level of the statistical value (0.05), which indicates that there are no significant differences between the months from a statistical point of view, and despite the difference in the months and the climatic factors in them, no temporal variation appeared.

Table (5) Results of statistical analysis of the concentration Falling Dust for the study areas and months

Monthly Concentration	Month	Mean	Comparison Between Two Months	Mean Difference	Std. Error	p-value
			Nov. _ Jan.	14.81625	61.15142	.995
	November	63.6613	Nov. _ Mar.	-11.81742	62.16225	.998
	January	48.8450	Nov. _ Apr.	-8.65816	60.24542	.999
	March	75.4787	Jan. _ Mar.	3.15925	61.27120	1.000
	April	72.3194	Jan. _ Apr.	-26.63367	62.16225	.973
			Mar. _ Apr	-23.47441	60.24542	.980
ANOVA p = 0.937 , F = 0.075						
Concentration by region	Region	Mean	Comparison Between Two Regions	Mean Difference	Std. Error	p-value
	Residential	21.5738	Ind. _ Com.	119.75375*	46.42753	.033
	Commercial	15.7550	Ind. _ Res.	125.57250*	51.90756	.048
	Industrial	141.3275	Com. _ Ind.	5.81875	51.90756	.993
ANOVA p =0.017 , F=34.327						

In contrast, **Table (5)** shows that the amount of dust falling in the study areas was concentrated at a very high rate in the industrial areas at site S1 (Kubisa Cement Factory), with a high spatial average of (703.94) g/m²/month. The highest concentration was recorded at site S4 (Refinery Residential Complex), with an average of (27.4) g/m²/month, while the highest spatial average was recorded in the commercial areas at site S9 Heet, with an average of (18.63) g/m²/month.

Figure (6) shows these differences, with four measurements in the industrial areas exceeding 500 g/m²/month, very far from their arithmetic median value, while the residential and commercial areas showed a very close distribution between their median and recorded values, with a clear absence of extreme values.

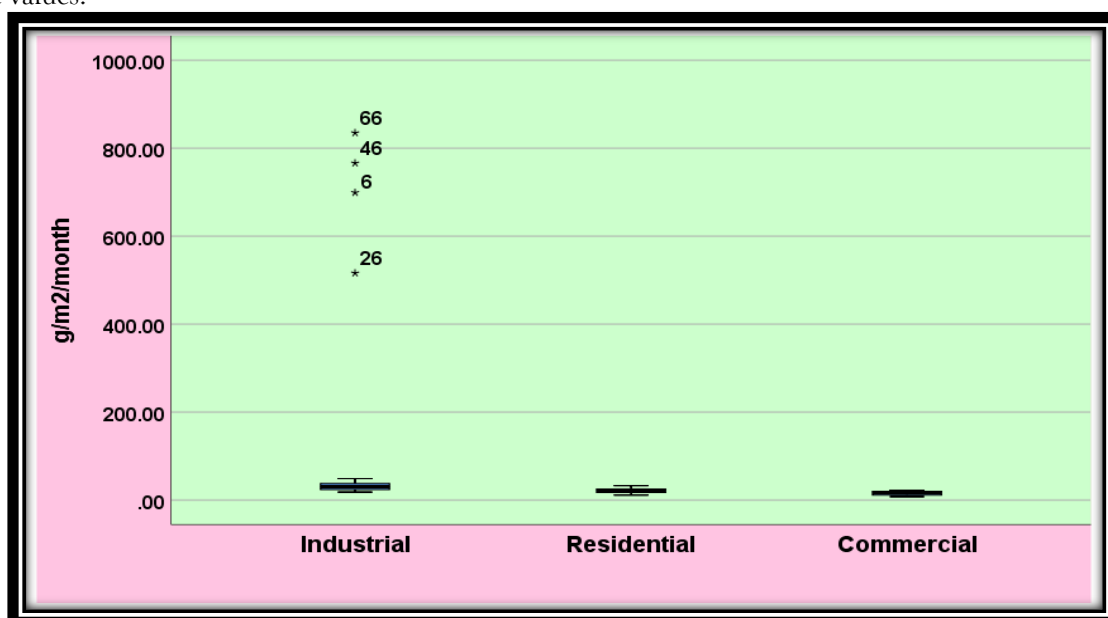


Figure (6) The variation between the distribution of falling dust and the study areas

While the results of the statistical tests in **Table (5)** confirmed the existence of statistically significant differences between the types of sites, where the value reached a probability of $P = 0.017$ for the one-way analysis of variance test, indicating that the site has a role in determining pollution levels. While the pairwise comparison between the regions (industrial-residential, industrial-commercial) showed a probability value of ($P < 0.05$), confirming the existence of significant statistical differences between those regions, while between (residential-commercial) showed a probability value higher than ($P > 0.05$), there

are no significant statistical differences. The high dust levels in cement plants are explained by the complex production processes that involve grinding and crushing the cement, mixing it with raw materials, and then burning it in special kilns. This releases large quantities of dust and dirt from fixed sources of various sizes into the air, leading to the production of the intermediate material called clinker (23). Dust pollution is not limited to the production stage alone, but extends to storage and transportation. It was observed that clinker, which consists of lightweight particles, is stored after production in open yards rather than in closed warehouses or storage areas. The slightest wind movement can cause the particles to be stirred up, carried in the air, and dropped elsewhere, causing an increase in the amount of dust in the atmosphere. This is consistent with the findings of a study by the European Environmental Protection Agency (24), which confirmed that clinker storage and transportation areas contribute to increased release of suspended particles.

4. The Effect of Climatic Factors on Particulate Matter and Dust Concentrations

Climatic factors (temperature, relative humidity, and wind speed) directly or indirectly affect the average concentrations of dust pollutants, depending on the type of area, either increasing or decreasing their concentrations. The results recorded in **Table (6)** show spatial variation in some climatic factors. Average temperatures ranged between 23-24.75°C, 23-24.25°C, and 23-24.5°C, while relative humidity ranged between 33-39.5%, 37-40.5%, and 38-40.5%. Wind speeds ranged between 2.52-3.33 m/s, 2.92-3.76 m/s, and 3.13-3.51 m/s in industrial, residential, and commercial areas, respectively.

In contrast, **Table (6)** noted a temporal variation in the study months. Average temperatures in November ranged between (21.6°C in November - 37.05°C in April), and relative humidity ranged between (26.5% in April - 49.45% in January), while wind speed ranged between (2.52 m/s in November - 3.94 m/s in

Region	Station No.	Temperature (°C)					Wind Speed (m/s)					Relative Humidity (%)	
		Nov.	Jan.	Mar.	Apr.	Spatial Average	Nov.	Jan.	Mar.	Apr.	Spatial Average	Nov.	Jan.
Industrial	A9	22	9	28	40	24.75	2.94	2.73	3.27	3.65	3.15	53	48
	A5	21	9	30	36	24	3.32	2.94	3.92	4.41	3.65	46	53
	A6	23	10	28	37	24.5	2.64	2.78	2.74	4.02	3.05	50	50
	A7	22	9	28	40	24.75	2.44	2.30	2.19	3.14	2.52	50	48
	A12	20	10	28	39	24.25	3.02	3.13	3.12	4.03	3.33	52	52
	A1	21	9	28	34	23	2.70	2.14	3.34	4.03	3.05	43	53
	A2	23	10	28	35	24	2.68	2.32	2.22	3.75	2.74	45	56
	A3	22	11	30	36	24.75	3.01	2.52	3.48	4.08	3.27	44	33
	A15	24	10	27	36	24.25	2.97	2.60	3.45	4.04	3.27	55	46
	A18	21	10	26	39	24	2.86	2.15	2.95	3.03	2.75	48	52
Residential	A4	21	11	26	39	24.25	3.04	2.62	3.53	3.94	3.28	43	49
	A8	20	11	25	38	23.5	3.61	2.73	4.49	4.21	3.76	44	45
	A11	23	10	27	37	24.25	2.42	2.61	3.20	3.75	3.00	42	63
	A14	22	10	27	38	24.25	2.74	2.16	3.11	3.66	2.92	41	49
	A17	20	10	26	37	23.25	3.08	2.43	3.45	3.98	3.24	43	51
	A20	20	12	25	35	23	3.48	2.74	3.53	4.13	3.47	44	47
Commercial	A10	25	10	27	36	24.5	2.85	2.67	3.61	4.25	3.35	55	48
	A13	20	9	28	35	23	3.44	2.53	3.32	4.11	3.35	50	49
	A16	22	9	26	37	23.5	2.75	2.09	3.53	4.16	3.13	45	50
	A19	20	12	26	37	23.75	3.22	2.23	4.21	4.39	3.51	47	47
Time Average		21.6	10.05	27.2	37.05	23.97	2.96	2.52	3.33	3.94	3.19	47.15	49.45
Control (A21)		20	9	22	33	20.75	2.18	2	2.1	2.8	2.27	39	31

April). **Table (6)** Average readings recorded for climatic factors for the selected sites during the study months.

It was noted in **Table (7)** of the results of the correlation coefficient analysis that there is a statistically significant relationship between some climatic factors and pollutant concentrations, as it showed an inverse relationship linking (wind speed, temperature) and particle concentrations (PM10, PM2.5), which confirms the role of winds in increasing the dispersion of these particles and preventing their accumulation. This is consistent with the study (25), as well as that the rise in temperatures leads to a reduction in the concentration of particles by increasing photochemical reactions, consistent with the results of (26). The relative humidity factor showed a direct relationship with (PM2.5) with statistical significance, indicating that the increase in humidity is accompanied by an increase in the concentration of the pollutant (27), while the concentration of (PM10) did not record statistical significance with the relative humidity. In contrast, the concentrations of falling dust did not record any statistical relationship with the climatic factors.

Table No. (7) Results of the correlation analysis test between pollutant concentration and climatic factors.

Correlations		PM10	PM2.5	Falling Dust	Temp.	Relative Humidity	Wind Speed
PM10	Pearson Correlation	1	.819**	.692**	-.288**	.115	-.393**
	Sig. (2-tailed)		.000	.000	.009	.309	.000
PM2.5	Pearson Correlation	.819**	1	.326**	-.409**	.223*	-.465**
	Sig. (2-tailed)	.000		.008	.000	.047	.000
Falling Dust	Pearson Correlation	.692**	.326**	1	.040	-.044	-.024
	Sig. (2-tailed)	.000	.008		.752	.730	.848
Temp.	Pearson Correlation	-.288**	-.409**	.040	1	-.826**	.770**
	Sig. (2-tailed)	.009	.000	.752		.000	.000
Relative Humidity	Pearson Correlation	.115	.223*	-.044	-.826**	1	-.638**
	Sig. (2-tailed)	.309	.047	.730	.000		.000
Wind Speed	Pearson Correlation	-.393**	-.465**	-.024	.770**	-.638**	1
	Sig. (2-tailed)	.000	.000	.848	.000	.000	
**. Correlation is significant at the 0.01 level (2-tailed).							
*. Correlation is significant at the 0.05 level (2-tailed).							

While the results in **Table (8)** showed that both wind speed and relative humidity had a statistically significant inverse effect on PM10 and PM2.5, indicating that PM2.5 is more sensitive to climate change. The results indicated that climatic factors did not affect falling dust, and no statistical significance was recorded, despite the dry, semi-desert environment of Anbar Governorate. This explains why fixed human activities, based on the source from which large quantities of dust are emitted (the cement factory), contributed to recording high dust concentrations, significantly impacting climatic factors. This is consistent with (28)

Table No. (8) Results of linear regression analysis between climatic factors and dust pollutants

Pollutant	R Square	Climate Factor	Non-Standardized B	Standardized Coefficients Beta	Relationship Type	Sig	Statistical Significance
PM10	0.211	Temperature	-.963	-.287	Negative	.194	Not Sig.

		Relative Humidity	-1.097	-.391	Negative	.034	Sig.
		Wind Speed	-21.024	-.422	Negative	.010	Sig.
PM _{2.5}	0.337	Temperature	-.455	-.426	Negative	.047	Sig.
		Relative Humidity	-.325	-.364	Negative	.040	Sig.
		Wind Speed	-5.853	-.369	Negative	.019	Sig.
Falling Dust	0.021	Temperature	2.373	.137	Positive	.645	Not Sig.
		Relative Humidity	-.908	-.061	Negative	.808	Not Sig.
		Wind Speed	-48.033	-.182	Negative	.423	Not Sig.

CONCLUSIONS:

1. The concentrations of particulate matter in the study sites exceeded the permissible environmental limits, particularly in industrial and commercial areas. This reflects the direct impact of human and industrial activities on air quality.
2. The study revealed a clear discrepancy between pollution levels and the study stations, with higher levels in industrial and commercial areas and lower levels in residential areas.
3. The influence of some climatic factors on the spread and accumulation of particulate matter. The study showed that winds contribute to the transport of pollutants from one area to another, while high humidity contributes to the accumulation and deposition of particulate matter. Meanwhile, moderate weather conditions lead to the accumulation of particulate matter in the air layers close to the Earth's surface.

REFERENCES & RECOURSES

1. Kumar, P., Singh, A. B., Arora, T., Singh, S., & Singh, R. (2023). Critical review on emerging health effects associated with the indoor air quality and its sustainable management. *Science of The Total Environment*, 872, 162163
2. Nawaz, S., Riaz, B., & Naseer, F. (2025). impact of air borne particulate matter on plants, climate, ecosystems, and human health: a comprehensive review. *the research of medical science review*, 3(1), 68-81.
3. Edo, G. I., Itoje-akpokiniowo, L. O., Obasohan, P., Ikpekor, V. O., Samuel, P. O., Jikah, A. N., ... & Agbo, J. J. (2024). Impact of environmental pollution from human activities on water, air quality and climate change. *Ecological Frontiers*.
4. Awadh, S. M. (2024). Drought and Desertification Hazard in Iraq. In *Environmental Hazards in the Arabian Gulf Region* (pp. 377-395). Springer, Cham.
5. Nwabueze, I., & Chinero, N. A. (2023). Welding Activities and their Associated Impacts in an Urban Area: Necessity for Environmental Standards and Regulation. *Journal of Geography, Meteorology and Environment*, 6(1), 1-9.
6. Ajayi, S. A., Adams, C. A., Dumedah, G., Adebajji, A. O., & Ackaah, W. (2023). The impact of traffic mobility measures on vehicle emissions for heterogeneous traffic in Lagos City. *Scientific African*, 21, e01822.
7. ASTM International. (2010). ASTM D1739-98(2010): Standard test method for collection and measurement of dustfall (settleable particulate matter).
8. IBM Corp. (2017). IBM SPSS Statistics of windows , version 25.0. IBM Corp
9. Kara, Y., Şevik, S. E. Y., & Toros, H. (2024). Comprehensive analysis of air pollution and the influence of meteorological factors: a case study of adiyaman province. *Environmental Monitoring and Assessment*, 196(6), 525.
10. Ebrahimikhushfi, Z., & Dargahian, F. (2022). Investigation of the Climatic parameters Effect on the Concentration Change of Particles Matter less than 10 μm and its Relation to Wind Erosion Occurrence in Arid Regions. *Journal of Arid Regions Geographic Studies*, 9(34), 76-92.
11. Ibrahim, M. H., Isa, N. K. M., Hashim, M. H., Ismail, K., Ariffin, K., Shafii, H., ... & Omar, M. H. C. (2021). Investigation of Particulate Matter (PM₁₀) Pollution in Ipoh City, Malaysia. *International Journal of Integrated Engineering*, 13(5), 232-238.
12. Zhai, H., Yao, J., Wang, G., & Tang, X. (2022). Study of the effect of vegetation on reducing atmospheric pollution particles. *Remote Sensing*, 14(5), 1255.
13. Millán-Martínez, M., Sánchez-Rodas, D., de la Campa, A. S., Alastuey, A., Querol, X., & de la Rosa, J. D. (2021). Source contribution and origin of PM₁₀ and arsenic in a complex industrial region (Huelva, SW Spain). *Environmental Pollution*, 274, 116268.
14. World Health Organization. (2021). WHO global air quality guidelines: Particulate matter (PM_{2.5} and PM₁₀), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide – Executive summary. Geneva: World Health Organization

15. Subhanullah, M., Hassan, N., Rahman, G., Rawan, B., Ullah, W., & Ilyas, M. (2025). Concentration of particulate matter and its impact on public health in different cities in Pakistan-a review. *Environmental Forensics*, 26(2), 146-162.
16. Ministry of Health and Environment. (2018). National ambient air quality standards: Regulation No. 2 of 2018. Republic of Iraq
17. Bikis, A. (2023). Urban air pollution and greenness in relation to public health. *Journal of environmental and public health*, 2023(1), 8516622.
18. Zender-Świercz, E., Galiszewska, B., Telejko, M., & Starzomska, M. (2024). The effect of temperature and humidity of air on the concentration of particulate matter-PM2. 5 and PM10. *Atmospheric Research*, 312, 107733.
19. Liu, Z., Shen, L., Yan, C., Du, J., Li, Y., & Zhao, H. (2020). Analysis of the Influence of Precipitation and Wind on PM2. 5 and PM10 in the Atmosphere. *Advances in Meteorology*, 2020(1), 5039613.
20. Dahari, N., Muda, K., Latif, M. T., Dominick, D., Hussein, N., & Khan, M. F. (2022). Seasonal variations of particle number concentration and its relationship with PM2. 5 mass concentration in industrial-residential airshed. *Environmental Geochemistry and Health*, 44(10), 3377-3393.
21. Wang, Z., Xu, H., Gu, Y., Feng, R., Zhang, N., Wang, Q., ... & Cao, J. (2022). Chemical characterization of PM2. 5 in heavy polluted industrial zones in the Guanzhong Plain, northwest China: Determination of fingerprint source profiles. *Science of the Total Environment*, 840, 156729
22. Zahra, S. I., Iqbal, M. J., Ashraf, S., Aslam, A., Ibrahim, M., Yamin, M., & Vithanage, M. (2022). Comparison of ambient air quality among industrial and residential areas of a typical south Asian city. *Atmosphere*, 13(8), 1168.
23. Gupta, R. K., Majumdar, D., Trivedi, J. V., & Bhanarkar, A. D. (2012). Particulate matter and elemental emissions from a cement kiln. *Fuel processing technology*, 104, 343-351.
24. United States Environmental Protection Agency. (2013). Portland cement NESHAP: Compliance alternatives for open clinker storage piles (EPA Publication No. EPA-456/F-13-003).
<https://www3.epa.gov/airtoxics/cement/OpenClinkerStoragePile.pdf>
25. Sinoya, A. S. (2021). Mining Activities, Cement Production Process And Quality Control. *Cell*, 265(8827), 999929934.
26. Li, J., Wang, W., Liang, Y., Ye, Z., Yin, S., & Ding, T. (2024). Research on characteristics and influencing factors of road dust emission in a southern city in China. *Environmental Monitoring and Assessment*, 196(10), 890.
27. Jiang, Y., Liu, C., Wen, C., & Long, Y. (2024). Study of summer microclimate and PM2.5 concentration in campus plant communities. *Scientific Reports*, 14(1), 3311.
28. Eivazzadeh, M., Yadeghari, A., & Gholampour, A. (2019). Temporal and spatial variations of deposition and elemental composition of dust fall and its source identification around Tabriz, Iran. *Journal of Environmental Health Science and Engineering*, 17, 2940.