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Alia Wokan and Madalina Iordache [*]

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Ecosystem Services Provided by an Urban Green Space in Timișoara (Romania): Linking Urban Vegetation with Air Quality and Heat Risk

Alia Wokan and Madalina Iordache

Affiliation

*   Correspondence: madalina.borca@usvt.ro

Abstract: This study was conducted in a temperate-continental city of Europe (Timișoara, Romania) and aimed to investigate the contribution of urban vegetation in maintaining air quality and mitigating the heat in the analyzed city. It was studied The Central Park „Anton von Scudier" located in the downtown of Timișoara City (45°45′05″N, 21°13′16″E) for the following air parameters: fine particulate matter $PM_{2.5}$ (aerodynamic diameter <2.5 μm), fine particulate matter PM_{10} (aerodynamic diameter <10 μm), AQI (Air Quality Index) (resulted from $PM_{2.5}$ and PM_{10}), particles number, air temperature, air relative humidity, TVOC (total volatile organic compounds), HCHO (formaldehyde). Nine sample points of air monitoring were established: seven inside the green space and two outside it. The air monitoring was done in the late August, in four consecutive working days (Monday-Thursday), within 12:00-14:00 a.m. The air measurements were made using a portable device for outdoor air monitoring (**Temtop LKC-1000 Series Air Quality Monitor)**. The results of this study show that urban vegetation remains a reliable factor in reducing $PM_{2.5}$ and PM_{10} in cities air and in keeping the AQI within the limits corresponding to good air quality, but also that air relative humidity counteracts the contribution of vegetation in achieving this goal. Thus, the study highlights the importance of air humidity in enhancing the values of $PM_{2.5}$, PM_{10}, AQI, and in exceeding their admissible or recommended limits for air quality. There was not confirmed by this study the effect of wet deposition of the airborne particles as effect of precipitations. Inside the park, the HCHO concentration increased by up to 4-5 times compared to the outside, and this increase was not caused by vehicle traffic, but rather by the photochemical reactions generating HCHO. Regarding the cooling effect on air temperature, the studied green space did not exhibit this effect, as the air temperature inside it increased by up to 1-6°C compared to the outside, which means it did not achieved its goal of providing climatic comfort to citizens during the summer and serving as a cooling spot in the city. Our results contrast the general perception and conviction that urban parks and green spaces are cooler islands within the cities and draw attention to the fact that having a green space in a city does not necessarily mean achieving environmental goals, such as reducing the heat risk of cities. In this study, based on the results, we consider that the main limitations in achieving these objectives were the park's small size (88 hectares) and its morphology and architecture resulting from the integration of the species that compose it. It follows from these data that it is not enough that an urban green space to be established, but its design must be combined with urban morphology strategies if the heat mitigation effect is to be achieved and the cooling benefits are to be maximized in cities. Therefore, in the urban planning, the environmental strategies should comprise not only aesthetic criteria, but also scientific criteria in order to reach the final goal of the urban green spaces in the cities: a sustainable, healthy, and comfortable environment.

Keywords: urban park; urban ecosystem; urban health; urban resilience; ecosystem services; heat island; urban pollution

1. Introduction

Urban green spaces represent the connection between humans and nature in cities. The way people's emotional reactions are influenced by accessing green spaces, as well as the social consequences resulting from this connection, have been a topic of interest, especially in recent years. Surveys of the urban population have shown that city dwellers primarily access urban green spaces for reasons related to recreation and spending leisure time in an area with natural elements, but also because of need to access a cooler area during the summer, as well as because the belief that urban green spaces are, within cities, islands with clean air, or at least with cleaner air than the surrounding areas [1]. It follows from this that the general perception of city dwellers is that urban green spaces are places for recreation and means of ensuring air quality in cities, as well as thermal comfort in the context of climate change and urban warming so strongly felt in urban environments.

Policies to ensure air quality in areas human inhabited are diverse, but the nature-based ones are by far the most implementable and feasible, mainly due to the non-static and continuously dynamic nature of this environmental factor, which is why other remedial solutions are less applicable. It thus becomes evident that, on a global scale, the only truly viable option for ensuring air quality is self-purification, which involves the contribution of biological factors in achieving this result. Most studies on this topic have been conducted in urban environments, as these areas have multiple major sources of air pollution, and because a large part of the human population resides in cities (over 70% in Europe and America), and is predicted that by 2050, more than 70% of the world's population will be urban [2]. The use of vegetation as a tool to obtain quality air in cities has been widely studied in many parts of the world [3–5]. Most of the studies approach many industrialized urban areas of the world with the aim to highlight the role of urban vegetation in providing ecosystem services that ensure urban air quality. Thus, the results of research in the field to date, have shown that urban vegetation, especially woody vegetation, is able to extract and sequester the atmospheric carbon dioxide and to retain and trap the airborne particulate matter or other air pollutants [6]. Also, the urban vegetation can act like a protective barrier between pollutants and their sources and population [7]. To achieve these goals, numerous factors are decisive. Some of these are vegetation related, such as canopy size, leaf area and shape [7], stomata characteristics [7], trichomes presence [7], intercellular spaces available for gas diffusion in the case of gaseous pollutants [8], evapotranspiration, leaf architecture and morphology in generating the shading effect. However, other factors pertain to chemical and physical processes occurring both at the plant level and in its surrounding environment. Therefore, some approaches to the role of urban vegetation in ensuring air quality look at the impact on the adjacent microclimate [9] or on the local climate of the site. Thus, it results that the plant potential in pollution mitigation in urban areas is a species-specific mechanism. Urban studies have shown that plants have the ability to capture the atmospheric pollutants based on species-specific physiological and morphological characteristics that differentiate them in terms of efficiency, making them, from this point of view, more or less preferable for inclusion in urban green space planning. For example, some studies [10] have shown that mature trees with large canopy are major contributors in optimizing and regulating the ecosystem services in cities, while large and open urban green spaces with extensive natural vegetation provide multi-functionality in regulating services [11]. The leaf morphology and microstructure influence the retention patterns of the pollutants and also their removal with fallen precipitations or with wind. Therefore, in urban green planning, is important to select urban vegetation by estimating species contribution to air purification according to the meteorological conditions of the zone. The climatic patterns are also important. Several studies [12] have shown that, in the removal process of the pollutants from plant leaves, is more influencing the rainfall phase than other factors, such as particle diameter or particle adherence to the leaf. Meteorological conditions significantly influence the atmospheric pollution levels, affecting the dispersion, transport, and accumulation of pollutants. Essential meteorological factors that intervene in these processes include thermal inversions, wind speed and direction, atmospheric humidity, and precipitations. In the case of thermal inversions, if a warmer air layer is situated above a cooler, denser air layer that contains pollutants, it prevents the

dispersion of pollutants and traps them in the lower layer, potentially increasing local pollution. Urban vegetation can mitigate this phenomenon by ensuring a more efficient local air circulation through evapotranspiration processes, by shading the ground, but also as an effect of the vertical disposition of individuals of different heights.

Wind speed and direction play an important role in the transport and dispersion of pollutants.

Strong winds help dilute and remove particulate pollutants, reducing their concentrations in a given area. However, strong winds can also cause surface erosion of buildings in cities, increasing levels of pollutants such as airborne particulate matter. Low wind speeds can also impact urban air quality by favoring air stagnation and keeping pollutants in certain areas for longer periods, resulting in a higher local exposure risk.

Besides the effect in pollutants capture and air phytoremediation, the urban vegetation can emit biogenic substances with supporting role in human healts, such as biogenic volatile organic compounds (VOC), strengthening public's and authorities' conviction of the necessity of having a reasonable area of green space per inhabitant in cities. World Health Organization (WHO) recommends a minimum surface of green space by 9 m^2 per person and an ideal surface by 50 m^2 per person [13], whereas considers as acceptable the physical accessibility of urban green spaces by residents within a short distance, a 5 minute walk or a distance up to 300 m. Also, for climatic purposes, WHO recommend a minimum width of green corridors by 50 m, ideally over 300 m [14].

Another important ecosystem service provided by urban green spaces is their critical role in mitigating the effect of urban heating, contributing thus to urban resilience. The urban resilience could be increased when, for establishing urban parks, are used the most suitable species [15] to reach this goal, such as native or alien species, species resistant to drought stress, or long-life species. The urban vegetation contributes to energy saving in cities by enhancing the thermal performance of the buildings [16] and representing thus an unconventional and sustainable solution of cooling in the dense populated areas.

The intrinsic relationship existing for long time between humans and nature generated their strong feeling of biophilia [17] towards other living beings in the global ecosystem, which also creates the special need of city dwellers to connect with nature through urban green spaces. Studies have shown the psychological, emotional, and social benefits of urban green parks [18] for those who access them, through sensory experiences and interactions (visual, auditory, olfactory, and even tactile) that benefit human health and wellbeing..

In light of the above exposed arguments, the research aimed to investigate the contribution of an urban green space in maintaining air quality and mitigating the warming in a Romanian city, as related to its surrounding environment, in order to reveal the ecosystem services provided by the urban green spaces in urban areas. This study brings data about the importance of the green spaces in the urban matrix and about the ecosystem services provided by urban vegetation. The results highlight that urban vegetation is a reliable factor in maintaining air quality, but also draw attention to the fact that simply having green spaces in cities does not necessarily mean achieving environmental objectives, such as reducing the urban heat risk, therefore urban morphology strategies must be implemented to maximize cooling benefits and effectively mitigate heat.

2. Materials and Methods

2.1. Research Site

The research was carried out in the Central Park „Anton von Scudier" in downtown Timișoara (Figure 1), Romania (45°45′05″N, 21°13′16″E).
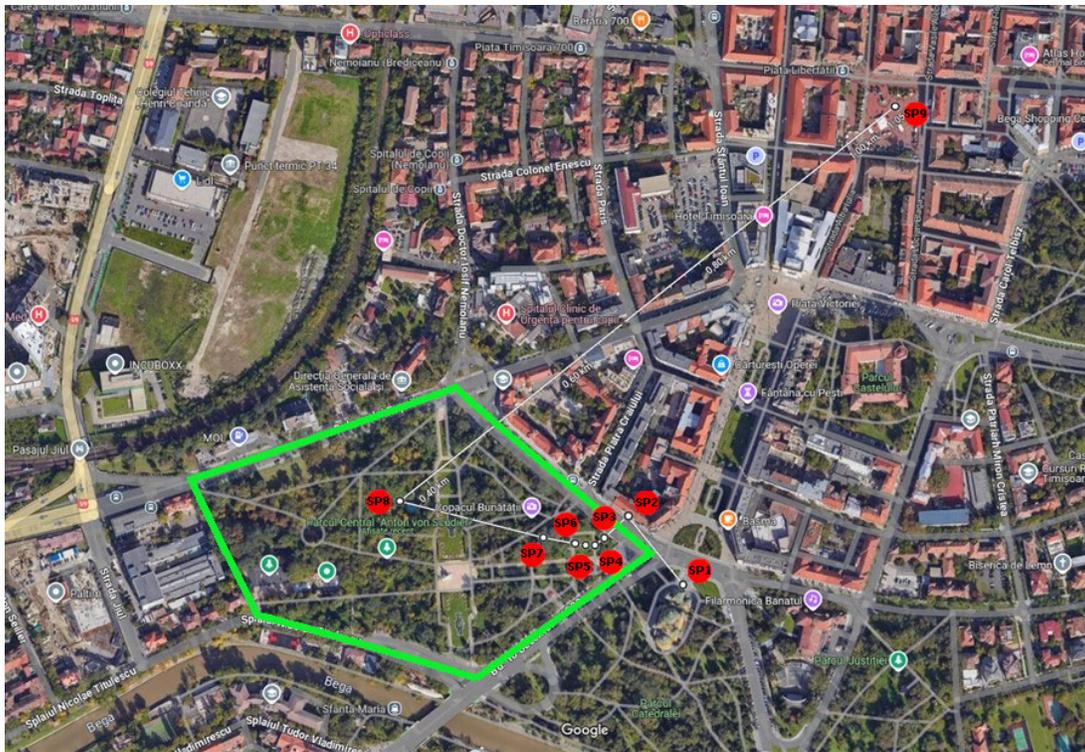
Figure 1. Sample points (SP) of air monitoring inside and outside urban green space Antoine von Scudier, Timişoara City, Romania (45°45′05″N, 21°13′16″E) (Google Maps capture).

This urban green space has a temperate-continental climate, covers an area by 87,663 m², and is one of the oldest parks in Timișoara, being established in 1880 by order of General Anton von Scudier (an Austro-Hungarian officer of German origin who served as a military governor of Timișoara, known for his military career and contributions to the city's development, and who lived between 1818 and 1885). This study monitored 9 sample points (SP) noted as SP1, SP2, SP3, SP4, SP5, SP6, SP7, SP8, and SP9. These sample points were established in relation to the park's boundary line, as follows: SP1 – outside park, at 93 m from park border; SP2 – outside park, at 55 m from park border; SP3 – on the park border; SP4 – inside park, at 10 m from border; SP5 – inside park, at 20 m from border; SP6 – inside park, at 30 m from border; SP 7 – inside park, at 164 m from border; SP8 – inside park, at 275 m from border; SP9 – outside park, at 583 m from border. The sample point SP9 was chosen at a greater distance from the park because it was aimed for it to be located both far from vegetation and enclosed by buildings, to determine if there are similarities or differences in the monitored parameters between the vegetated-environment and the built-up, vegetation-free environment.

2.2. Research Methodology

Air quality monitoring was conducted over four consecutive days at the end of August, from August 19 to August 22, 2024 (working days, Monday to Thursday), between 12:00 and 14:00, at nine fixed points (Figure 1). The monitoring days were labeled as Day 1, Day 2, Day 3, and Day 4. The measurements were performed using the device **Temtop LKC-1000 Series Air Quality Monitor** [19]. This is an air quality monitoring tool, a low-cost sensor capable of measuring a variety of essential parameters for the assessment of environmental conditions. Low-cost sensors provide real-time air monitoring and highly localized air information, and, despite their low cost, accurate information [20]. Also, low-cost and accessible instruments [21–23] and at the same time portable [23,24] have shown to be reliable in air quality monitoring. The instrument used for this research was suitable for the intended purpose because it uses high-precision sensors and has a compact size (177×65.5×32 mm), which makes it conveniently portable, and regarding the operating conditions, the device

functions optimally at temperatures ranging from 0 to 50°C and at an air relative humidity of 0 to 90%. Additionally, the device is designated to operate at standard atmospheric pressure (1 atm). The following air parameters were monitored with this device: fine particulate matter $PM_{2.5}$ (with aerodynamic diameter <2.5 µm), fine particulate matter PM_{10} (with aerodynamic diameter <10 µm), air temperature, air relative humidity, TVOC (total volatile organic compounds), HCHO (formaldehyde). As well, the Air Quality Index (AQI) and the particles number were monitored, both being indicators derived from the corroboration of the values recorded for $PM_{2.5}$ and PM_{10}. The Air Quality Index (AQI) is an indicator used to communicate air quality to the public in a format easily understood by a wide audience. The Temtop LKC-1000 Series Air Quality Monitor measures the particles number as an air indicator different from the sum of particles $PM_{2.5}$ and PM_{10}, because it also includes particles of other, smaller sizes. Although the detailed specifications regarding the exact size range of particles detectable by this device are not stated in the supplied specifications, in general, similar laser sensors can detect particles ranging from approximately 0.3 µm to 10 µm [25]. This does not mean that we know the exact size range the device used in this research is capable of measuring, but it suggests that it may measure particles smaller than those in the $PM_{2.5}$ and PM_{10} categories, i.e., very fine particles.

The device was used to measure air parameters at the same height from the ground (approximately 1 meter above the ground) on all four days, and samples were taken from the same point each day. Three samples were taken from each point at equidistant time intervals, every 2 minutes (the device operated for 2 minutes, after which it was paused to record the data). The monitored parameters and the measurement characteristics of the air quality monitor (measurement range and resolution) are presented in Table 1.

Table 1. Measurement characteristics of the air quality monitor (measurement range and resolution) [26].

Measurement characteristics	Air parameter					
	$PM_{2.5}$	PM_{10}	HCHO	TVOC	Air Temperature	Air Relative Humidity
Measurement range	0 - 999 µg/m³	0 - 999 µg/m³	0 - 5 mg/m³	0 - 5 mg/m³	0-50°C	0-90%
Measurement resolution	0.1 µg/m³	0.1 µg/m³	0.01 mg/m³	0.01 mg/m³	0.01°C	0.01%

2.3. Results Interpretation

For the interpretation of the recorded values, there are multiple assessment scales. The device used reports the recorded data with reference to the standards of the United States Environmental Protection Agency (EPA) only for the parameters $PM_{2.5}$, PM_{10} and AQI (Table 2) [26], while for the parameters TVOC and HCHO, it follows the Air Quality Guidelines of the World Health Organization (WHO) (Table 3) [26,27]. However, for interpreting the results obtained in this study, to ensure consistency in interpretation and because WHO standards are more restrictive and therefore more relevant for assessing the impact of the measured values on human health (compared to Romanian standards in Table 2 and Table 3), it was decided that reporting the analyzed parameters to the WHO-recommended standards would be more appropriate (exception air temperature, air relative humidity and AQI, this last one being interpreted according to EPA standards - Table 2) [27,28].

For the interpretation of HCHO and TVOC values, some clarifications are necessary. WHO provides recommendations for maximum permissible limits for HCHO only for indoor air (Table 3) [27], while for TVOC, it recommends a range of 0.3-0.5 mg/m³ [27]. In Romania, there is legislation that regulates permissible limits for HCHO in the air (Law No. 104 of 15 June 2011) [29], which aligns with European Union standards (Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004) [30]. According to this European directive, the annual concentration limit for HCHO in the air is 0.1 mg/m³ (equivalent to 100 µg/m³), i.e. the same as that recommended

by the WHO (Table 3) and the value to which the measured HCHO levels in this study were referenced. This value represents the maximum permissible long-term concentration of HCHO in the air over a period of one year. If this limit is exceeded in the long term, adverse effects on human health may occur, and public health protection measures must be implemented. Regarding TVOC, there is no specific national regulation in Romania that imposes a certain limit in outdoor ambient air, similar to the limits for PM_{10} and $PM_{2.5}$, or for HCHO. However, European regulations (Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008) [31] influence the monitoring and management of TVOC emissions in the air, and these are applicable in Romania under environmental legislation. But, this directive also does not specify a certain concentration threshold for TVOC in the air. However, since TVOCs are considered a group of chemical pollutants that can affect human health, they are monitored within the air quality monitoring system, and the interpretation of this parameter's values is made according to WHO recommendations (Table 3).

Table 2. Reference levels and air quality ratings for the parameters $PM_{2.5}$, PM_{10} and AQI (Air Quality Index).

Air quality parameter									
$PM_{2.5}$ (μg/m³)				PM_{10} (μg/m³)				AQI	
United States Environmental Protection Agency (EPA) Standards [26]		Air Quality Guidelines of World Health Organization [28]	Romanian Standard (Law no. 104/15 iunie 2011) [29]	United States Environmental Protection Agency (EPA) Standards [26]		Air Quality Guidelines of World Health Organization [28]	Romanian Standard (Law no. 104/15 iunie 2011) [29]	United States Environmental Protection Agency (EPA) Standards [26]	
$PM_{2.5}$ Value (μg/m³)	Air quality level	$PM_{2.5}$ Value (μg/m³)		PM_{10} Value (μg/m³)	Air quality level	PM_{10} Value (μg/m³)	PM_{10} Value (μg/m³)	AQI Value	Air quality level
≤12	Good			≤54.9	Good		50 μg/m³ – Daily limit value for human health protection, which must not be exceeded more than 35 days a year	≤50	Good
12.1 - 35.4	Moderate		20 μg/m³ – Annual limit value for human health protection, which must be respected throughout the entire calendar year	55 – 154.9	Moderate			51 - 100	Moderate
35.5 - 55.4	Unhealthy for Sensitive Groups			155 – 254.9	Unhealthy for Sensitive Groups			101 - 150	Unhealthy for Sensitive Groups
55.5 - 150.4	Unhealthy	5 (Annual)	15 (24 h)		255 – 354.9	Unhealthy	15 (Annual)	45 (24 h)	40 μg/m³ – Annual limit value for human health protection, this being the value that must be respected throughout the entire calendar year	151 - 200	Unhealthy
150.5 - 250.4	Very Unhealthy			355 – 424.9	Very Unhealthy			201 - 300	Very Unhealthy
≥ 250.5	Hazardous			≥425				≥301	Hazardous

Table 3. Reference levels and air quality ratings for formaldehyde (HCHO) and TVOC concentrations [26,27].

Air quality parameter							
TVOC (mg/m³)				HCHO (mg/m³)			
United States Environmental Protection Agency (EPA) Standards [26]		Air Quality Guidelines of World Health Organization [27]		Air Quality Guidelines of World Health Organization [27]			Romanian Standard (Law no. 104/15 iunie 2011; Directive 2004/107/CE) [29]
TVOC Value (mg/m³)	Air quality rating	TVOC Value (mg/m³)		HCHO Value (mg/m³)			HCHO Value (mg/m³)
		Annual	24 h	Annual	24 h	30 min.	
≤0.5	Healthy			-	≤0.1	≤0.1	≤0.1
>0.5	Unhealthy	-	0.3-0.5 mg/m³	-	>0.1	>0.1	

Regarding AQI, Romania does not have specific legislation regulating precise values for this air parameter. However, AQI is a concept used to assess air quality, and it is also utilized in Romania to inform the public about pollution levels and associated risks through various platforms. The AQI is

an air quality index with multiple calculation methods across different countries. In this study, the AQI measured by the Temtop LKC-1000 device is derived exclusively from the measured $PM_{2.5}$ and PM_{10} values, and its interpretation was made according to WHO standards (Table 2).

As for the total number of particles measured by the Temtop LKC-1000 Series Air Quality Monitor used in this study, there is no standardized maximum allowable limit expressed in particles per liter of air (pcs/L). This is because air quality standards typically focus on the mass of suspended particles ($PM_{2.5}$ and PM_{10}), expressed in $\mu g/m^3$. The limit values for interpreting $PM_{2.5}$ and PM_{10} levels therefore refer to particle mass and not to the total number of particles. Since the number of particles and their mass do not have a simple direct relationship (as particles of different sizes contribute differently to the total mass), there are no regulated standards for the total number of particles per liter of air. Regarding particulate matter, the $PM_{2.5}$ and PM_{10} limit values for ambient air quality in force in Romania (according to Law No. 104 of 15 June 2011) (Table 2) were not considered in this study. This is because they are less stringent than those recommended by WHO, and we believe they downplay the concern that should be maintained regarding ambient air quality for the protection of human health.

Measurements were conducted over four consecutive weekdays to capture periods of intense human activity, at the same time intervals, at the same height, and in the same locations, allowing for the observation of the evolution and modification of the analyzed parameters. Since weather conditions varied on certain days, they were taken into account in the interpretation of results. Pearson correlations ($p<0.05$) were analyzed to determine whether the measured factors influenced each other and whether any relationships existed between them. Additionally, statistically significant differences (Paired-samples *t*-test, $p<0.05$) were examined between the recorded values at different depths within the park and outside of it. Graphs were created using Microsoft Office Excel (2010), and statistical analysis was performed using IBM SPSS Statistics version 28.0.

3. Results and Discussion

The measured values of the air parameters are presented in Table 4, by monitoring days and sample points (SP1-SP9).

Table 4. Air quality parameters in the monitoring sample points, within the analyzed period.

Monitoring date	Sample point (SP)	Air parameter							
		$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	Air Temperature (°C)	Air Relative Humidity (%)	AQI	HCHO (mg/m^3)	TVOC (mg/m^3)	Number of particles
Day 1	SP1 – outside park, at 93 m from park border	8.86 ±3.23	14.33 ±4.80	32.90 ±0.26	39.10 ±0.43	36.33 ±12.74	0.013 ±0.005	0.04 ±0.04	1393.66 ±453.18
	SP2 – outside park, at 55 m from park border	9.66 ±2.71	15.00 ±4.50	34.83 ±0.50	38.60 ±0.40	40.00 ±11.53	0.03 ±0.010	0.13 ±0.03	1473.00 ±359.63
	SP3 – on the park border	6.83 ±0.49	11.66 ±0.58	37.50 ±0.62	34.13 ±0.51	28.00 ±1.73	0.02 ±0.01	0.10 ±0.04	1151.66 ±102.92
	SP4 – inside park, at 10 m from border	7.03 ±0.86	11.13 ±0.46	38.76 ±0.30	34.10 ±0.10	28.66 ±3.51	0.04 ±0.00	0.18 ±0.00	1087.33 ±122.83
	SP5 – inside park, at 20 m from border	5.53 ±0.40	8.86 ±0.70	38.86 ±0.11	34.13 ±0.55	22.66 ±1.52	0.05 ±0.00	0.21 ±0.01	914.66 ±8.38
	SP6 – inside park, at 30 m from border	7.33 ±1.05	11.86 ±1.66	38.13 ±0.15	33.86 ±0.95	30.00 ±4.58	0.03 ±0.005	0.17 ±0.02	1203.66 ±172.81
	SP 7 – inside park, at 164 m from border	5.73 ±0.96	9.40 ±1.67	36.90 ±0.10	34.03 ±0.05	23.33 ±4.04	0.03 ±0.01	0.15 ±0.03	894.00 ±164.83
	SP8 – inside park, at 275 m from border	4.96 ±0.50	8.33 ±1.45	35.06 ±0.20	37.30 ±0.70	20.33 ±2.51	0.04 ±0.005	0.18 ±0.01	859.33 ±116.42
	SP9 – outside park, at 583 m from border	6.63 ±1.96	11.23 ±3.61	36.56 ±0.92	35.13 ±1.68	27.00 ±7.81	0.01 ±0.005	0.07 ±0.01	1045.66 ±281.03

Day	Location								
Day 2	SP1 – outside park, at 93 m from park border	15.23 ±1.82	26.06 ±3.18	30.63 ±0.50	46.40 ±0.30	57.00 ±3.60	0.01 ±0.00	0.04 ±0.01	2308.66 ±273.63
	SP2 – outside park, at 55 m from park border	11.66 ±0.50	19.26 ±1.02	32.00 ±0.20	44.70 ±0.45	48.33 ±2.51	0.02 ±0.00	0.08 ±0.01	1816.66 ±101.63
	SP3 – on the park border	10.50 ±1.70	16.86 ±1.87	36.50 ±1.17	40.73 ±1.49	43.33 ±7.09	0.02 ±0.005	0.00 ±0.00	1613.66 ±262.8
	SP4 – inside park, at 10 m from border	10.90 ±0.90	17.66 ±1.70	38.46 ±0.60	37.60 ±0.95	45.00 ±4.00	0.03 ±0.005	0.15 ±0.01	1682.33 ±174.61
	SP5 – inside park, at 20 m from border	10.33 ±1.61	16.93 ±2.45	37.66 ±1.15	37.30 ±0.79	42.33 ±7.02	0.03 ±0.005	0.15 ±0.01	1654.66 ±204.39
	SP6 – inside park, at 30 m from border	10.30 ±0.78	16.90 ±0.72	35.00 ±0.30	40.20 ±0.78	43.00 ±1.73	0.03 ±0.005	0.16 ±0.02	1663.33 ±105.64
	SP 7 – inside park, at 164 m from border	7.76 ±1.90	14.40 ±1.30	36.60 ±1.27	38.60 ±1.90	34.66 ±3.78	0.02 ±0.005	0.11 ±0.01	1306.00 ±110.43
	SP8 – inside park, at 275 m from border	8.13 ±1.15	10.53 ±1.89	32.76 ±0.35	43.10 ±0.70	27.66 ±6.11	0.03 ±0.00	0.13 ±0.01	1039.00 ±208.51
	SP9 – outside park, at 583 m from border	9.56 ±1.20	16.26 ±1.80	33.56 ±0.80	43.13 ±1.68	39.33 ±5.03	0.01 ±0.005	0.07 ±0.02	1541.00 ±125.03
Day 3	SP1 – outside park, at 93 m from park border	20.33 ±8.05	33.50 ±14.70	32.26 ±2.02	47.73 ±3.69	70.00 ±19.97	0.01 ±0.00	0.01 ±0.01	3109.00 ±1229.73
	SP2 – outside park, at 55 m from park border	10.96 ±1.00	18.10 ±2.06	33.46 ±0.25	45.10 ±0.80	45.00 ±4.00	0.01 ±0.00	0.06 ±0.01	1736.33 ±172.63
	SP3 – on the park border	9.96 ±0.85	16.96 ±2.05	35.83 ±1.32	41.26 ±3.05	40.66 ±3.21	0.01 ±0.005	0.08 ±0.02	1527.66 ±173.09
	SP4 – inside park, at 10 m from border	11.16 ±1.95	16.10 ±4,58	37.96 ±0.15	38.16 ±0.72	45.33 ±7.50	0.02 ±0.005	0.11 ±0.01	1736.66 ±305.78
	SP5 – inside park, at 20 m from border	10.13 ±0.15	16.90 ±0.34	37.20 ±0.17	39.30 ±0.10	41.33 ±0,57	0.02 ±0.005	0.12 ±0.01	1576.33 ±48.8
	SP6 – inside park, at 30 m from border	10.10 ±0.98	16.36 ±1.75	36.30 ±0.90	40.70 ±1.15	41.33 ±4.16	0.03 ±0.005	0.15 ±0.01	1583.33 ±163.72
	SP 7 – inside park, at 164 m from border	8.56 ±1.07	14.20 ±1.60	37.76 ±2.10	38.00 ±2.23	35.00 ±4.35	0.02 ±0.00	0.10 ±0.01	1315.00 ±186.67
	SP8 – inside park, at 275 m from border	10.86 ±1.42	18.50 ±2.26	35.03 ±1.05	39.66 ±0.66	45.00 ±6.08	0.03 ±0.00	0.14 ±0.01	1740.00 ±218.86
	SP9 – outside park, at 583 m from border	12.93 ±0.55	20.70 ±1.37	35.33 ±2.01	38.33 ±2.81	51.66 ±1.15	0.01 ±0.005	0.08 ±0.01	1938.66 ±80.32
Day 4	SP1 – outside park, at 93 m from park border	23.26 ±0.32	39.63 ±0.98	27.56 ±0.15	61.10 ±0.26	74.00 ±1.00	0.01 ±0.00	0.04 ±0.01	3551.00 ±47.46
	SP2 – outside park, at 55 m from park border	16.70 ±1.73	28.40 ±3.73	32.23 ±1.71	53.63 ±3.46	60.00 ±3.60	0.01 ±0.00	0.02 ±0.01	2571.66 ±278.5
	SP3 – on the park border	17.63 ±4.25	29.83 ±7.57	32.90 ±1.76	50.63 ±1.92	62.00 ±8.71	0.01 ±0.005	0.07 ±0.01	2690.33 ±597.53
	SP4 – inside park, at 10 m from border	15.80 ±2.83	26.63 ±4.16	32.76 ±0.90	51.03 ±1.00	58.33 ±5.85	0.01 ±0.005	0.04 ±0.01	2400.66 ±433.96
	SP5 – inside park, at 20 m from border	14.80 ±0.30	24.70 ±1.68	32.03 ±0.80	51.06 ±1.32	56.66 ±0.57	0.02 ±0.00	0.08 ±0.01	2254.33 ±122.78
	SP6 – inside park, at 30 m from border	13.40 ±1.15	23.06 ±1.97	30.16 ±0.30	54.40 ±0.52	53.00 ±2.00	0.02 ±0.00	0.09 ±0.01	2069.00 ±173.51
	SP 7 – inside park, at 164 m from border	16.76 ±0.05	29.20 ±0.52	33.56 ±1.04	49.06 ±1.68	60.66 ±0.57	0.01 ±0.005	0.05 ±0.01	2620.66 ±26.63
	SP8 – inside park, at 275 m from border	14.46 ±3.02	25.70 ±5.12	29.60 ±1.15	55.06 ±2.45	56.00 ±6.24	0.02 ±0.00	0.08 ±0.01	2436.00 ±484.90
	SP9 – outside park, at 583 m from border	18.63 ±5.29	31.83 ±8.94	30.76 ±1.41	51.36 ±3.35	64.33 ±11.37	0.01 ±0.00	0.03 ±0.02	2861.66 ±794.31

3.1. Particulate Matter PM$_{2.5}$

It was observed that in the first day of monitoring, for PM$_{2.5}$, there is a decreasing trend in its concentration as one moves deeper into the park (Figure 2). The measurement points SP1 – SP2 are located outside the park, in areas with high traffic and car congestion, and they served as control points against which the recorded values were compared. Thus, the measurement point SP3 is located right at the edge of the park, at the park entrance, and it is the first point where a significant decrease in PM2.5 is observed on Day 1 compared to the SP1 and SP2 points, with reductions of 22.92% and 29.3%, respectively (Figure 2)
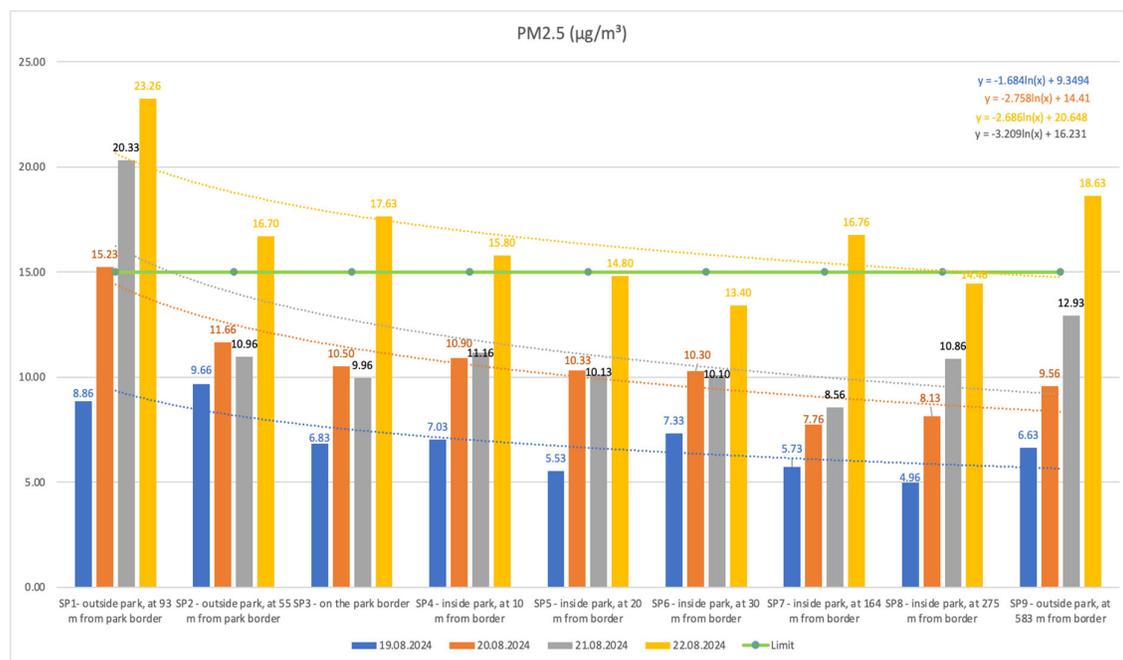
Figure 2. Evolution of air PM$_{2.5}$ concentrations ($\mu g/m^3$) in the sample points (SP), within the analyzed period, related to daily (24 h) WHO recommended limit.

As entering deeper into the park, oscillations in PM$_{2.5}$ values are observed, but the overall trend is a decrease compared to the values measured outside the park. At a distance of 20 meters inside the park (SP5), it was found that PM$_{2.5}$ values had decreased by 42.76% compared to the more distant exterior point (SP2) located 55 meters away from the park boundary. A point of interest was located in the middle of the vegetation, 275 meters from the park entrance (SP8), where a significant decrease in PM$_{2.5}$ values was observed compared to the park's exterior (SP2) (Table 5), specifically a reduction of 48.66% (Figure 2), meaning a substantial decrease, almost half of the concentration outside the park. We consider this effect is due to the presence of tree vegetation in the park, related to which other studies have shown that higher levels of urban green space are associated with decreased pollution levels [21; 32].

Some studies have shown that when aiming to avoid high concentrations of PM$_{2.5}$, it is not enough to have urban parks with vegetation; it is essential for these parks to contain trees [33]. However, there are also studies [34,35] indicating that in cities, PM$_{2.5}$ reduction has also occurred in built-up areas where the presence of buildings limits air ventilation and, consequently, air currents, suggesting that, at least from a physical perspective, buildings can serve as a physical source of limitation for PM$_{2.5}$ concentrations. This is supported by the results of this study, as it was observed that, at the monitoring point SP9, located 583 meters from the park in a square surrounded by buildings and devoid of vegetation, PM$_{2.5}$ concentrations were 31.37% lower compared to the exterior of the park, which is not bordered by buildings and lacks vegetation (SP2). This effect is comparable to the one recorded at the park entrance (SP3). When interpreting this result, we must also consider

that the points SP1, SP2, and SP9 share the characteristic of being located outside the studied urban park. However, they differ in that at SP9, access by vehicles is restricted, whereas at SP1 and SP2, vehicle traffic is intense. Other major sources for airborne particulate matter (such as industrial sources) were not considered, because the research site was located in the downtown of the city, without industrial objectives. Only the plant pollen could be a source [36,37] or the aeolian erosion of buildings, but these were as well excluded due to the seasonal moment of the monitoring and local meteorological conditions in the monitoring days. Regarding the presence of the cars, a study conducted in another city in Romania [38] showed that the noise produced by them plays an important role in the propagation of the particulate matter along with the sound, because the vehicle-related noise penetrates the atmosphere and the airborne particulate matter formed at the noise source are ulteriorly lifted in the atmosphere by the sound waves. The same study also showed that vehicles are responsible for raising dust particles into the atmosphere through the rolling of their tires. Therefore, we consider that the higher $PM_{2.5}$ values recorded at the exterior points SP1 and SP2 compared to the exterior point SP9 are also due to this factor (vehicle traffic), not just the absence of a mechanical barrier provided by buildings. However, these results also highlight the importance of urban morphology and architecture in achieving goals related to air quality in cities.

On the second day of monitoring, it was observed that the evolution of $PM_{2.5}$ concentrations was similar to that of the first day. On the night between Day 3 and Day 4, it rained, which we consider to be the cause of the significant increase in $PM_{2.5}$ concentrations on Day 4 compared to the previous days (Figure 2, Figure 3). Thus, on Day 4, after the rain during the night, $PM_{2.5}$ exceeded the daily maximum limit of 15 µg/m³ recommended by WHO [28] in almost all monitoring points, including inside the park (except for SP6 and SP8), situation that was not observed for any sample point on Day 1, and on Day 2 and Day 3 it was only observed at the point outside the park (SP1). Therefore, on Day 2, only at the point SP1 located outside the park was exceeded the limit recommended by WHO, and the same occurred on Day 3. The recorded results indicate that atmospheric humidity is a factor that counteracts the contribution of vegetation as a factor for reducing $PM_{2.5}$ concentrations in the air. Although no statistically significant correlation was found between $PM_{2.5}$ concentration and air relative humidity in the study (Figures 4–7), significant statistical differences (Table 5) regarding these parameters confirm what other researchers have found, namely that there is a strong positive correlation between air humidity and the increase in $PM_{2.5}$ concentration [39]. This suggests that, depending on the air humidity, both the quantitative variation of these particles and their deposition differ, as some studies have shown that $PM_{2.5}$ particles are enveloped with a hydrolayer within the condensing process, which determines an increased deposition [24]. It results that the presence of $PM_{2.5}$ particles in the atmosphere is influenced by atmospheric humidity and precipitation [22]. However, if we compare the $PM_{2.5}$ concentration in the air on Day 4 at SP1 and SP9, i.e. the points farthest from the park and thus from the presence of vegetation, we observe that it increased significantly compared to the other points (Figure 2), which strengthens the idea that vegetation remains a reliable factor for reducing $PM_{2.5}$ in the air.
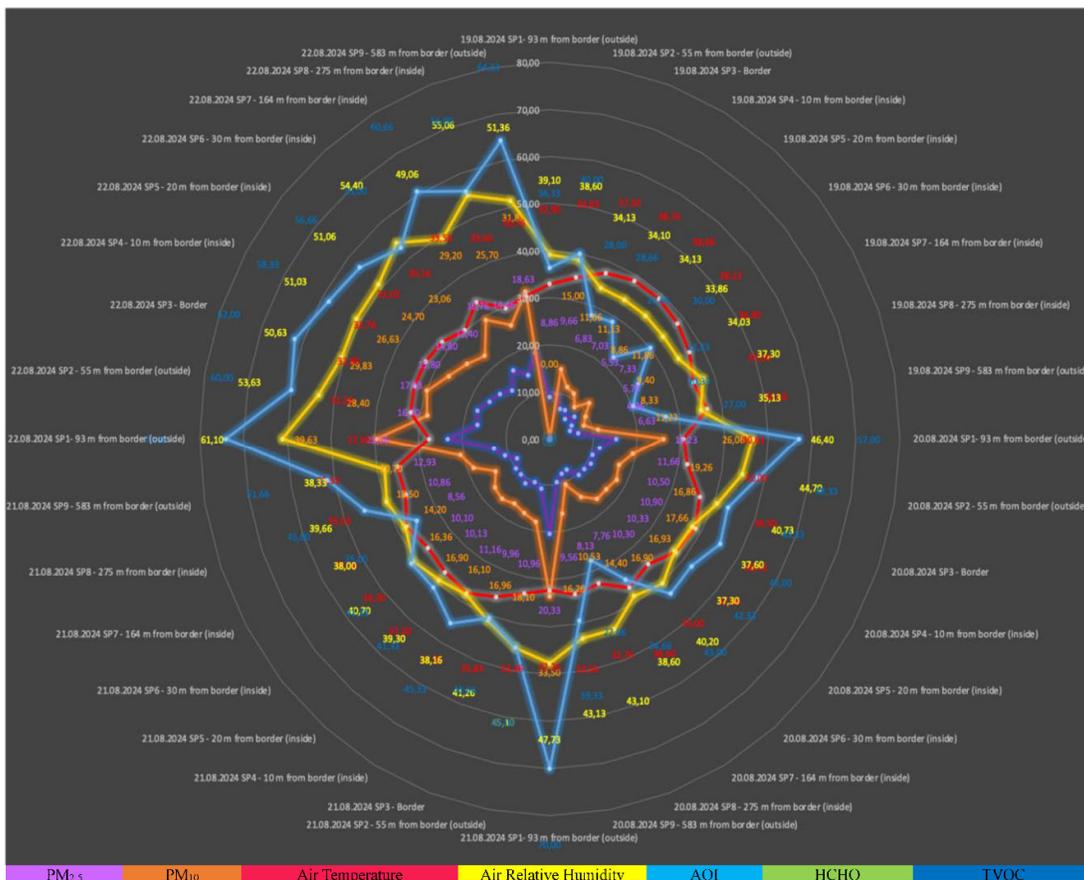
Figure 3. Dynamics of air parameters by sample points (SP) and days (because of the large differences between values, HCHO and TVOC are not visible on the chart although are present in the chart center).

Figure 4. Statistically significant correlations (Pearson correlations, *p*<0.05) between air quality parameters measured in the sample points (SP) – Day 1.

Correlations – 20.08.2024

		SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9
PM10	Pearson Correlation			(PM2.5) .998*						(PM2.5) .999*
	Sig. (2-tailed)			.044						.020
Air Temperature (T)	Pearson Correlation	(PM2.5) -.999*				(PM10) .999*				
	Sig. (2-tailed)	.028				.021				
Air Relative Humidity (ARH)	Pearson Correlation			(T) -1.000*	(T) -1.000**					
	Sig. (2-tailed)			.020	.003					
Air Quality Index (AQI)	Pearson Correlation		(PM 2.5) 1.000**	(PM10) 1.000** / (PM2.5) .998*	(PM2.5) 1.000**	(T) .998* / (PM10) 1.000* / (PM2.5) .998* / (PM2.5) .998*				(PM10) .999* / (PM2.5) 1.000*
	Sig. (2-tailed)		<.001	.004 / .039	<.001	.036 / .015 / .039 / .041				.032 / .012
HCHO	Pearson Correlation							(ARH) 1.000**		
	Sig. (2-tailed)							<.001		
TVOC	Pearson Correlation					(HCHO) 1.000**	(T) 1.000**	(PM 10) 1.000**		(ARH) .997* / (T) -.999*
	Sig. (2-tailed)					<.001	<.001	<.001		.048 / .027
Particles number	Pearson Correlation	(T) -.999* / (PM 2.5) 1.000**						(AQI) 1.000*	(AQI) 1.000**	(HCHO) -.997*
	Sig. (2-tailed)	.023 / .005						.014	.004	.046

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Figure 5. Statistically significant correlations (Pearson correlations, *p*<0.05) between air quality parameters measured in the sample points (SP) – Day 2.

Correlations – 21.08.2024

		SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9
PM10	Pearson Correlation	(PM2.5) 1.000**	(PM2.5) 1.000**							
	Sig. (2-tailed)	.010	.007							
Air Relative Humidity (ARH)	Pearson Correlation	(T) -1.000**		(T) -1.000**						(T) -1.000**
	Sig. (2-tailed)	.004		.009						.008
Air Quality Index (AQI)	Pearson Correlation	(PM10) 1.000** / (PM2.5) 1.000**	(ARH) 1.000**	(PM2.5) 1.000*	(PM2.5) .999*	(PM10) 1.000**	(PM2.5) 1.000**	(PM2.5) 1.000*	(PM2.5) 1.000*	
	Sig. (2-tailed)	.002 / .008	<.001	.013	.023	<.001	.009	.016	.015	
HCHO	Pearson Correlation				(ARH) .998*					(AQI) 1.000**
	Sig. (2-tailed)				.044					<.001
TVOC	Pearson Correlation			(HCHO) 1.000**			(ARH) .997*			
	Sig. (2-tailed)			<.001			.048			
Particles number	Pearson Correlation	(AQI) 1.000** / (PM10) 1.000** / (PM2.5) 1.000**	(PM10) .999* / (PM2.5) .998*	(AQI) .999* / (PM2.5) .998*			(HCHO) 1.000* / (PM10) .998*		(AQI) .999* / (PM2.5) 1.000**	
	Sig. (2-tailed)	<.001 / .002 / .008	.031 / .038	.029 / .043			.020 / .040		.022 / .007	

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Figure 6. Statistically significant correlations (Pearson correlations, *p*<0.05) between air quality parameters measured in the sample points (SP) – Day 3.

| Correlations -22.08.2024		SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9
PM10	Pearson Correlation	(PM2.5) .999*		(PM2.5) .998*						(PM2.5) .998*
	Sig. (2-tailed)	.035		.041						.039
Air Temperature (T)	Pearson Correlation		(PM2.5) -.998*			(PM 2.5) -.997*				
	Sig. (2-tailed)		.042			.046				
Air Relative Humidity (ARH)	Pearson Correlation	(PM2.5) .999*	(PM2.5) .998*	(T) -1.000**					(T) -1.000**	
	Sig. (2-tailed)	.022	.038	.002					.005	
Air Quality Index (AQI)	Pearson Correlation		(ARH) 1.000* / (PM2.5) .999*	(PM2.5) 1.000*	(PM10) .999* / (PM2.5) .999*		(PM2.5) .997*	(PM2.5) 1.000**	(ARH) -1.000* / (T) 1.000*	(PM10) .999* / (PM2.5) 1.000*
	Sig. (2-tailed)		.012 / .026	.017	.025 / .027		.048	<.001	.011 / .015	.026 / .013
TVOC	Pearson Correlation		(PM10) .998*		(ARH) -.998*	(AQI) -1.000**		(AQI) -1.000** / (PM2.5) -1.000**		
	Sig. (2-tailed)		.043		.037	<.001		<.001 / <.001		
Particles number	Pearson Correlation	(TVOC) -1.000**	(PM10) .997*	(AQI) 1.000** / (PM2.5) 1.000*	(PM2.5) .999*	(PM10) .998*				(AQI) .999* / (PM10) 1.000** / (PM2.5) .998*
	Sig. (2-tailed)	.008	.048	.006 / .011	.024	.042				.024 / .002 / .037
* Correlation is significant at the 0.05 level (2-tailed).										
** Correlation is significant at the 0.01 level (2-tailed).										

Figure 7. Statistically significant correlations (Pearson correlations, $p<0.05$) between air quality parameters measured in the sample points (SP) – Day 4.

The range of PM$_{2.5}$ concentrations measured in the air varied between 4.96 µg/m³ (inside the park, Day 1, SP8 – at 275 m from the border, among trees) and 23.26 µg/m³ (outside the park, Day 4, SP1 – at 93 m from the border, after rain) (Table 4, Figure 3). Although these data show the extremes of the measurements and only punctually exceed the daily limit recommended by WHO (15 µg/m³), when analyzing Table 4, very high values of this air parameter are observed compared to other values recorded in other cities. For example, a similar study conducted in Dublin (Ireland) showed air values of PM$_{2.5}$ by 6-7 µg/m³ [21], lower than those recorded in this study

The effect of vegetation caused the PM$_{2.5}$ values recorded in this study to remain lower inside the park, with significant increases only on Day 4 after precipitation falling, when the relative humidity of the air also increased. The concentrations were more frequently elevated outside the park, even at lower relative humidity levels in the atmosphere.

3.2. Particulate Matter PM$_{10}$

Regarding the PM$_{10}$ particles, it was observed that the dynamics of their concentration over the 4 consecutive days of monitoring generally resemble the trend of PM$_{2.5}$ concentrations, with a decreasing trend as entering further into the park. As with PM$_{2.5}$ particles, the lowest concentration was recorded in all monitoring days at point SP8, located deep within the park and surrounded by vegetation. These findings are similar with others showing an inverse association of urban green space with PM$_{2.5}$ and PM$_{10}$ [40]. For example, compared to SP2, which is located outside the park and 55 meters from its border, the PM$_{10}$ concentration at SP8, located in the heart of the vegetation, was 44.47% lower (Figure 8), a statistically significant difference (Table 5). None of the recorded PM10 concentrations exceeded the daily recommended limit of 45 µg/m³ set by WHO, nor the 50 µg/m³ limit enforced in Romania. As with PM$_{2.5}$ particles, a significant increase (Table 5) in PM$_{10}$ concentrations was observed on Day 4, following the precipitation that occurred overnight between Day 3 and Day 4.
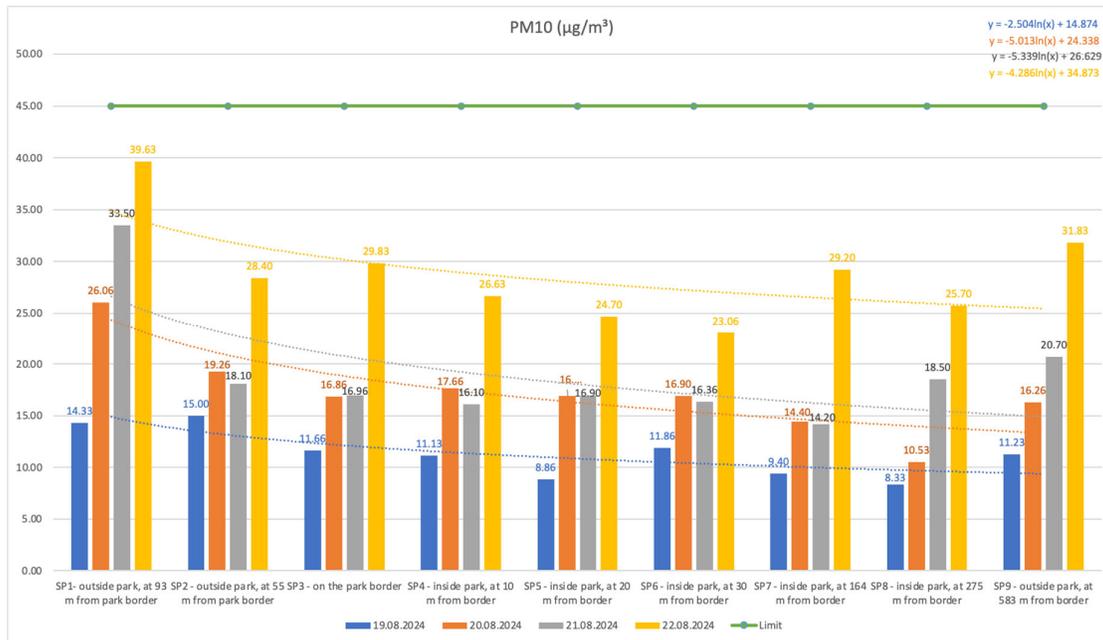
Figure 8. Evolution of air PM$_{10}$ concentrations (μg/m³) in the sample points (SP), within the analyzed period, related to daily (24 h) WHO recommended limit.

3.3. Air Quality Index (AQI)

The AQI values measured during the four consecutive days of monitoring are presented in Figure 9. The device used in this study calculates the AQI index exclusively based on the concentrations of PM$_{2.5}$ and PM$_{10}$, which is why this indicator follows the trends of the two parameters that determine it. According to the EPA's air quality standards, which specify a maximum AQI value of 50 for good air quality (Table 2), with no negative effects on the human population, it was found that, for this study, the AQI values indicated good air quality inside the park, except for Day 4, when the value was exceeded following the precipitation from the previous night, resulting in moderate air quality. At the monitoring point SP1, the farthest from the park and lacking the physical protection of buildings, but near vehicle routes, the AQI values for good air quality were exceeded on Days 2-4. Similarly, at SP9, between buildings and without vegetation, AQI values were exceeded on Days 3-4 (Figure 9), suggesting that proximity to an urban park, an area with vegetation, cannot fully compensate for the presence of vehicles that generate PM$_{2.5}$ and PM$_{10}$ particles.
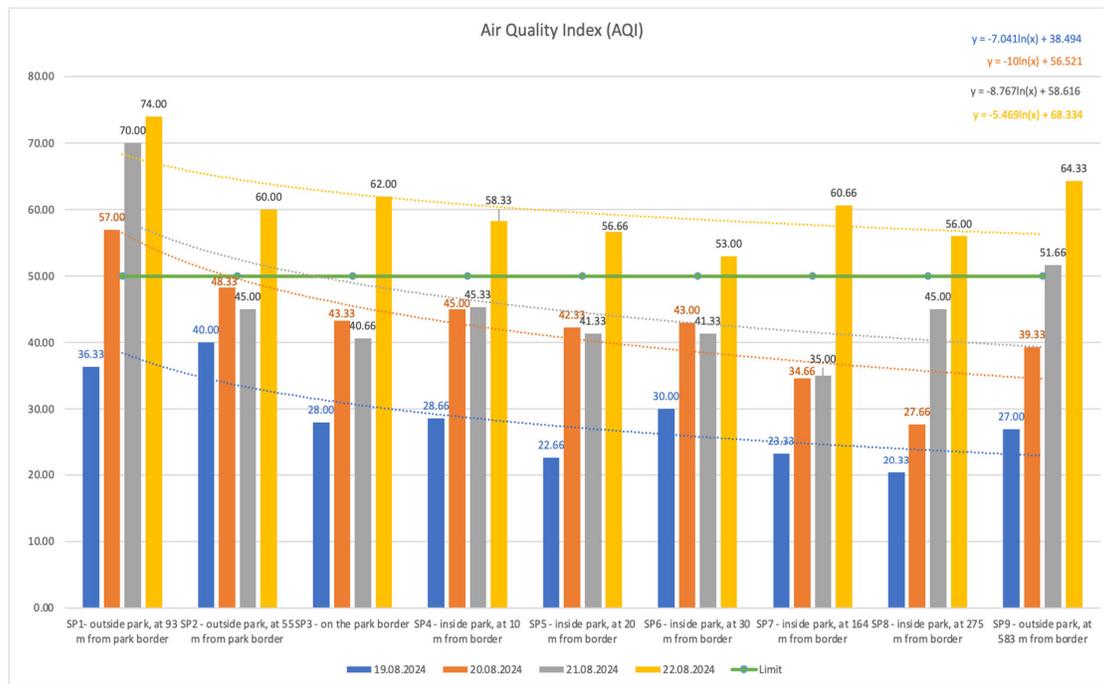
Figure 9. Evolution of Air Quality Index (AQI) in the sample points (SP), within the analyzed period, related to United States Environmental Protection Agency (EPA) Standards (limits).

Comparing Figures 2 and 8, it results that the contribution of $PM_{2.5}$ particles is more significant in determining AQI values, as the permissible concentrations for PM_{10} were not exceeded at any measurement point. Throughout the 4 days of monitoring, a decreasing trend in AQI values was observed at the inner points of the park (SP3-SP8) compared to the outer points (SP1, SP9). The SP8 point inside the park showed the lowest AQI values during the first two measurement days. In interpreting the AQI values, the relative humidity of the air at the time of measurement was also taken into account. Thus, it was observed that on days with higher humidity, inside the park, where tree vegetation is much denser, AQI values had an increasing trend, reflecting lower air quality compared to previous days with lower humidity (Figure 9, Figure 12), and similarly in the park's exterior. Therefore, the increase in AQI values was consistent on Day 4 compared to Day 1 at all sampling points, with the increase exceeding 50% in nearly all measurement points, except SP2 and SP6 (Figure 9). On Day 4, it was also found that AQI positively correlated with the relative humidity of the air in the park's exterior at SP2 (Figure 7), and negatively at SP8, located deeper within the vegetation (Figure 7). Similar results were found by Zender-Świercz et al. (2024) [22], who observed that AQI positively correlates with air humidity, especially when its values place the air quality in the unhealthy and moderate range. These results highlight the importance of air humidity in enhancing the concentration values of several air quality parameters ($PM_{2.5}$, PM_{10}, AQI) and in exceeding their admissible or recommendable limits. Statistically significant correlations were found between AQI and the concentrations of $PM_{2.5}$ and PM_{10} (Figures 4–7), but these were expected, considering that the AQI measured by the device used in the study is the expression of these two indicators, and since similar findings have been made in other studies of the same kind [22]. However, AQI correlated more frequently with $PM_{2.5}$ concentration than with PM10 concentration (Figures 4–7), indicating that $PM_{2.5}$ concentration carries more weight in determining its value.

3.4. Particles Number

The measurement of the particle count (pcs/L) in the air showed that inside the park, the number of particles was lower than outside throughout all 4 days (Figure 10). Similarly to other monitored indicators, on Day 4, after precipitation, the amount of particles in the air increased considerably compared to the previous days. Thus, at SP8, the point located the deepest within the vegetation, the particle count was the lowest compared to other inner points of the park; however, here, on Day 4, it was 64.73% higher than on Day 1, a significant and noteworthy difference (Table 5). These results highlight both the importance of vegetation and the impact of meteorological conditions, in this case the relative atmospheric humidity resulting from the precipitation that fell the night before, on the amount and dynamics of particles in the air. Atmospheric humidity influences the composition and concentration of particles in the air. In conditions of high humidity, hygroscopic particles absorb water, leading to an increase in their size and changes in their physico-chemical properties. This process can have a dual effect: on one hand, it can facilitate the deposition and removal of pollutants from the atmosphere through wet deposition, and on the other hand, in the presence of fog or secondary aerosols, it can lead to the formation of fine liquid particles that contribute to an increase in their atmospheric proportion due to their suspension in the air for varying periods of time.
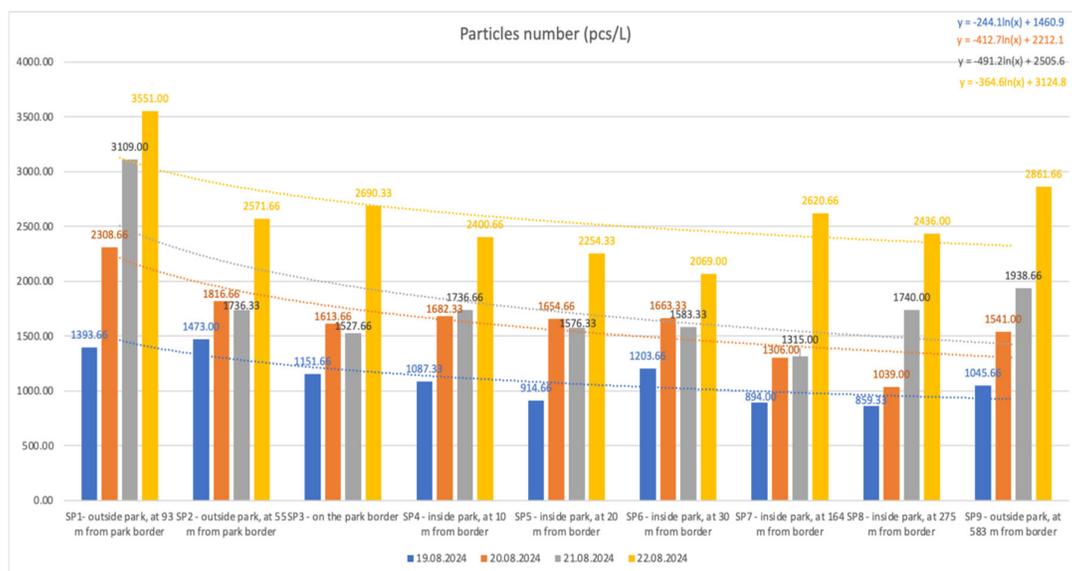

Figure 10. Evolution of air particles number (amount, pcs/L) in the sample points (SP), within the analyzed period.

Among the meteorological variables, it was found that air relative humidity can predict the accumulation of particulate matter [41]. Results supporting the involvement of the same factors in the dynamics of particulate matter in the air have also been found and explained in the literature [42]. The vegetation of the studied park is predominantly represented by trees, which have been found to reduce the amount of particles in the air through retention mechanisms at the leaf level [43,44], absorption at the stomata level [44], or dispersion [45]. However, the situation observed on Day 4, when the particle concentration in the air increased significantly after the precipitation compared to previous days, was contradictory to the estimated expectations, as the wet deposition effect of the particles reported by other studies [24] was not confirmed.

3.5. Air Temperature

Temperature monitoring was also conducted on all four days and sample points taken for the study. The hypothesis and expectations underlying the research were that, as entering further into the park, the air temperature would decrease. These expectations were based on studies [46–49]

showing that urban parks act as significant buffers against high temperatures during hot seasons. However, this hypothesis was not confirmed in the present study (Figure 11), as it was found that the air temperature was higher inside the park (SP3-SP8) than outside it (SP1, SP2, SP9) on almost all the days of measurement. Thus, the temperature differences between the park's exterior points and the interior points ranged from 1-6°C. A decrease in air temperature was observed on Day 4 compared to previous days, correlating with the rainfall the night before and the increase in relative humidity. Inside the park, the lowest air temperature was recorded at the point surrounded by tree vegetation, although this value remained approximately 2-3°C higher than the exterior of the park.
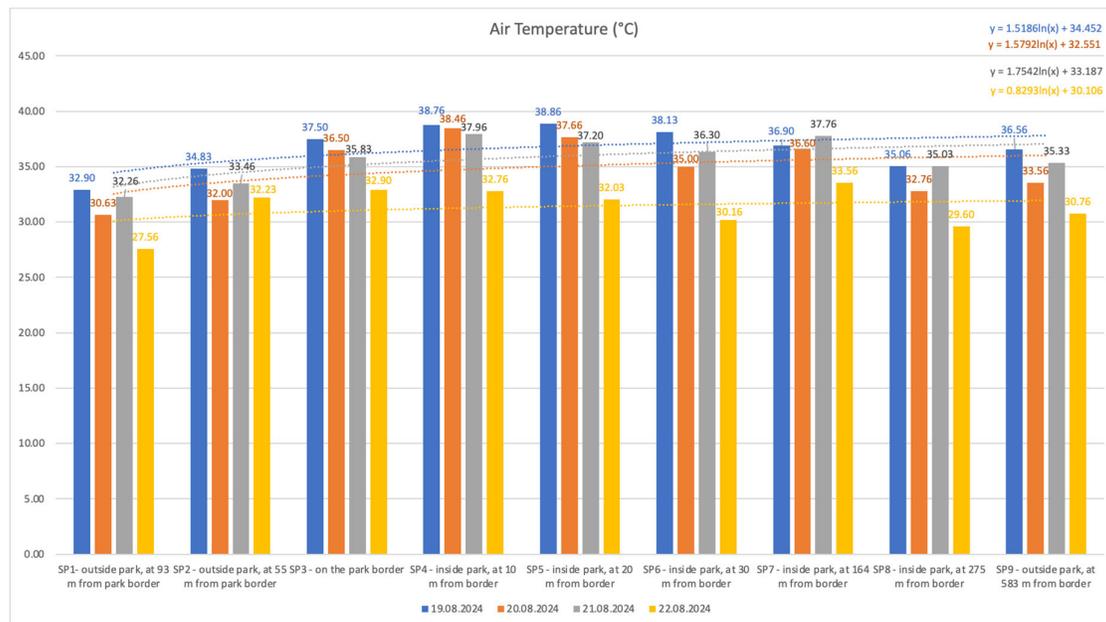
Figure 11. Evolution of air temperature (°C) in the sample points (SP), within the analyzed period.

These results, similar to the variation in PM2.5 and PM10 particles, support the contribution of urban vegetation to influencing the dynamics of air quality parameters in urban areas. A higher air temperature inside an urban green space than outside it has been reported in other urban studies [33], and it can be explained by several hypotheses. One explanation might be that within the park, air ventilation through air currents is insufficient to reduce the air temperature, as happens outside it, and this fact could be influenced by the morphology of the surrounding environmental characteristics, such as vegetation structure and distribution [50], canopy porosity [51], landscape composition and morphology [49], and the presence and density of buildings [52,53], as well as alley and building albedo [54]. The monitoring point SP8, was surrounded by trees, and is possible that plant evapotranspiration to contribute to the increased of air humidity through aerosol formation, as this point had the highest relative humidity. Aerosols and water vapors in the air can absorb solar radiation, determining an increase in air temperature [55]. As well, air humidity can influence the rate of evapotranspiration of vegetation in the park, and if this process is reduced, its cooling effect on the ambient air temperature diminishes or is overtaken by solar radiation absorption [56,57]. Other interior sample points in the park (SP2-SP7) were near concrete alleys, so it's possible that they released accumulated heat, thus increasing the air temperature. SP9 is situated in a square paved with concrete slabs and is lacked by vegetation, so it does not benefit from shading effects, as SP1 does, which is near a very tall building. Moreover, the presence of buildings can limit wind speed [58], and buildings and pavements absorb heat and release it, which could explain the additional 2-4°C observed at this point compared to other exterior points of the park (SP1 and SP2). It results from these data that it is not enough that an urban green space to be established, but its design must be integrated with urban morphology strategies if is aimed that the heat mitigation effect be achieved

and maximized in cities. In addition, besides technical elements of urban design and those vegetation-related, importance should be given to the soils of the parks as related to their impact on local temperature increases. Some studies have shown that soil impermeability plays an important role in raising air temperature in urban green spaces [59]. Soils in urban parks, especially in urban arboreta, are minimally disturbed technosols due to maintenance work, and therefore their compaction degree and impermeability may be high. Therefore, it should pay attention to other factors involved in maintaining soil permeability in urban parks, such as pedofauna, since its contribution to the soil permeability was demonstrated [60–62]. No significant and consistent correlations were found in this study between air temperature and other parameters, as some other studies have shown. For instance, some studies have indicated that air pollution amplify the intensity of the urban heat island effect especially when the green spaces have small sizes [63], while other studies support this idea, showing a strong correlation between air temperature $PM_{2.5}$ concentration [64] and that PM_{10} concentration increases when the temperature is low [65]. No significant positive correlation was found between air temperature and its relative humidity, meaning that other factors likely influenced the increase in air temperature inside the park compared to outside, possibly factors related to shading architecture [66], tree density [58], airflow [67], vegetation cover and layouts [68], or even alley surface materials. It is possible that the small size of the studied park (approximately 88 hectares) to be as well a factor which determined the increase of air temperature inside it compared to the outside, because it was found that larger parks with good vegetation (tree) coverage may better enhance the evapotranspiration rate and pollutant absorbtion, increasing thus their cooling effect [63]. A study [33] revealed that urban green spaces smaller than 525 hectares have a cooling effect only by approximately 1°C. Thus, our findings show the importance of the integrated urban green space design in maximizing the cooling benefits of the urban green spaces. This is aspect is very important when the urban park attendance is considered, as it may be affected [69] because people are specifically seeking the cooling effects of urban green spaces, and if this is absent, their thermal comfort level is not ensured.
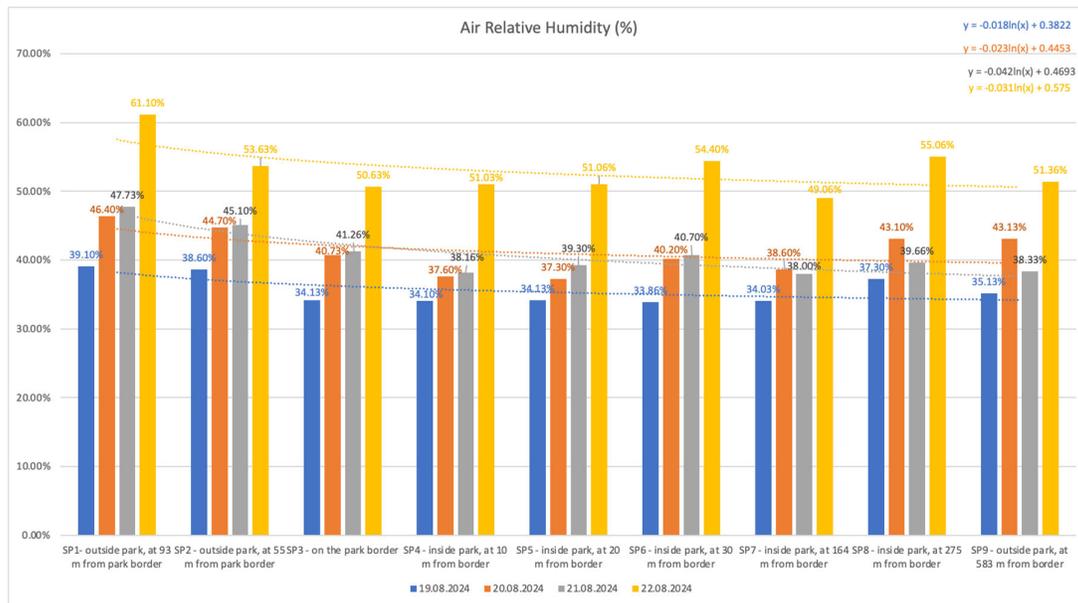
3.6. Air Relative Humidity

The relative humidity of the air decreased as entering deeper into the park (Figure 12) compared to the exterior points SP1 and SP2. However, when comparing the exterior points of the park, it was observed that the one located between buildings showed a lower air relative humidity than those near the park. It is possible that the proximity to vegetation be the reason for the higher air relative humidity around it, due to the evapotranspiration effect [66]. Clearly, as a result of the precipitation that occurred during the night from Day 3 to Day 4, the relative humidity of the air increased on Day 4 both inside the park, with values ranging from 30.64% (SP7) to 37.76% (SP6), and outside, with values ranging from 28.03% (SP2) to 36.01% (SP1). It was found that, inside the park, the relative humidity of the air increased the most in the point where the trees become denser (SP8), surrounded by tree vegetation, likely as a result of the evapotranspiration effect exhibited by the plants. However, it still remained lower than the air relative humidity outside the park.

The decrease in relative air humidity as advancing towards the interior of an urban park can possibly be explained by the connection between plant evapotranspiration and local warming. Since in the studied urban green space the air temperature increased compared to the exterior, it is possible that the trees in the park release water vapor through transpiration, but this process may also be accompanied by the absorption of solar radiation by the water vapor or aerosols, thus causing the air temperature to rise. If the air temperature increases within the park due to the retention of heat as a result of this mechanism, for which we suspect as primary cause the inefficient circulation of air masses, then the relative humidity of the air decreases.

Thus, an inverse proportional relationship between air temperature and air relative humidity results. This relationship was not statistically validated in this study, but that does not mean it does not exist, especially since it has been reported by other researches. For example, it has previously been shown that the urban heat island effect is due to the lack of humidity [70], which determines an

increase in air temperature, making cities warmer, and other studies have also found that increased atmospheric humidity was associated with higher air temperature, as well as with soil moisture and soil electrical conductivity in the first 5-7 cm of urban park soil [71]. The evapotranspiration of urban vegetation is a physiological process that influences urban air humidity, which in turn is an indicator of cities sustainability, as it has been shown to be strongly influenced by urbanization and directly related to the phenomenon of global warming [72]. However, at the microclimate level, some studies have shown that in urban parks, the shading effect of trees plays nearly three times larger role as evapotranspiration in cooling the environment [69]. The decrease in air relative humidity in cities has also been reported by other studies, which have shown that cities are, in this regard, urban dry islands [47], especially in the summer season in temperate cities [48,72]


Figure 12. Evolution of air relative humidity (%) in the sample points (SP), within the analyzed period.

Towards the edge of the park, it was observed that the relative humidity of the air is slightly higher. Some bibliographic sources have shown that at the edges of urban green spaces, air humidity can also be influenced by external sources that are not vegetation-related, such as the proximity of wet surfaces (lakes, fountains, sea) [33], or sources generating moisture, such as the humidity resulting from urban traffic and buildings [73]. The latter situation applies to the studied site and may explain the higher air relative humidity at the marginal sample points, because the park is surrounded by heavily trafficked roads and partially by buildings (Figure 1), and some studies have shown that traffic gas emissions tend to be bound with water particles [74] and remain suspended in the air, thus increasing air humidity. Other factors that could explain the lower relative humidity of the air inside the analyzed green space may include the absorption of moisture by vegetation and soil. The soil and tree foliage can retain moisture from the air, especially in the deeper areas of the park, where the vegetation layer is denser. This effect may lead to a local decrease in relative humidity because water vapor is absorbed by the leaves and soil before it can contribute significantly to the air humidity. Additionally, the effect of moist air consumption through condensation on leaves could be a cause, as, in certain situations, cooler leaves can condense water vapor from the air, reducing the relative humidity of the air [75].

3.7. Air Volatile Organic Compounds (TVOC)

The concentration of total volatile organic compounds (TVOCs) was monitored (Figure 13), and values comparable to those reported by other studies [76] were observed. An increase in TVOC

concentrations was noted inside the park compared to its exterior. Although we expected higher concentrations outside the park, specifically in SP1 and SP2, based on the argument that these points are closer to roadways where VOCs are more present due to incomplete fuel combustion and the fact that VOC abundances are generally concentrated very near their sources [77], the measurements showed the opposite. The increase in TVOC concentration inside the park is considered to have its source in the emissions of biogenic volatile organic compounds by the park vegetation [78]. As Bao et al. (2024) [79] have shown, these biogenic VOCs can lead to the formation of secondary pollutants (ozone, organic aerosols) in the urban green areas, but they can also enhance human health (emotional balance, immunity). The same study reported a contribution of approximately 20% of biogenic VOCs to the total VOCs. The recommended limit by the WHO [27,77,80] (0.3-0.5 mg/m³ as emissions) was not exceeded for this parameter.
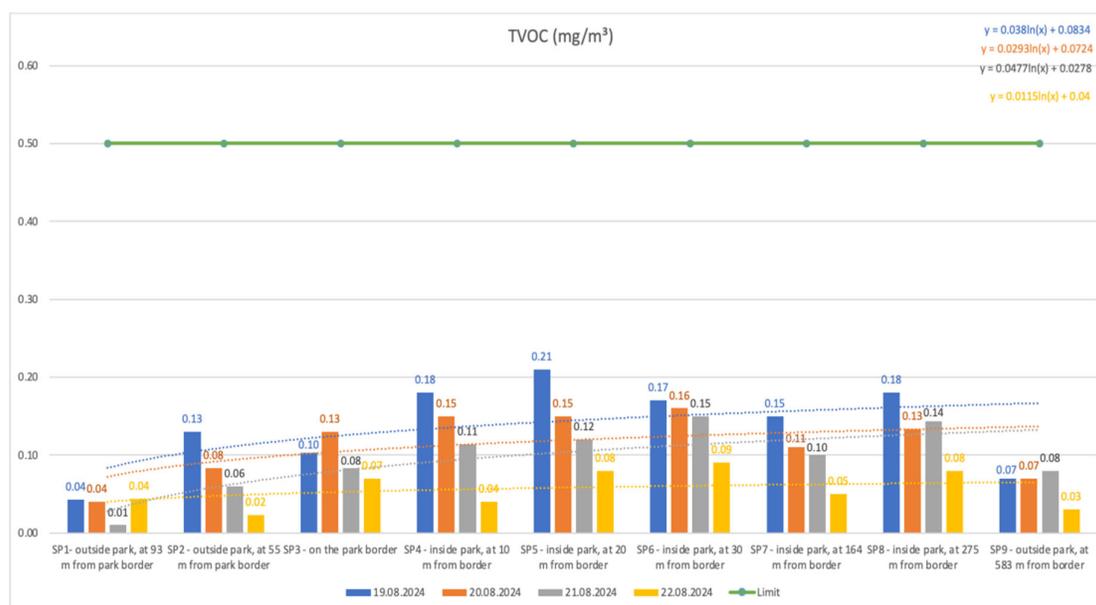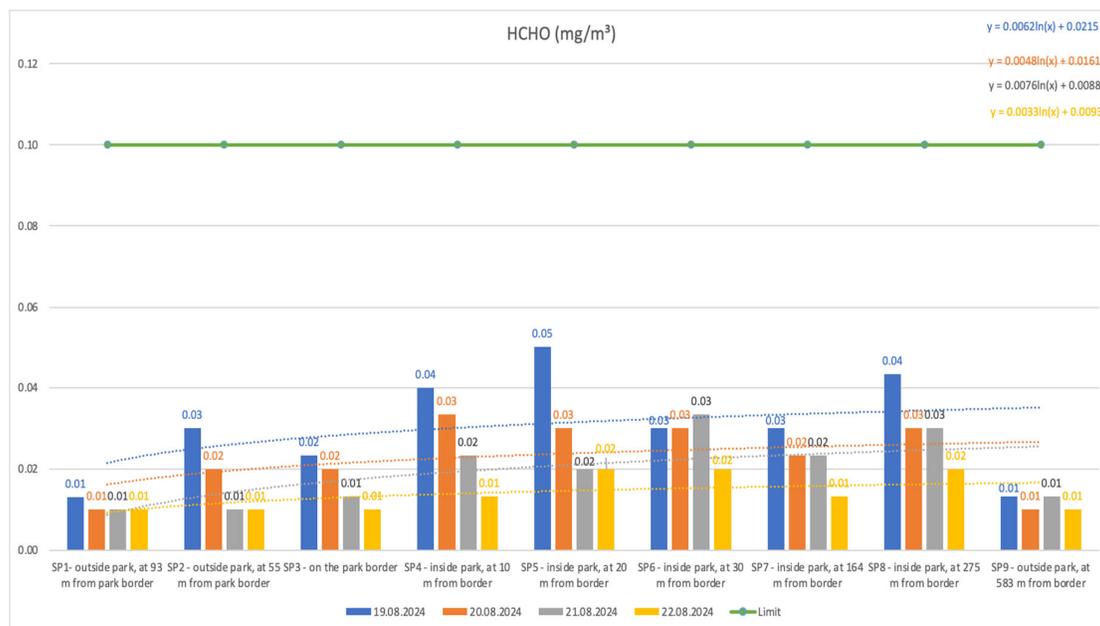

Figure 13. Evolution of total volatile organic compounds (TVOC) concentrations (mg/m³) in the sample points (SP), within the analyzed period related to daily (24 h) WHO recommended limit.

The daily measured values ranged from 0.01 to 0.21 mg/m³, with the highest value recorded in SP5 inside the park, and the lowest in SP1 outside the park. This indicator did not show increases on Day 4, when air relative humidity was high; on the contrary, its concentration decreased on this day. However, the statistically significant correlations observed (Figures 4–7) were contradictory. Thus, in our study, TVOC was positively correlated with air relative humidity during the first three days of monitoring, both inside and outside the park (Figures 4–6), but negatively correlated inside the park on the fourth day (Figure 7), when the air relative humidity was higher after previous precipitation, confirming the inverse proportionality relationship between TVOC and relative humidity on Day 4. In attempting to find out what could determine the increase of TVOC concentration when air relative humidity decreases inside the monitored urban green space, frequently invoqued were physico-chemical and biological mechanisms. Thus, TVOC may interact with the water vapors. Studies have strongly suggested that VOC ability to form hydrogen bonds is a key factor of VOC transfer in the condensed water when the air relative humidity was high [81]. This could explain our findings, because in conditions of decreasing air humidity, this bond formation may be reduced and VOC remain suspended in the atmosphere. Other studies revealed that an increase of the air temperature can reduce the effect of the air relative humidity on VOC removal [82], which can explain why in our study there was found an inverse relationship between air temperature and air humidity simultaneously with TVOC increase. Also, it was found that TVOC was negatively corelated with the

content of PM$_{2.5}$ and with AQI in SP8, inside vegetation. Lopes et al. (2025) [63] showed that air PM$_{2.5}$ interacts with gases and influence several chemical reactions involving VOC in the athmosphere.

3.8. Air Formaldehyde (HCHO)

The formaldehyde (HCHO) is a VOC substance. Monitoring of formaldehyde (HCHO) concentration in the studied park (Figure 14) was decided based on the argument that in cities there are both natural sources of formaldehyde (emissions from vegetation due to metabolic processes, decomposition of organic matter, organic photodegradation, emissions from the soil) and anthropogenic sources (urban pollution from industrial sources, vehicle exhaust gases, urban furniture, smoking), as well as because its implications on human health (carcinogenic nature). However, the most significant contributor to formaldehyde emissions in the urban areas is the incomplete combustion of the motor vehicle [83] and heating systems [84]. Urban parks, especially arboretums and those dominated by woody vegetation, are both sources of formaldehyde originated from biotic VOCs, which can be dispersed into the atmosphere and reach areas outside the parks, but they can also act as attenuators of this volatile organic compound's concentration in the air, as vegetation can absorb and partially degrade formaldehyde through complex chemical and biological processes specific to phytoremediation [85]. A first hypothesis in the research was that formaldehyde levels would not be too high in the studied park, based on the results of many studies that confirmed this fact, as well as on the consideration that the park is located in the central area of the city, where there are no industrial sources likely to emit formaldehyde, although there is still, in the vicinity of the park, the source of the exhaust gasses of the vehicles, which was taken into account for a second hypothesis, namely that, due to this factor, but also because the plants are capable of HCHO phytoremediation, the park would have lower HCHO concentrations than its exterior. The first hypothesis was confirmed, so that the formaldehyde levels were below the recommended WHO limit (<0.1 mg/m^3) in all monitoring points (Figure 14), with concentrations ranging from 0.01-0.05 mg/m^3. However, the second hypothesis was not confirmed, as it was found that the formaldehyde concentration inside the park was up to 4-5 times higher compared to the exterior.

Figure 14. Evolution of formaldehyde (HCHO) concentrations (mg/m^3) in the sample points (SP), within the analyzed period related to daily (24 h) WHO recommended limit.

The highest HCHO concentration was recorded 20 meters from the park's boundary towards the interior, specifically at SP5 (Figure 14), which is located in the close proximity of the roadway, heavily trafficked during the measurement period (especially because the monitored site is an ultracentral area of the city and the measurements were performed in the first working days of the week). Therefore, we consider that the contribution of exhaust gases plays a determining role in establishing the HCHO concentration at this point. The same as TVOC, HCHO concentrations did not increase on Day 4 following precipitation; on the contrary, they decreased compared to the previous days. This effect is likely due to the fact that HCHO is very water soluble [24] and the wet deposition has occured.

In contrast, the differences in HCHO concentration are significant between the exterior and interior of the park, being 2 to 5 times higher inside than outside (Figure 14, Table 5). Explaining these results is difficult, as other analyses were not included in the current study. However, if we consider the factor of road traffic, it is possible that this not be the cause, since studies have shown high HCHO concentrations even in rural air with low traffic levels, due to photochemical reactions [86,87]. The formaldehyde is easily photolyzed and therefore it has short lifetime. As the points inside the park recorded the highest HCHO concentrations and not the points outside it, which were the closest to the source of car traffic, it is possible that, here too, the cause of the increased HCHO concentration is not road traffic, but rather the photochemical reactions [88] of biogenic VOCs. The photolysis and photooxidation of organic compounds can lead to formaldehyde formation in the atmosphere [89]. The biogenic VOC emitted by vegetation as response to the environmental stressors are major driver of air formaldehyde variability [90], because the biogenic VOC are precursors of HCHO. The relationship between biogenic volatile organic compounds and formaldehyde is so tight that it can be used as indirect tool to determine the biogenic VOC levels in the air [91]. Thus, HCHO emissions in the studied park may serve as an indicator of biogenic VOCs released in response to thermal stress, given the elevated air temperatures recorded during the monitoring period. Sporadically, on certain monitoring days and in specific sample points, but always located inside the urban green space (Figures 4–7), positive correlations were found between HCHO concentration and air relative humidity, which contradicts previous results that showed an inverse relationship between formaldehyde concentrations and relative humidity [92]. The fact that the dynamics of HCHO concentrations followed the trend of TVOC concentrations in the study area, along with the finding that HCHO and TVOC concentrations were lower outside the urban park than inside, suggests that HCHO concentration inside the green space is the result of the photochemical oxidation of VOCs caused by intense sunlight during the summer monitoring period. However, the phytoremediation ability of vegetation in the urban green space should be considered and supported, through several urban planning strategies that can enhance and valuate this ability of urban vegetation in HCHO purification, such as strategies regarding the species combination or architectural arrangements that favour the enxymatic apparatus of the green plants involved in the HCHO phytoremediation, for which they have been referred to as the "green liver" [93] of the planet.

Table 5. Statistical significant differences (Paired-samples *t*-test, $p<0.05$) between sample points (SP) regarding the values of the measured air parameters, within the analyzed period.

Crt. No.	Statistically significant differences (Paired-samples *t*-test, $p<0.05$) regarding the air quality parameters between sample points (SP) – Day 1							
	Air parameter							
	PM$_{2.5}$	PM$_{10}$	AQI	Particles number	Air Relative Humidity	Air Temperature	TVOC	HCHO
1	SP2 - SP7	SP2 - SP7	SP2 - SP7	SP2 - SP4	SP1 - SP2	SP1 - SP2	SP1 - SP2	SP1 - SP4
2	SP2 - SP8	SP3 - SP5	SP2 - SP8	SP3 - SP5	SP1 - SP3	SP1 - SP3	SP1 - SP4	SP1 - SP5
3	SP3 - SP5	SP3 - SP8	SP3 - SP5	SP5 - SP6	SP1 - SP4	SP1 - SP4	SP1 - SP5	SP1 - SP6
4	SP3 - SP8	SP4 - SP5	SP3 - SP8	-	SP1 - SP5	SP1 - SP5	SP1 - SP6	SP1 - SP7
5	SP4 - SP7	SP4 - SP8	SP4 - SP7	-	SP1 - SP6	SP1 - SP6	SP1 - SP7	SP2 - SP5
6	SP4 - SP8	SP5 - SP6	SP4 - SP8	-	SP1 - SP7	SP1 - SP7	SP1 - SP8	SP2 - SP9

No.	PM2.5	PM10	AQI	Particles number	Air Relative Humidity	Air Temperature	TVOC	HCHO
7	SP5 - SP6	-	SP5 - SP6	-	SP1 - SP8	SP1 - SP8	SP2 - SP5	SP3 - SP5
8	SP6 - SP8	-	-	-	SP1 - SP9	SP1 - SP9	SP2- SP8	SP3 - SP6
9	-	-	-	-	SP2 - SP3	SP2 - SP3	SP2 - SP9	SP4 - SP9
10	-	-	-	-	SP2 - SP4	SP2 - SP4	SP3 - SP4	SP5 - SP6
11	-	-	-	-	SP2 - SP5	SP2 - SP5	SP3 - SP5	SP5 - SP9
12	-	-	-	-	SP2 - SP6	SP2 - SP6	SP3 - SP6	SP6 - SP9
13	-	-	-	-	SP2 - SP7	SP2 - SP7	SP4 - SP5	SP7 - SP9
14	-	-	-	-	SP2 - SP8	SP2 - SP9	SP4 - SP9	SP8 - SP9
15	-	-	-	-	SP2 - SP9	SP3 - SP4	SP5 - SP6	-
16	-	-	-	-	SP3 - SP8	SP3 - SP5	SP5 - SP9	-
17	-	-	-	-	SP4 - SP8	SP3 - SP8	SP6 - SP9	-
18	-	-	-	-	SP5 - SP8	SP3 - SP9	SP7 - SP9	-
19	-	-	-	-	SP6 - SP8	SP4 - SP7	SP8 - SP9	-
20	-	-	-	-	SP6 - SP9	SP4 - SP8	-	-
21	-	-	-	-	SP7 - SP8	SP4 - SP9	-	-
22	-	-	-	-	-	SP5 - SP6	-	-
23	-	-	-	-	-	SP5 - SP7	-	-
24	-	-	-	-	-	SP5 - SP8	-	-
25	-	-	-	-	-	SP5 - SP9	-	-
26	-	-	-	-	-	SP6 - SP7	-	-
27	-	-	-	-	-	SP6 - SP8	-	-
28	-	-	-	-	-	SP7 - SP8	-	-

Statistically significant differences (Paired-samples *t*-test, $p<0.05$) regarding the air quality parameters between sample points (SP) – Day 2

No.	Air parameter							
	PM2.5	PM10	AQI	Particles number	Air Relative Humidity	Air Temperature	TVOC	HCHO
1	SP1 - SP2	SP1 - SP2	SP1 - SP2	SP1 - SP2	SP1 - SP2	SP1 - SP2	SP1 - SP2	SP1 - SP3
2	SP1 - SP3	SP1 - SP3	SP1 - SP3	SP1 - SP3	SP1 - SP3	SP1 - SP3	SP1 - SP3	SP1 - SP4
3	SP1 - SP4	SP1 - SP4	SP1 - SP4	SP1 - SP4	SP1 - SP4	SP1 - SP4	SP1 - SP4	SP1 - SP5
4	SP1- SP5	SP1 - SP5	SP1 - SP5	SP1 - SP5	SP1 - SP5	SP1 - SP5	SP1 - SP5	SP1 - SP6
5	SP1 - SP6	SP1 - SP6	SP1 - SP6	SP1 - SP6	SP1 - SP6	SP1 - SP6	SP1 - SP6	SP1 - SP7
6	SP1 - SP7	SP1 - SP7	SP1 - SP7	SP1 - SP7	SP1 - SP7	SP1 - SP7	SP1 - SP7	SP2 - SP4
7	SP1 - SP8	SP1 - SP8	SP1 - SP8	SP1 - SP8	SP1 - SP8	SP1 - SP8	SP1 - SP8	SP2 - SP5
8	SP1 - SP9	SP1 - SP9	SP1 - SP9	SP1 - SP9	SP1 - SP9	SP1 - SP9	SP2 - SP3	SP2 - SP6
9	SP2 - SP7	SP2 - SP3	SP2 - SP7	SP2 - SP7	SP2 - SP3	SP2 - SP3	SP2 - SP4	SP4 - SP9
10	SP2 - SP8	SP2 - SP6	SP2 - SP8	SP2 - SP8	SP2 - SP4	SP2 - SP4	SP2 - SP5	SP5 - SP7
11	SP4 - SP7	SP2 - SP7	SP3 - SP8	SP3 - SP8	SP2 - SP5	SP2 - SP5	SP2 - SP6	SP5 - SP9
12	SP4 - SP8	SP2 - SP8	SP4 - SP7	SP4 - SP7	SP2 - SP6	SP2 - SP6	SP2 - SP7	SP6 - SP7
13	SP5 - SP8	SP3 - SP8	SP4 - SP8	SP4 - SP8	SP2 - SP7	SP2 - SP7	SP2 - SP8	SP8 - SP9
14	SP6 - SP7	SP4 - SP7	SP5 - SP7	SP5 - SP7	SP2 - SP8	SP2 - SP9	SP3 - SP4	-
15	SP6 - SP8	SP4 - SP8	SP6- SP7	SP5 - SP8	SP3 - SP4	SP3 - SP4	SP3 - SP7	-
16	-	SP5 - SP7	SP6 - SP8	SP6 - SP7	SP3 - SP5	SP3 - SP8	SP3 - SP9	-
17	-	SP5 - SP8	-	SP6 - SP8	SP3 - SP7	SP3 - SP9	SP4 - SP7	-
18	-	SP6 - SP7	-	SP8 - SP9	SP3 - SP9	SP4 - SP6	SP4 - SP9	-
19	-	SP6 - SP8	-	-	SP4 - SP6	SP4 - SP7	SP5 - SP7	-
20	-	SP8 - SP9	-	-	SP4 - SP8	SP4 - SP8	SP5 - SP9	-
21	-	-	-	-	SP4 - SP9	SP4 - SP9	SP6 - SP7	-
22	-	-	-	-	SP5 - SP6	SP5 - SP6	SP6 - SP8	-
23	-	-	-	-	SP5 - SP8	SP5 - SP8	SP6 - SP9	-
24	-	-	-	-	SP5 - SP9	SP5 - SP9	SP7 - SP8	-
25	-	-	-	-	SP6 - SP8	SP6 - SP8	SP7 - SP9	-
26	-	-	-	-	SP7 - SP8	SP7 - SP8	SP8 - SP9	-
27	-	-	-	-	SP7 - SP9	SP7 - SP9	-	-

No.	Statistically significant differences (Paired-samples *t*-test, $p<0.05$) regarding the air quality parameters between sample points (SP) – Day 3
	Air parameter

	PM$_{2.5}$	PM$_{10}$	AQI	Particles number	Air Relative Humidity	Air Temperature	TVOC	HCHO
1	SP2 - SP3	SP1 - SP4	SP1 - SP4	SP2 - SP3	SP1- SP3	SP1 - SP3	SP1 - SP2	SP1- SP4
2	SP2 - SP7	SP2 - SP7	SP1 - SP6	SP2 - SP7	SP1- SP4	SP1 - SP4	SP1 - SP3	SP1 - SP5
3	SP2 - SP9	SP3 - SP7	SP1 - SP8	SP3 - SP9	SP1 - SP5	SP1 - SP5	SP1 - SP4	SP1 - SP6
4	SP3 - SP9	SP3 - SP9	SP2- SP3	SP5 - SP9	SP1 - SP6	SP1 - SP7	SP1 - SP5	SP1 - SP7
5	SP5 - SP9	SP5 - SP7	SP2 - SP7	SP6 - SP9	SP1- SP7	SP1 - SP9	SP1 - SP6	SP2 - SP4
6	SP6 - SP9	SP5 - SP9	SP2 - SP9	SP7 - SP9	SP1 - SP8	SP2 - SP3	SP1 - SP7	SP2 - SP5
7	SP7 - SP9	SP6 - SP8	SP3 - SP9	-	SP1 - SP9	SP2 - SP4	SP1 - SP8	SP2 - SP6
8	SP8 - SP9	SP6 - SP9	SP5 - SP9	-	SP2 - SP3	SP2 - SP5	SP1 - SP9	SP2 - SP7
9	-	SP7 - SP8	SP6 - SP9	-	SP2 - SP4	SP2 - SP6	SP2 - SP4	SP3 - SP6
10	-	SP7 - SP9	SP7 - SP9	-	SP2 - SP5	SP2 - SP7	SP2 - SP5	SP3 - SP8
11	-	-	-	-	SP2 - SP6	SP3 - SP7	SP2- SP6	SP6 - SP9
12	-	-	-	-	SP2 - SP7	SP4 - SP5	SP2 - SP7	SP8 - SP9
13	-	-	-	-	SP2 - SP8	SP4 - SP6	SP2- SP8	-
14	-	-	-	-	SP2 - SP9	SP4 - SP8	SP3 - SP6	-
15	-	-	-	-	SP3 - SP7	SP5 - SP8	SP3- SP8	-
16	-	-	-	-	SP3 - SP9	SP6 - SP8	SP4 - SP6	-
17	-	-	-	-	SP4 - SP5	SP7 - SP9	SP4 - SP8	-
18	-	-	-	-	SP4 - SP6	-	SP4 - SP9	-
19	-	-	-	-	SP4 - SP8	-	SP5 - SP9	-
20	-	-	-	-	-	-	SP6 - SP7	-
21	-	-	-	-	-	-	SP6 - SP9	-
22	-	-	-	-	-	-	SP7 - SP8	-
23	-	-	-	-	-	-	SP8 - SP9	-

Statistically significant differences (Paired-samples t-test, $p<0.05$) regarding the air quality parameters between sample points (SP) – Day 4

No.	Air parameter							
	PM$_{2.5}$	PM$_{10}$	AQI	Particles number	Air Relative Humidity	Air Temperature	TVOC	HCHO
1	SP1 - SP2	SP1 - SP2	SP1 - SP2	SP1 - SP2	SP1 - SP2	SP1 - SP2	SP1 - SP5	-
2	SP1 - SP4	SP1 - SP4	SP1 - SP4	SP1 - SP4	SP1 - SP3	SP1 - SP3	SP1 - SP6	-
3	SP1 - SP5	SP1 - SP5	SP1 - SP5	SP1 - SP5	SP1 - SP4	SP1 - SP4	SP1 - SP8	-
4	SP1 - SP6	SP1 - SP6	SP1 - SP6	SP1 - SP6	SP1 - SP5	SP1 - SP5	SP2 - SP3	-
5	SP1 - SP7	SP1 - SP7	SP1 - SP7	SP1 - SP7	SP1 - SP6	SP1 - SP6	SP2 - SP5	-
6	SP1 - SP8	SP1 - SP8	SP1 - SP8	SP1 - SP8	SP1 - SP7	SP1 - SP7	SP2 - SP6	-
7	SP2 - SP6	SP2 - SP4	SP2 - SP6	SP2 - SP6	SP1 - SP8	SP1 - SP8	SP2 - SP7	-
8	SP5 - SP7	SP2 - SP6	SP3 - SP8	SP5 - SP6	SP1 - SP9	SP1 - SP9	SP2 - SP8	-
9	SP6 - SP7	SP4 - SP6	SP5 - SP6	SP5 - SP7	SP2 - SP7	SP2 - SP7	SP3 - SP4	-
10	-	SP5 - SP7	SP5 - SP7	SP6 - SP7	SP2 - SP9	SP2 - SP9	SP3 - SP7	-
11	-	SP6 - SP7	SP6 - SP7	-	SP3 - SP6	SP4 - SP6	SP4 - SP5	-
12	-	-	-	-	SP3 - SP8	SP4 - SP8	SP4 - SP6	-
13	-	-	-	-	SP4 - SP6	SP4 - SP9	SP4 - SP7	-
14	-	-	-	-	SP4 - SP7	SP5 - SP6	SP4- SP8	-
15	-	-	-	-	SP5 - SP6	SP5 - SP8	SP6 - SP7	-
16	-	-	-	-	SP5 - SP8	SP6 - SP7	SP6 - SP9	-
17	-	-	-	-	SP6 - SP7	SP7 - SP8	SP7 - SP8	-
18	-	-	-	-	-	SP7 - SP9	SP8 - SP9	-
19	-	-	-	-	-	SP8 - SP3	-	-

Conclusions

The results of this study showed that the studied urban green space confirmed what other studies have also found, namely that urban vegetation and the establishment of green spaces in cities contribute to maintaining air quality, at least in terms of the studied aspects, specifically PM2.5 and PM10 concentrations and AQI values. The results indicated that urban vegetation remains a reliable factor in reducing PM2.5 and PM10 levels in cities air, but the air relative humidity proved to be a

counteracting factor that diminishes the contribution of vegetation in decreasing PM2.5 and PM10 concentrations and in maintaining an AQI corresponding to good air quality. This study highlights the importance of air humidity in enhancing the values of PM2.5, PM10, and AQI and in exceeding their admissible or recommended limits for air quality. The effect of wet deposition of airborne particles, as reported by other studies in relation to precipitation, was not confirmed by this study.

Inside the park, HCHO concentrations increased by up to 4-5 times compared to the exterior. Since the highest HCHO concentrations were recorded at points inside the park and not at exterior points closest to the traffic source, it is possible that the increased HCHO concentration is not due to road traffic but rather to the photochemical reactions of biogenic VOCs.

Regarding the air temperature cooling effect, the studied green space showed results contrary to other findings in the field, revealing an increase in air temperature of up to 1-6°C inside the park compared to the exterior. This means that it did not achieve the goal of providing climatic comfort to citizens during the summer or serving as a cooling spot in the city. Our results contrast with the general perception and conviction that urban parks and green spaces are cooler islands within cities. Our findings draw attention that simply having a green space in a city does not necessarily mean achieving environmental objectives such as reducing the heat risk of cities or enhancing air quality, as some monitored parameters registered higher values inside the green space than outside.

In this study, based on the results, we consider that the main limitations in achieving these goals were the small size of the park (88 hectares) and its morphology and architecture, which resulted from the integration of the species that compose it. These findings suggest that establishing an urban green space is not sufficient; rather, its design must align with urban morphology strategies if the heat mitigation effect is to be achieved and cooling benefits are to be maximized in cities. This aspect is very important when it comes to urban park attendance by the population, because it could be affected, as people seek exactly the cooling effect of urban green spaces, and if this effect lacks, their thermal comfort is not ensured. Therefore, in urban planning, environmental strategies should comprise not only aesthetic criteria but also scientific criteria in order to reach the ultimate goal of urban green spaces in cities: a sustainable, healthy, and comfortable environment.

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