



Effect of Morpho-Climatic Parameters Interaction on Particle Concentration within a Canyon Street in Algiers

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Summary

Background: Algiers, like most cities in the world, suffers from the problem of ambient air pollution. Road traffic is the main source of atmospheric pollutants and fine particulate matter (PM) in urban street canyons, endangering the health of pedestrians. This phenomenon also depends on factors relating to site-specific conditions and morpho-climatic variables.

Objective and methods: Our study aims to assess the correlation between the concentration PM and morpho-climatic parameters in two streets, located in the 19th-20th century urban fabric specific to the city, using in-situ measurements during the summer season and statistical methods.

Results: The findings showed that canyon geometry and trees were the main factors affecting PM concentration in urban street canyons, compared to temperature, which acted as a secondary parameter.

Conclusion: This study could serve as a guide for future urban planning by taking into account the morphological, microclimatic and roughness parameters of urban canyons when designing future urban projects in order to improve local air quality and protect human health.

Keywords: PM concentration, morpho-climatic parameters, urban canyons, statistical methods, Algiers.

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Влияние взаимодействия морфоклиматических параметров на концентрацию взвешенных частиц в городских каньонах Алжира

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Резюме

Введение. Как и большинство городов мира, Алжир страдает от проблемы загрязнения атмосферного воздуха. Дорожное движение является основным источником загрязняющих веществ и тонких взвешенных частиц в каньонах городских улиц, подвергаящим опасности здоровье пешеходов. Этот феномен также зависит от факторов, связанных с условиями конкретного участка и морфоклиматическими переменными.

Цель и методы: Наше исследование направлено на оценку корреляции между концентрацией взвешенных частиц и морфоклиматическими параметрами на двух улицах, расположенных в характерной городской застройке XIX–XX веков, с использованием результатов фактических измерений в летнее время и статистических методов.

Результаты. Результаты показали, что геометрия городских каньонов и деревья являются основными факторами влияния на концентрацию взвешенных частиц на таких улицах, а не температура, которая выступала в качестве вторичного параметра.

Заключение. Полученные результаты могут способствовать будущему эффективному городскому планированию, демонстрируя важность учета неровностей, морфологических и микроклиматических параметров при проектировании с целью улучшения качества воздуха и охраны здоровья жителей.

Ключевые слова: концентрация взвешенных частиц, морфоклиматические параметры, городские каньоны, статистические методы, Алжир.

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Introduction

Most cities in the world, particularly capital cities, are facing pollution problems due to rapid industrialization, urbanization, and transport. Road traffic contributes considerably to the deterioration of air quality in dense urban areas through the emission of various types of pollutants, such as PM and gaseous

pollutants. It is widely accepted that pollution has adverse effects on human health and on the natural and urban environment. [1]

Urban air quality deterioration is a significant concern on the scale of the urban canyons characteristic of large and dense cities. This type of urban space comprises buildings on either side located continuously

along the street. [2] To date, the increase in pollutant concentrations in urban canyons has received much attention. [3, 4] This is due to the main factors related to urban canyons, such as canyon geometry, meteorological conditions, vegetation, etc. [5] The geometry of Canyon Street is determined by the buildings' height (H), width (W), and the street length (L). Two key ratios define the configuration of the street canyon, namely the aspect ratio (H/W) and the lateral aspect ratio (LAR) (L/W). [6, 7] The aspect ratio (H/W) has been the subject of numerous studies in terms of its significant effect on the concentration of pollutants. [5, 7] As such, Han and Lee [4] and da Silva et al [8] have found that a deep canyon with a higher aspect ratio has a high concentration of pollutants, whereas a wider street is characterized by a low accumulation of pollutants at the pedestrian level. Similarly, the lateral aspect ratio (LAR) has drawn the attention of researchers. [6, 7, 9] Based on this ratio, urban canyons have been classified by Hunter et al [10] where a street with $LAR < 3$ is short, $LAR = 5$ is medium, and $LAR > 7$ is long. This has a considerable effect on the occurrence of different flow regimes [11] and therefore has a significant impact on the variation of pollution levels in urban streets. [7] It is recommended to use a threshold value for the lateral aspect ratio ($LAR = 3$) and not to exceed it to optimize ventilation and consequently pollution dispersion and dilution within the urban canyon. [6, 12]

On the relationship between urban vegetation and air pollution, we know that vegetation in the urban environment, particularly on Canyon Street, is adopted by urban planners to purify the air and preserve human health. [13] Recent research has exploited the aspect of vegetation as much as a passive method to adjust the configuration of canyons according to the airflow to better distribute pollutants inside canyons and even outside cities. [14] In this respect, tree stand density, tree crown morphology, leaf area density, and plant positioning and arrangement have been identified as characteristic factors governing the distribution and accumulation of pollutants within urban canyons. [15]

On the other hand, air pollutant concentrations, as a function of time and space, are strongly subject to meteorological conditions. This was more evident in the study by He et al [16] showing that more than 70 % of the daily variation in the average concentration of pollutants corresponded to microclimatic parameters, and the study by Voordeckers et al [7] demonstrating that air temperature, relative humidity, wind velocity and direction were the key factors that significantly stimulated this phenomenon, particularly on a local scale. When it comes to the temperature parameter, studies have shown that an increase in temperature corresponds to an increase in the concentration of pollutants in the atmosphere. [17] Moreover, the effect of temperature on PM concentration is greater in summer than in other seasons, [18, 19] meaning that higher temperatures lead to increased concentrations of fine particles in the urban canyon street through increases in traffic-related emissions and the formation and accumulation of secondary aerosols linked to photochemical reactions. [19]

It is important to study the relationship between pollutant concentration and climate conditions in different climatic contexts to better identify and understand this relationship. Several studies have been carried out in different climatic contexts, for example, a tropical wet and dry climate, [20] a semi-arid climate, [21] an arid climate, [22] a subtropical climate, [23] and a Mediterranean climate. [24] Our work addresses pollution in the context of Mediterranean cities to enrich the debate on this relationship between climates by focusing on temperature. Algiers, the capital city of Algeria, like other cities in the world, has suffered from the problem of urban pollution because of the significant economic, demographic, and urban development that it has experienced in recent decades. The high presence of fine particles in the urban environment of the city, caused mainly by the intense growth of the car fleet, constitutes a threat to the natural and urban environment as well as to human health, especially as PM_{10} and $PM_{2.5}$ levels are extreme and exceed international and WHO standards. [25]

Air pollutant concentration in the city of Algiers has been widely studied on a large scale, [25] while it has not been implemented at the local level in particular "Canyon Street" until now. The **aim of our study** is to explain and evaluate the variation of the concentration levels of fine particles within two distinctive morphologies of urban canyons located in a particular urban fabric of the 19th–20th centuries built under French rule, which dominates the city of Algiers. Our work focuses on exploring the following parameters: aspect ratio (H/W), lateral aspect ratio (L/H), vegetation, and temperature. To achieve this objective, in situ measurements are taken, followed by statistical analysis using IBM SPSS software, including pair-wise Pearson correlation coefficient R , principal component analysis (PCA), and multiple linear regression. The purpose of these statistical analyses is to evaluate the nature of the correlation models between morpho-climatic variables and the concentration of fine particles within the selected canyons in the city's hypercenter, as well as to verify their validity. Our study results could enrich the body of knowledge in not only Algiers but also worldwide, particularly focusing on air quality at the local urban scale. Additionally, they could contribute to constituting a reference guide for town planners, offering guidance during the design and planning phases of major sustainable urban development projects aiming to improve air quality within cities.

Materials and Methods

Study area

Algiers, the capital city, is located in the north of the country, covering the area of about 120 km². The hyper-center zone is positioned on the Algiers plateau, where the relief is flat and heterogeneous, with an altitude between 100 and 200 m. [26] The population is growing rapidly and is expected to reach 3,977,000 million in 2025. [27] According to the Köppen climate classification, the city has a Mediterranean climate, with mild, wet winters and hot, dry summers. In winter, daily minimum and maximum temperatures

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vary between 16 °C and 19 °C, while in summer, the minimum daily temperature reaches 31 °C during June and September, and the maximum daily temperature reaches 35 °C during July and August. [28]

The streets selected for this study are located in the lower part of the city center, more precisely in the 19th–20th century fabric dating from the French rule. Figure 1 shows the study area and the selected urban canyons: FRERES BELAGOUNE and LARBI BEN M’HIDI Streets. The selection of canyons depends on the diversity of morphological features that characterize the colonial fabric of the 19th and 20th centuries, giving canyons a specific geometric shape and urban microclimate. These characteristics, when combined, have an effect on concentrations of fine particulate matter in the ambient air. Table 1 shows the morphological and other factors specific to each street canyon covered by this study

Measurements and data acquisition

To measure temperature and air quality indices, the study included 36 samples taken at human height i.e., 1.5 meters above ground level for the two canyons selected. Each canyon contains two measurement points at the extremities and one in the middle to have different positions and to take into account the wind flow within the canyons (see Figure 1). Measurements were carried out simultaneously using a mobile device called a fine particle analyzer fitted with the

GP2Y1010AU0F sensor, which is used to measure PM concentrations and temperature, [29] and a STANLEY laser rangefinder was used to measure vertical and horizontal distances to calculate the ratios H/W and L/H. The campaign of measurement lasted three months, from July to September 2022, and covered almost the entire summer season, i.e., two days of each month were chosen, one working day and one public holiday, in a period corresponding to the peak hour from 12:00 to 13:30.

Statistical methods

In this work, we performed Pearson correlation analysis to examine the correlations between the dependent and independent variables, [30] and multiple linear regression analysis to validate the significance of the analysis model. Additionally, we conducted principal component analysis (PCA) to target the parameters most involved in the variation of PM concentrations, adopting a two-dimensional, principal and secondary correlation circle with their percentages of variance as the graphical design of the variables. [7] The pairwise Pearson correlation analysis and the multiple linear regression tests were carried out using IBM SPSS version 21 statistical software. On the other hand, PCA was performed using the open-source software R and R Studio for Windows version 4.3.2 with packages such as missMDA, FactoMineR, and factoextra. [31]

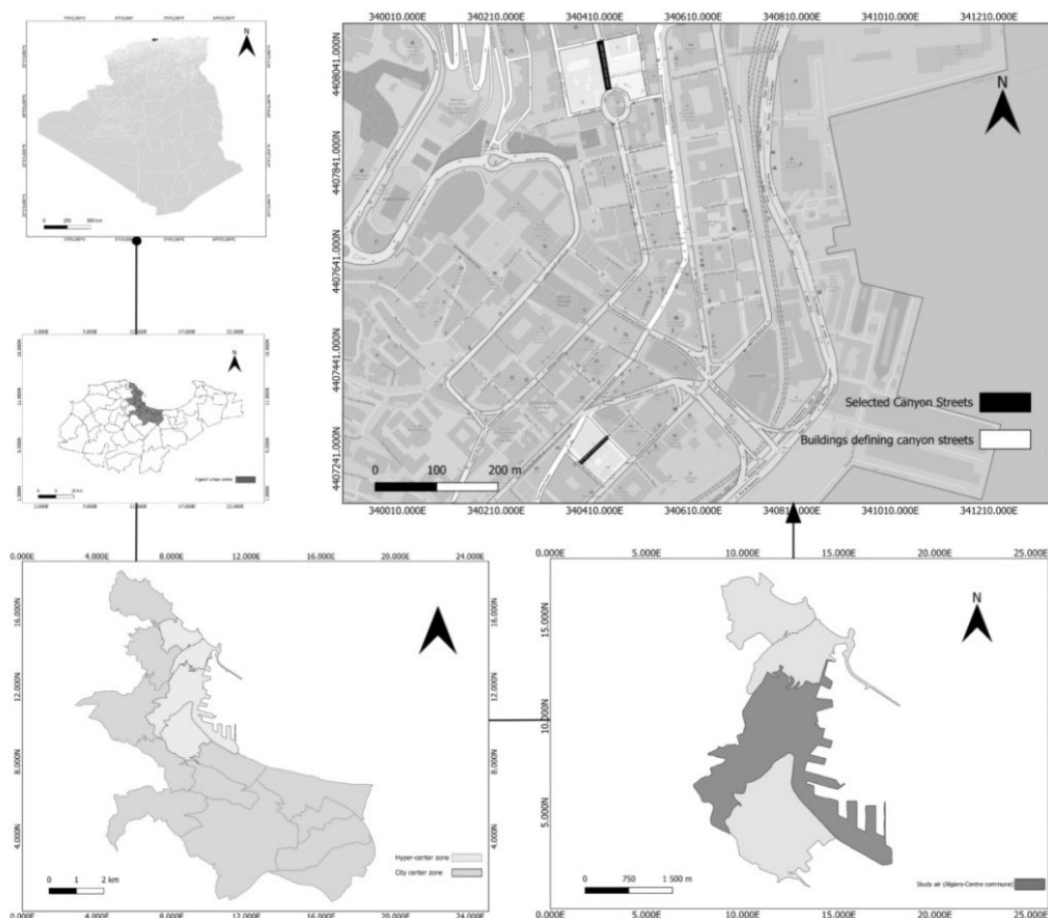


Fig. 1. Location of the selected canyons in the Algiers city’s hyper-center
Рис. 1. Расположение выбранных каньонов в гиперцентре города Алжира

Table 1. Characteristics of FRERES BELLAGOUNE and LARBI BEN M'HIDI canyon streets
Таблица 1. Описание каньонов городских улиц FRERES BELLAGOUNE и LARBI BEN M'HIDI



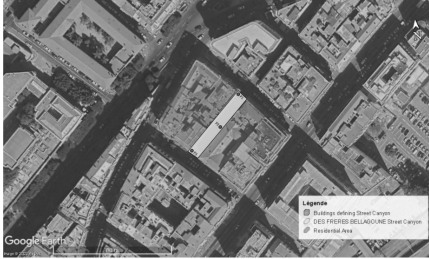

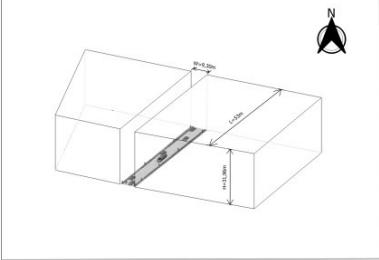
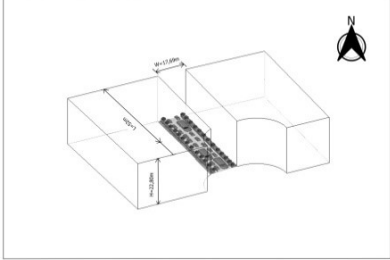
SELECTED CANYON STREETS CHARACTERISTICS / Описание выбранных улиц		
	FRERES BELLAGOUNE Street	LARBI BEN M'HIDI Street
Selected canyon streets / Выбранные улицы-каньоны		
		
Streets geometry / Геометрия улиц		
H/W / В/Ш	3,43	1,28
L/H / Д/В	Short Canyon / Короткий каньон 1,66	Short Canyon / Короткий каньон 2,93
Tree planting / Наличие деревьев	Zero trees / Отсутствуют	Trees on both sides of the canyon / Деревья по обеим сторонам каньона
Road traffic / Интенсивность дорожного движения	Low flow traffic / Низкая	High flow traffic / Высокая

Table 2. Pairwise Pearson correlation coefficients (r) between pairs of temperature (°C), aspect ratio (AR), lateral aspect ratio (LAR), vegetation surface area, and particle concentrations (µg/m³); *p < 0.05; **p < 0.01
Таблица 2. Парные коэффициенты корреляции Пирсона (r) между переменными температуры (°C), соотношения сторон (CC) и латерального соотношения сторон (ЛСС) улиц, площади поверхности растительности и концентраций частиц (мкг/м³); *p < 0,05; **p < 0,01

	Particle concentrations, µg/m³ / Концентрации частиц, мкг/м³	Temperature / Температура, С°	AR / CC	LAR / ЛСС	Number of trees per linear meter (T/m) / Число деревьев на линейный метр
Particle concentrations, µg/m³ / Концентрации частиц, мкг/м³	1				
Temperature / Температура, С°	0,296*	1			
AR / CC	-0,422**	-0,400**	1		
LAR / ЛСС	0,422**	0,400**	-1,000**	1	
Number of trees per linear meter (T/m) / Число деревьев на линейный метр (д/м)	0,422**	0,400**	-1,000**	1,000**	1

Results

Pairwise Pearson correlations and multiple linear regressions

Table 2 shows the Pearson correlation coefficients for each pair of parameters used in the study. There

are notable significant correlations between the pairs of parameters at the threshold of p-value < 0.05 (the probability obtained is 5 %) and p < 0.01 (the probability obtained is 1 %). The lateral aspect ratio (LAR) and the number of trees per linear meter (T/m) showed

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significant positive correlations with PM concentrations at a significance level of 0.01 with Pearson's coefficient value of 0.422. In contrast, a correlation between the H/W aspect ratio and fine particle concentrations was found to be a significant negative correlation ($r = -0.422$) at $p < 0.01$. We also found a weakly significant positive correlation with Pearson's correlation coefficient value of 0.296 at $p < 0.05$ between air temperature and the concentration of fine particles.

Following the results of the Pearson correlation coefficients between the variables studied, the multiple linear regression analysis showed that no multicollinearity effect was observed between the independent variables, as the values of the two determining indicators fall within the norms, including variance inflation factor ($VIF = 1.90$) < 10 and tolerances ($T = 0.840$) > 0.1 . Furthermore, the quality of the multiple linear regression models was determined by analyzing the R^2 values, the adjusted R^2 , and the Fisher F -test. As a result, the value of ($R^2 = 0.197$) lies between 0 and 1, which means that the explanatory variables contribute 19.7 % to the variance of the variable to be explained (PM). The F change is equal to 4.060, and the significance of the F change is equal to 0.027, which means that it is significant, and this was also confirmed by ANOVA. We can therefore say that the significance level is good ($0.027 < 0.05$), which means that the regression equation is good and allows us to say that the four explanatory variables contribute significantly to the scores of the PM variable. In addition, the relationship between the explanatory variables and the variable to be explained was determined by analyzing the standardized beta regression coefficient, the Student's t -test, and the significance test. The results of these coefficients indicate that the variable "number of trees per linear meter" is the one that contributes most to the variance of the PM compared with other variables, where the standardized beta regression coefficient is equal to 0.362, the Student's t -value is equal to 2.126, and the significance test ($\text{sig} = 0.041$). Moreover, the validity of the model was assessed by examining the residuals, in particular, the Durbin-Watson test and the graphs. The Durbin-Watson test is used to assess the correlation between residuals and errors with a value between 0 and 4. In our case, the Durbin-Watson test indicates a value of 2.432, which means that this value is close to 2, i.e., within the recommended norm. We can, therefore, say that the residuals are uncorrelated and that the regression model is valid. This is confirmed by the Gaussian P-P diagram of the standardized residual regression, showing the presence of slight deviations in the distribution of points around the straight line, which also confirms the validity of their distribution.

Principal component analysis (PCA)

The PCA results are based on two components: the principal component Dim 1 (the horizontal axis) and the secondary component Dim 2 (the vertical axis). These two first components explain about 85.95 % of the total variations. At the level of the component (Dim 1), we note that the loadings of variables such as lateral aspect ratio (LAR), number of trees per linear

meter (T/m), and aspect ratio (AR) are in robust contact with the circle of correlations, where the loading of the variables is significant and close to 1 and -1, which means that there are significant positive and negative correlations. Additionally, this indicates that these loadings contribute strongly to the formation of the principal component. While the loadings of PM and T variables show a distant connection to the correlation circle with loadings of less than 1, this means that they are clearly involved in the creation of the secondary component (Dim 2).

Air temperature (T) and fine particles (PM) form a very small angle, meaning that they are positively correlated, in the same way LAR and T/m are positively correlated. The vectors for the aspect ratio and fine particles diverge and form a significant angle, close to 180° , indicating that they are negatively correlated. We can, therefore, conclude that the variables that make up the main component (Dim 1) are more closely correlated or have a greater degree of variance (69.34 %) than the variables that make up the secondary component (Dim 2) (16.61 %). All this is consistent with what is shown in Table 2, at $p < 0.01$ (for Dim 1) and $p < 0.05$ (for Dim 2). Consequently, the morphological characteristics of urban canyons have a stronger influence on PM concentration than microclimatic characteristics. The results of the PCA analysis are shown in Figure 2.

Discussion

Impact of canyon geometry parameters on PM

Among the geometric parameters that determine the shape of the urban canyon are AR and LAR, which play a very important role in the concentration of fine particles. Regarding the relationship between AR and PM, Pearson correlation analysis and multiple linear regression analysis showed largely significant negative correlations with a Pearson correlation coefficient value ($r = -0.422$) (see Table 2). This result is consistent with a few published studies, [3, 32] which explained that the concentration of fine particles decreases with increasing AR, i.e., a deep street is less polluted than a wide street. On the other hand, the above result is not consistent with another study by Voordeckers et al [7] showing a highly significant positive correlation between AR and NO_2 pollution. They explained this by the variation in atmospheric pollutant concentrations, which are mainly influenced by meteorological conditions and by photochemical mechanisms that are also determined by real atmospheric situations. [7] Furthermore, the principal component analysis (PCA) showed a negative load for AR close to 1 for the first component (Dim 1) (see Figure 2), which is consistent with the PCA variable graph presented in the study by Miao et al. [3]

Since the correlation is negative, this means that there are two possibilities to explain this relationship. On the one hand, when the AR increases, which means that we have a narrow and deep canyon street, the concentrations decrease, such is the case of FRERES BELLAGOUNE Street. In this type of canyon, the flow paths carrying pollution rise along the street due to the formation of vertical vortices,

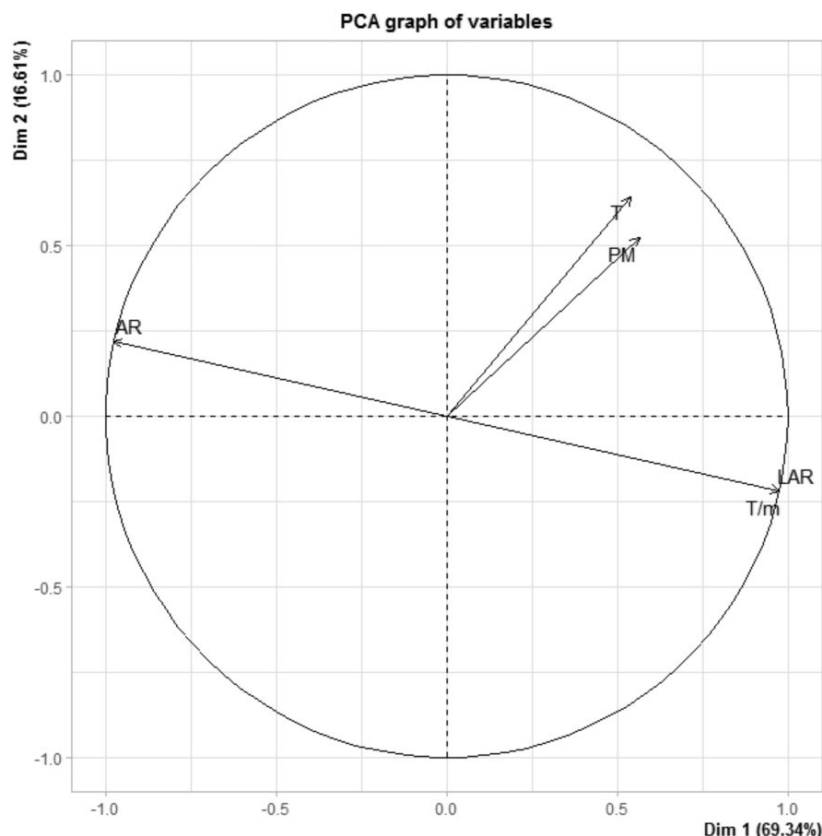


Fig. 2. Correlation circle between all variables

Рис. 2. Матрица корреляций между всеми переменными

resulting in a low concentration of pollutants at the pedestrian level. Several studies have noted that a deep, narrow street has lower concentrations of fine particles than a medium or wide street. [6, 32] On the other hand, when the AR decreases, i.e., we have a wide canyon street, the PM concentrations increase, which is consistent with the case study of LARBI BEN M'HIDI Street. According to Miao et al, [3] this can be attributed to the high volume of road traffic generated by this type of street, leading to large quantities of pollutant emissions. These emissions contribute significantly to the increased concentration of fine particles in the breathing zone of pedestrians. The findings are corroborated by the cases examined in this study, where the street with the lowest AR receives the heaviest traffic and therefore has a higher concentration of pollutants. Other parameters not examined in our study, notably wind speed and direction, are very likely to have an impact on the variation in measured PM values. [33]

Concerning the lateral aspect ratio (LAR), our study showed a significant positive correlation between PM concentration and LAR with a Pearson correlation coefficient value of ($r = 0.422$) (see Table 2). This result contradicts the findings of Voordeckers et al [7] showing no significant correlation between pollutant concentration and LAR. Using pollutant dispersion simulations in their study, the authors argued that simplified modeling of urban environments through CFD simulation software does not provide reliable results for understanding this relationship. However, the study by Michioka et al [9] is consistent with our result, as

it shows a positive relationship between the LAR and PM concentration, meaning that the longer the street, the greater the concentration of pollutants, and vice versa. In this sense, the authors explained that as the LAR decreases, the concentration of pollutants decreases due to increased lateral diffusion. Also, as the LAR increases, the concentration of pollutants becomes greater in the canyon street due to the increased flow of confined air in the canyon street, which means less dispersion of pollutants, leading to their significant accumulation. Moreover, this positive correlation has also been demonstrated by Oke, [11] who found that the different flow regimes in the street canyon are closely related to the lateral aspect ratio. Indeed, in the case of perpendicular winds, when the LAR increases, the accumulation of pollutants is favorable in the central part of the canyon, due to the reduction in lateral recirculation movements. [6] In the case of parallel winds, as the LAR increases, the accumulation of pollutants increases at the end of the canyon, due to the decrease in wind speed. [6] Regarding inclined winds, when the LAR (L/H) value is high, pollutant concentrations are higher at the end of the canyon than in the canyon with a low LAR value. [15] This means that the long canyon street is characterized by poor ventilation, which leads to pollutants being trapped inside the canyon street. [12] In addition, Gromke C and Ruck B [15] have indicated that this result is due to the formation of vortices and the accumulation of pollutants in certain areas of the street. This is influenced by the elongated shape of the buildings fronting the street, which

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favors the retention of pollutants at the leeward end of the canyon.

Impact of air temperature on PM

Microclimatic parameters have very significant impacts on the concentration of atmospheric pollutants on a human scale in urban canyons. [17] Each parameter has a different degree of influence on the concentration of pollutants in canyons. [34] The results of our study showed a positive correlation between air temperature and fine particles with a Pearson correlation coefficient value ($r = 0.296$) at 1.5 m above the ground during the summer season (Table 2). This result is consistent with the study carried out by Miao et al [35] demonstrating a significant positive correlation between PM and temperature at the pedestrian level, meaning that when the temperature rises, the concentration of PM increases. They explain this by the presence of thermal stress that generally characterizes stagnant synoptic situations with low wind speed, which reduces turbulent flow, hinders the dispersion of atmospheric pollutants, and therefore increases their concentration. [35] Other studies contradicting the above result were carried out by Miao et al [3, 17] showing a significant negative correlation between temperature and PM concentration at 1.5 m. This can be explained by the fact that lower air temperature encourages the trapping of fine particles in urban canyons, due to a reduction in mixing height leading to inversion conditions and stable atmospheric conditions. [17] Based on these findings, one possible explanation for our result concerning the positive correlation between temperature and PM concentration in the canyons studied is that it is due to the wind speed factor. In other words, given that the measurements were carried out in summer, during this period, temperatures reach their maximum, and wind speeds are low and stable compared with other seasons. [28] Likewise, Dong et al [36] observed in their study that the wind speed near the ground during the summer afternoon was almost zero. Therefore, the pollutant removal performance is poor with dispersed pollutant concentration due to the multi-vortex flow structure influenced by the heated walls of buildings. In addition, Miao et al [30] also mentioned in their study that temperature effect is important in summer compared to wind speed, which acts more in autumn. Consequently, a positive correlation appeared between temperature and pollutant concentration due to the effect of temperature on atmospheric turbulence and chemical reactions. [16, 37] With regard to atmospheric turbulence, for example, Kang et al [38] reported that canyon street flow was ineffective in terms of reducing pollutant concentration, as it was influenced by heating of the street bottom. The effect of temperature on chemical reactions is significant; for example, Zhong et al [37] mentioned in their study that the temperature increase in the canyon street plays a crucial role in accelerating the chemical reaction processes that lead to the formation of primary reactive pollutants and the formation of secondary pollutants, and thus the chemical reaction rate increases with the heating intensity, leading to the deterioration of the air quality in the canyon street, due to the significant impact of

chemical reactions on the concentration of measured pollutants, as pointed out by Vardoulakis et al [39]. Furthermore, Pascal et al [18] demonstrated that the summer season, with its very high air temperature, strongly favors the concentration of pollutants (PM and ozone). Consequently, during this season, the health of the population exposed to the risks of pollution is enormous. As a result, air quality monitoring and warning measures must take account of the summer season.

Impact of trees on PM

According to some studies, the role that trees can play in purifying ambient air of various pollutants is today questionable. [6, 15] Indeed, it has been shown that the presence of trees in canyon street configurations has a significant effect on reducing wind speed and air exchange, and therefore leads to an increase in pollutant concentrations. Consequently, the effect of trees on local air quality can be positive, negative, or both negative and positive. [40] Our findings showed a significant positive correlation between the number of trees per linear meter (T/m) and PM with the value of Pearson's correlation coefficient ($r = 0.422$). In other words, the more trees there are, the higher the concentration of PM, as was shown by Xue and Li. [41] The result of the study carried out by Wang et al [42] showed a value of Pearson coefficient of ($r = 0.43$), which is almost equal to the value that was found in our study ($r = 0.44$) (see Table 2). They explained that this significant positive correlation is due to vegetation-related characteristics, in particular the density of the vegetation cover. In other words, as the density of vegetation cover increases, the daily average concentration of PM, particularly total suspended particles (TSP), shows a significant upward trend. Moreover, Tong et al [43] argued that the dense crown of trees helps to impede the flow and exchange of air within the canyon and therefore leads to a significant accumulation of PM.

In addition, the multiple linear regression model showed that the number of trees per linear meter (T/m) had a significant influence on the PM concentration measured in canyons compared with the other parameters studied (see Table 2). Principal component analysis also showed that there was a highly significant positive correlation between LAR, (T/m), and PM concentration (see Figure 2). On the other hand, the (T/m) load is overlaid with the LAR load, with a Pearson correlation coefficient value ($r = 1.000$) (see Table 2), which means that a long canyon street is likely to have more trees along the street, and consequently, this method of planting trees in rows is not recommended, as it increases the concentration of fine particles. [44]

The study by Voordeckers et al [7] contradicts the above result. The authors demonstrated a negative correlation between the concentration of the NO₂ pollutant and the number of trees per linear meter (T/m). According to the authors, this can be partially explained by the negative significant correlation between the number of trees per linear meter (T/m), and the aspect ratio (AR) indicating that trees are more likely to be present in wide canyons, which generally

have higher NO₂ atmospheric pollutant values. [3, 7] In this sense, we can say that the impact of trees on PM concentration also depends on the morphology of the canyon, which is in agreement with the findings of Miao et al. [45] Another explanation for this negative association is that trees affect air quality because of several vegetation-related variables, such as tree planting density, tree crown porosity, leaf surface density, and trunk height and density. [6] Trees characterized by high crown porosity, low leaf area density, low stand density, and low trunk height are recommended in a street canyon configuration. [6]

Conclusions

This study examined the relationship between PM concentration and four morpho-climatic parameters, which include temperature (T), number of trees per linear meter (T/m), aspect ratio (AR), and lateral aspect ratio (LAR). All these variables were measured in the street canyons situated within the French urban fabric characteristic of the city of Algiers. Data relating to the concentration of fine particles and morpho-climatic factors were measured during the summer, covering the months of July, August, and September 2022 with a number of 36 samples. Besides field measurements, statistical methods, namely the Pearson correlation coefficient *r* test, multiple linear regression analysis, and principal component analysis (PCA), were used to qualitatively assess the role of canyon street geometry on PM concentration in real urban environments.

The results of the pairwise Pearson correlation coefficient (*r*) showed significant correlations between all the morpho-climatic variables and PM concentration at two levels of significance: $p < 0.05$ and $p < 0.01$. The R^2 ($R^2 = 0.197$) of the multiple linear regression analysis indicates that the model was effective in describing the relationship between the variables. AR, LAR, and T/m largely influence PM concentration compared with the temperature parameter in principal component analysis (PCA). Combining the results of the three types of statistical analysis performed, our study found that the number of trees per linear meter (T/m) is the variable that has the greatest impact on PM concentration in selected canyons compared to the other variables studied. However, other variables not considered in this study, such as wind speed and direction and hourly road traffic volume, would have a significant influence on the measured PM values.

Ultimately, this study has corroborated the link between morpho-climatic parameters and pollutant concentration. The results could enrich the body of knowledge on urban air pollution in Algiers as well as in similar geographical contexts and give guidance in the design of future urban projects, with the aim of improving local urban air quality and thus protecting human health.

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REFERENCES / СПИСОК ЛИТЕРАТУРЫ

- Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirozoglou E. Environmental and health impacts of air pollution: A review. *Front Public Health*. 2020;8:14. doi: 10.3389/fpubh.2020.00014
- Hassan S, Akter UH, Nag P, Molla MM, Khan A, Hasan MF. Large-eddy simulation of airflow and pollutant dispersion in a model street canyon intersection of Dhaka City. *Atmosphere*. 2022;13(7):1028. doi: 10.3390/atmos13071028
- Miao C, Yu S, Hu Y, et al. How the morphology of urban street canyons affects suspended particulate matter concentration at the pedestrian level: An in-situ investigation. *Sustain Cities Soc*. 2020;55(5):102042. doi: 10.1016/j.scs.2020.102042
- Han J, Lee J. A comparative study of air pollution levels in different urban street configurations in Pangyo New Town, South Korea. *Build Environ*. 2023;243(8):110695. doi: 10.1016/j.buildenv.2023.110695
- Huang Y, Lei C, Liu CH, et al. A review of strategies for mitigating roadside air pollution in urban street canyons. *Environ Pollut*. 2021;280(7):116971. doi: 10.1016/j.envpol.2021.116971
- Voordeckers D, Lauriks T, Denys S, Billen P, Tytgat T, Van Acker M. Guidelines for passive control of traffic-related air pollution in street canyons: An overview for urban planning. *Landsch Urban Plan*. 2021;207(6):103980. doi: 10.1016/j.landurbplan.2020.103980
- Voordeckers D, Meysman FJR, Billen P, Tytgat T, Van Acker M. The impact of street canyon morphology and traffic volume on NO₂ values in the street canyons of Antwerp. *Build Environ*. 2021;197(2):107825. doi: 10.1016/j.buildenv.2021.107825
- da Silva FT, Reis NC Jr, Santos JM, Goulart EV, de Alvarez CE. Influence of urban form on air quality: The combined effect of block typology and urban planning indices on city breathability. *Sci Total Environ*. 2022;814:152670. doi: 10.1016/j.scitotenv.2021.152670
- Michioka T, Takimoto H, Sato A. Large-eddy simulation of pollutant removal from a three-dimensional street canyon. *Boundary-Layer Meteorol*. 2014;150(2):259–275. doi: 10.1007/s10546-013-9870-6
- Hunter LJ, Watson ID, Johnson GT. Modelling air flow regimes in urban canyons. *Energy Build*. 1990–1991;15(3–4):315–324. doi: 10.1016/0378-7788(90)90004-3
- Oke TR. Street design and urban canopy layer climate. *Energy Build*. 1988;11(1–3):103–113. doi: 10.1016/0378-7788(88)90026-6
- Yazid AWM, Sidik NAC, Salim SM, Saqr KM. A review on the flow structure and pollutant dispersion in urban street canyons for urban planning strategies. *Simulation*. 2014;90(8):892–916. doi: 10.1177/0037549714528046

<https://doi.org/10.35627/2219-5238/2025-33-6-65-74>

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13. Zhang L, Zhang Z, McNulty S, Wang P. The mitigation strategy of automobile generated fine particle pollutants by applying vegetation configuration in a street-canyon. *J Clean Prod.* 2020;274(11):122941. doi: 10.1016/j.jclepro.2020.122941
14. Buccolieri R, Carlo OS, Rivas E, Santiago JL, Salizzoni P, Siddiqui MS. Obstacles influence on existing urban canyon ventilation and air pollutant concentration: A review of potential measures. *Build Environ.* 2022;214(12):108905. doi: 10.1016/j.buildenv.2022.108905
15. Gromke C, Ruck B. Pollutant concentrations in street canyons of different aspect ratio with avenues of trees for various wind directions. *Boundary-Layer Meteorol.* 2012;144(1):41-64. doi: 10.1007/s10546-012-9703-z
16. He J, Gong S, Yu Y, et al. Air pollution characteristics and their relation to meteorological conditions during 2014–2015 in major Chinese cities. *Environ Pollut.* 2017;223(4):484-496. doi: 10.1016/j.envpol.2017.01.050
17. Miao C, Yu S, Zhang Y, Hu Y, He X, Chen W. Assessing outdoor air quality vertically in an urban street canyon and its response to microclimatic factors. *J Environ Sci (China).* 2023;124(2):923-932. doi: 10.1016/j.jes.2022.02.021
18. Pascal M, Wagner V, Alari A, Corso M, Le Tertre A. Extreme heat and acute air pollution episodes: A need for joint public health warnings? *Atmos Environ.* 2021; 249(10):118249. doi: 10.1016/j.atmosenv.2021.118249
19. Song J, Saathoff H, Gao L, et al. Variations of PM_{2.5} sources in the context of meteorology and seasonality at an urban street canyon in Southwest Germany. *Atmos Environ.* 2022;282(1):119147. doi: 10.1016/j.atmosenv.2022.119147
20. Yadav S, Praveen OD, Satsangi PG. The effect of climate and meteorological changes on particulate matter in Pune, India. *Environ Monit Assess.* 2015;187(7):402. doi: 10.1007/s10661-015-4634-z
21. Javan S, Rahdar S, Miri M, et al. Modeling of the PM10 pollutant health effects in a semi-arid area: A case study in Zabol, Iran. *Model Earth Syst Environ.* 2021;7(1):455-463. doi: 10.1007/s40808-020-00874-y
22. Li J, Kang CM, Wolfson JM, et al. Estimation of fine particulate matter in an arid area from visibility based on machine learning. *J Expo Sci Environ Epidemiol.* 2022;32(6):926-931. doi: 10.1038/s41370-022-00480-3
23. Li Z, Zhang H, Wen CY, Yang AS, Juan YH. Effects of height-asymmetric street canyon configurations on outdoor air temperature and air quality. *Build Environ.* 2020;183(8):107195. doi: 10.1016/j.buildenv.2020.107195
24. Çapraz Ö, Deniz A. Particulate matter (PM₁₀ and PM_{2.5}) concentrations during a Saharan dust episode in Istanbul. *Air Qual Atmos Health.* 2021;14(1):109-116. doi: 10.1007/s11869-020-00917-4
25. Boughedaoui M, Kerbachi R, Kessali D, Joumard R. Mesure de la pollution plombifère dans l'air ambiant d'Alger. *Pollut Atmos.* 2004;(181):105-111. (In French.) doi: 10.4267/pollution-atmospherique.1602
26. Abderrahim H, Chellali MR, Hamou A. Forecasting PM10 in Algiers: Efficacy of multilayer perceptron networks. *Environ Sci Pollut Res.* 2016;23(2):1634-1641. doi: 10.1007/s11356-015-5406-6
27. Naimi-Ait-Aoudia M, Berezowska-Azzag E. Algiers carrying capacity with respect to per capita domestic water use. *Sustain Cities Soc.* 2014;13(10):1-11. doi: 10.1016/j.scs.2014.03.006
28. Weather Algiers. Meteoblue. Accessed May 6, 2025. https://www.meteoblue.com/en/weather/week/algeria_algeria_2507480
29. Rahal F, Benabadji N, Bencherif M, Bencherif MM. Development of a low-cost outdoor carbon monoxide analyser applied to the city of Oran, Algeria. *J Fundam Appl Sci.* 2021;13(3):1495-1510. doi: 10.4314/jfas.v13i3.22
30. Miao C, Li P, Huang Y, Sun Y, Chen W, Yu S. Coupling outdoor air quality with thermal comfort in the presence of street trees: A pilot investigation in Shenyang, Northeast China. *J For Res.* 2023;34(3):831-839. doi: 10.1007/s11676-022-01497-y
31. Irawati I, Riswanto FDO, Riyanto S, Martono S, Rohman A. The use of software packages of R factoextra and FactoMineR and their application in principal component analysis for authentication of oils. *Indonesian J Chemom Pharm Anal.* 2021;1(1):1-10. (In Indonesian.) doi: 10.22146/ijcpa.482
32. Yang X, Zhang Y, Hang J, et al. Integrated assessment of indoor and outdoor ventilation in street canyons with naturally-ventilated buildings by various ventilation indexes. *Build Environ.* 2020;169(2):106528. doi: 10.1016/j.buildenv.2019.106528
33. Jon KS, Luo Y, Sin CH, Cui PY, Huang YD, Tokgo J. Impacts of wind direction on the ventilation and pollutant dispersion of 3D street canyon with balconies. *Build Environ.* 2023;230(10):110034. doi: 10.1016/j.buildenv.2023.110034
34. Ehrmsperger L, Klemm O. Air pollution in an urban street canyon: Novel insights from highly resolved traffic information and meteorology. *Atmos Environ X.* 2022;13(1):100151. doi: 10.1016/j.aeaoa.2022.100151
35. Miao C, He X, Gao Z, Chen W, He BJ. Assessing the vertical synergies between outdoor thermal comfort and air quality in an urban street canyon based on field measurements. *Build Environ.* 2023;227(1):109810. doi: 10.1016/j.buildenv.2022.109810
36. Dong J, Tan Z, Xiao Y, Tu J. Seasonal changing effect on airflow and pollutant dispersion characteristics in urban street canyons. *Atmosphere.* 2017;8(3):43. doi: 10.3390/atmos8030043
37. Zhong J, Cai XM, Bloss WJ. Coupling dynamics and chemistry in the air pollution modelling of street canyons: A review. *Environ Pollut.* 2016;214(7):690-704. doi: 10.1016/j.envpol.2016.04.052
38. Kang YS, Baik JJ, Kim JJ. Further studies of flow and reactive pollutant dispersion in a street canyon with bottom heating. *Atmos Environ.* 2008;42(20):4964-4975. doi: 10.1016/j.atmosenv.2008.02.013
39. Vardoulakis S, Fisher BEA, Pericleous K, Gonzalez-Flesca N. Modelling air quality in street canyons: A review. *Atmos Environ.* 2003;37(2):155-182. doi: 10.1016/S1352-2310(02)00857-9
40. Miao C, Yu S, Hu Y, et al. Seasonal effects of street trees on particulate matter concentration in an urban street canyon. *Sustain Cities Soc.* 2021;73:103095. doi: 10.1016/j.scs.2021.103095
41. Xue F, Li X. The impact of roadside trees on traffic released PM10 in urban street canyon: Aerodynamic and deposition effects. *Sustain Cities Soc.* 2017;30(4):195-204. doi: 10.1016/j.scs.2017.02.001
42. Wang X, Teng M, Huang C, Zhou Z, Chen X, Xiang Y. Canopy density effects on particulate matter attenuation coefficients in street canyons during summer in the Wuhan metropolitan area. *Atmos Environ.* 2020;240(1):117739. doi: 10.1016/j.atmosenv.2020.117739
43. Tong Z, Whitlow TH, MacRae PF, Landers AJ, Harada Y. Quantifying the effect of vegetation on near-road air quality using brief campaigns. *Environ Pollut.* 2015;201(6):141-149. doi: 10.1016/j.envpol.2015.02.026
44. Chen X, Wang X, Wu X, Guo J, Zhou Z. Influence of roadside vegetation barriers on air quality inside urban street canyons. *Urban For Urban Green.* 2021;63(6):127219. doi: 10.1016/j.ufug.2021.127219
45. Miao C, Li P, Yu S, Chen W, He X. Does street canyon morphology shape particulate matter reduction capacity by street trees in real urban environments? *Urban For Urban Green.* 2022;78(10):127762. doi: 10.1016/j.ufug.2022.127762

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