



The Role of Street Trees in Mitigating Particulate Matter Pollution: A Case Study of PM_{2.5} and PM₁₀ Concentrations in Urban Street Canyon

Pasita Ngowpradit¹, Wanarat Konisranukul^{1*} and Yaowatat Boongla¹

¹Faculty of Science and Technology, Thammasat University, Pathumthani 12120, Thailand

*E-mail : kwanarat@gmail.com

Article History; Received: 11 October 2025, Accepted: 19 January 2026, Published: 28 April 2026

Abstract

This study evaluates the effectiveness of street trees in reducing particulate matter (PM_{2.5} and PM₁₀) concentrations in an urban street canyon along Sukhumvit Road, Samut Prakan Municipality, Thailand. Field measurements were conducted at pedestrian level (1.5 m height) across three sidewalk microenvironments: beneath tree canopies, between trees, and in open, non-vegetated areas. Real-time particle counters monitored PM levels, temperature, humidity, and wind speed over a two-week period. Results demonstrated consistently lower PM concentrations on sidewalk with street trees. Relative Difference in Concentration (RDC) analysis revealed negative values for 70.8% of PM_{2.5} (17/24) and 75.0% of PM₁₀ (18/24) measurements, with average reductions of 3.74% and 4.11%, respectively, beneath tree canopies. Statistical analysis (ANOVA) confirmed significant PM₁₀ reduction ($p = 0.030$), while PM_{2.5} differences were marginally non-significant ($p = 0.058$). Tree canopies also moderated microclimate conditions, lowering ambient temperature by 0.33°C and wind speed by 0.83 m/s compared to non-vegetated areas. These findings highlight street trees as effective, sustainable interventions for urban air quality improvement, particularly for coarse particle (PM₁₀) mitigation. The study provides actionable insights for urban planners and policymakers advocating nature-based solutions in high-density built environments.

Keywords : street trees; PM_{2.5}; PM₁₀; urban; street canyon

Introduction

Rapid urbanization in Thailand has reshaped economic and social systems while markedly increasing environmental pressures in metropolitan areas. Densification, expanded transport networks, industrial activity, and construction have together elevated emissions of particulate matter (PM), making PM_{2.5} and PM₁₀ central indicators in national air-quality management. The World Health Organization's 2021 Global Air Quality Guidelines highlight the disproportionately large health risks of fine particulates and set annual PM_{2.5} targets far below current levels observed in Thai cities. National monitoring consistently reports frequent exceedances of Thailand's 24-hour ambient PM_{2.5} standard (37.5 µg/m³), particularly

during the cool season, with recurrent peaks across the Bangkok Metropolitan Region [1]. This chronic pattern highlights the persistence of particulate pollution in densely populated areas, where limited urban ventilation intensifies pollutant accumulation and cardiopulmonary health risks. Consequently, population exposure to PM remains a significant public-health concern, underscoring the urgent need for place-based mitigation strategies tailored to high-density urban environments.

The use of green infrastructure to mitigate particulate pollution and improve urban environmental quality has received growing attention in recent years. Street trees and vegetative barriers are increasingly recognized as effective nature-based solutions (NbS) for reducing near-road air pollution. Empirical

studies have reported strong associations between urban green-space coverage and lower ambient particulate matter concentrations [2-5]. In particular, the role of street trees in reducing the adverse effects of particulate matter in urban areas has been increasingly recognized. However, their influence on particulate dynamics within dense, built-up areas remains complex and highly context-dependent, varying with vegetation characteristics, and prevailing meteorological conditions [6]. Their effectiveness in capturing particulate matter and influencing local airflow, which may either enhance or inhibit pollutant dispersion depends on various factors [7-8].

Numerous field studies support the premise that increased vegetation coverage generally correlates with lower particulate pollution levels in urban settings [3, 5, 9]. Acting as natural biofilters, trees intercept airborne particles and absorb gaseous pollutants while modifying wind velocity, turbulence, and thermal conditions that affect pollutant dispersion [10]. These effects arise through interactions between vegetation, airflow, and particulate matter, whereby trees modify local wind patterns and facilitate the removal of both fine and coarse particles through deposition processes. Although studies report significant $PM_{2.5}$ reductions from these processes, outcomes vary widely with vegetation characteristics and canyon form [11-12]. For example, Gromke et al. [13] reported that larger tree crowns and reduced spacing between street trees can elevate PM concentrations along canyon walls due to restricted airflow. Similarly, tree-lined avenues can even increase concentrations compared to tree-free streets [14, 15]. These conflicting findings highlight the dual role of street trees. While trees can act as protective barriers against traffic emissions at the pedestrian level, their planting designs critically influence wind dynamics and pollutant dispersion [16]. Consequently, optimizing green infrastructure requires careful consideration of these trade-offs to maximize air quality benefits.

Meteorological conditions add another layer of complexity to this relationship. Parameters such as humidity, temperature, precipitation, and wind speed and direction differentially influence

PM behavior across particle sizes [17, 18]. As shown by Xu et al. [19], these variables govern the spatiotemporal variability of particulate pollution by regulating accumulation and dispersion. Additionally, large-scale weather patterns and various meteorological factors interact with local meteorological conditions to shape $PM_{2.5}$ and PM_{10} dynamics in urban environments [10-22]. Since vegetation also modifies local microclimates, particularly through effects on wind flow and humidity, understanding the interplay between meteorology and vegetation is essential for accurately assessing the effect of trees in street canyons.

In this context, this study examines the impact of street trees on particulate matter concentrations through direct field measurements of $PM_{2.5}$ and PM_{10} in street canyons with and without tree cover in Samut Prakan Municipality, a high-density urban area experiencing worsening particulate pollution. While many existing studies examine tree-air quality interactions primarily through numerical simulations or idealized modeling scenarios, this research focuses on tree effects under real-world urban conditions. The main objective is to assess how the presence or absence of street trees influences air quality at the pedestrian level, with particular emphasis on $PM_{2.5}$ and PM_{10} . Concurrent measurements of wind speed, air temperature, and relative humidity were conducted to identify key microclimatic drivers and support the interpretation of observed pollution patterns. Over the past three years, Samut Prakan has recorded an average of approximately 30 annual exceedances of the national $PM_{2.5}$ standard [23], underscoring the urgency of developing evidence-based and context-specific mitigation strategies. The findings are expected to inform climate-sensitive urban design and air-quality management by clarifying the functional role of street trees in mitigating particulate pollution within tropical urban environments.

Methodology

Study area

This study examines the impact of street trees on $PM_{2.5}$ and PM_{10} levels along Sukhumvit Road, a major traffic corridor in Samut Prakan

Municipality. Meteorological data from the urban district of Samut Prakan recorded a mean air temperature of 28.4°C, relative humidity of 74%, and a mean wind speed of 3.89 m/s. In 2022, the highest 24-hour average PM_{2.5} concentration reached 108 µg/m³, nearly triple Thailand's 24-hour standard (37.5 µg/m³), while the annual mean likewise exceeded the national limit (15 µg/m³). These violations correlate with the area's characteristics, including its high building density, diverse land-use activities, and consistently heavy traffic volume throughout the day. According to the Department of Highways (2022), the average daily traffic volume on Sukhumvit Road (Bearing–Tai Ban section) was 20,985 vehicles per day. Passenger cars formed the majority, followed by larger passenger vehicles and light-duty trucks, reflecting the corridor's mixed-use and commuter-dominated traffic pattern.

Structurally, Sukhumvit Road is a six-lane, concrete-paved arterial road with opposing traffic directions and an aspect ratio of approximately 0.5. Land uses along the corridor comprise commercial buildings, government offices, residential areas, industrial zones, and institutional facilities, with several segments featuring high-rise structures such as condominiums. Most buildings are low-rise, typically two to four stories in height, although open spaces such as parking lots and vacant parcels are also present. In many parts of the corridor, buildings are positioned close to the sidewalk with an average setback of about 2 m, forming a semi-enclosed street canyon. Additionally, an elevated rail structure runs above the roadway. Vegetation cover varies along the corridor, some sections are densely planted with trees, while others lack greenery entirely (**Figure 1**). This spatial variability provides a framework for assessing the effects of tree cover on air quality across both vegetated and non-vegetated sections.

Methods

To investigate the effect of street trees, sampling sites with similar background

concentrations were selected along Sukhumvit Road. Field measurements were carried out on the sidewalks of three segments of Sukhumvit Road in Samut Prakan Municipality, as shown in **Figure 2**. Since the road runs north to south, each sampling point was placed on the sidewalk within the street canyon on the leeward side of the prevailing wind direction to minimize the direct influence of roadside trees on pollutant concentrations [24].

Data Collection and Analysis

To achieve the research objectives, this study investigates the influence of street trees on particulate matter (PM) concentrations by measuring PM_{2.5}, PM₁₀, and microclimatic variables using real-time particle counters. The CEM DT-9880 was used for these measurements (**Figure 2**). The CEM DT-9880 utilizes a laser light-scattering principle to detect particle concentrations and incorporates built-in sensors that enable PM_{2.5}, PM₁₀, air temperature, and relative humidity to be collected simultaneously within the same device. The instrument records particulate matter with an accuracy of ±5% and microclimatic variables with an air-temperature accuracy of ±0.5°C (±1°F), and a humidity accuracy of ±2.5%, ensuring synchronized and consistent measurements across all sampling points. Wind speed was measured separately using a Hot Wire/Air Velocity Meter, which operates based on a hot-wire thermal anemometry principle. In each street segment, PM_{2.5}, PM₁₀, and microclimatic parameters were simultaneously recorded at three sidewalk sampling points: beneath tree canopies (BTC), between two trees (BWT), and in open areas without trees (WT). Both particulate matter and microclimatic data were logged at five-minute intervals, resulting in 12 measurements per hour and 132 measurements per day for each sampling point. Data collection was conducted between 20 January and 7 February 2022, from 07:00 to 18:00, on both weekdays and weekends, with five sampling days per street segment over a two-week period covering all three segments.

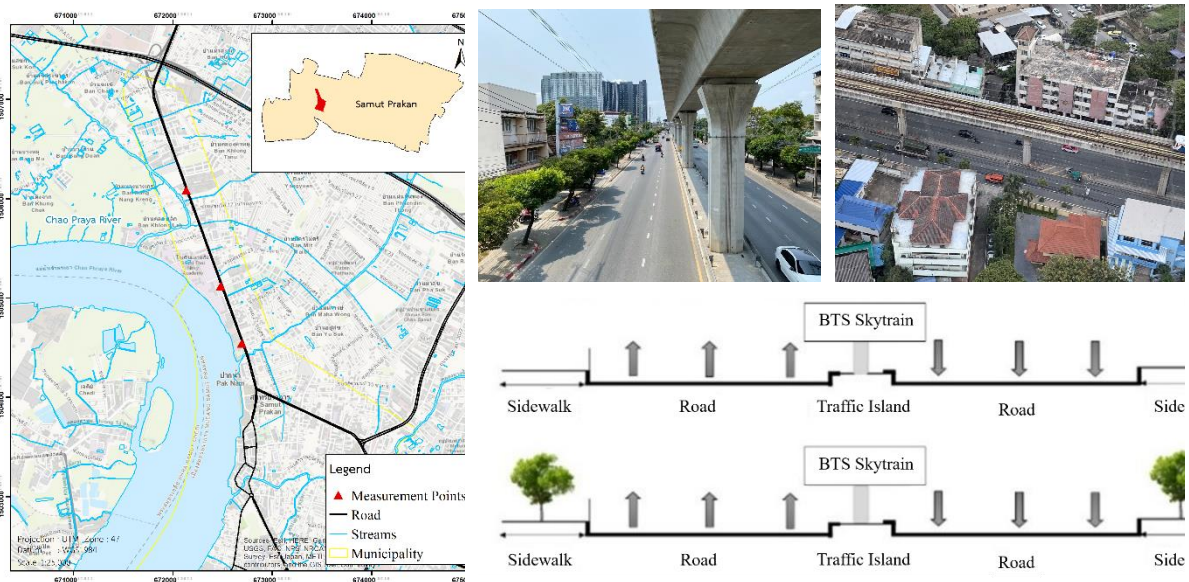


Figure 1 Study area and measurement locations along Sukhumvit Road, Samut Prakan Municipality

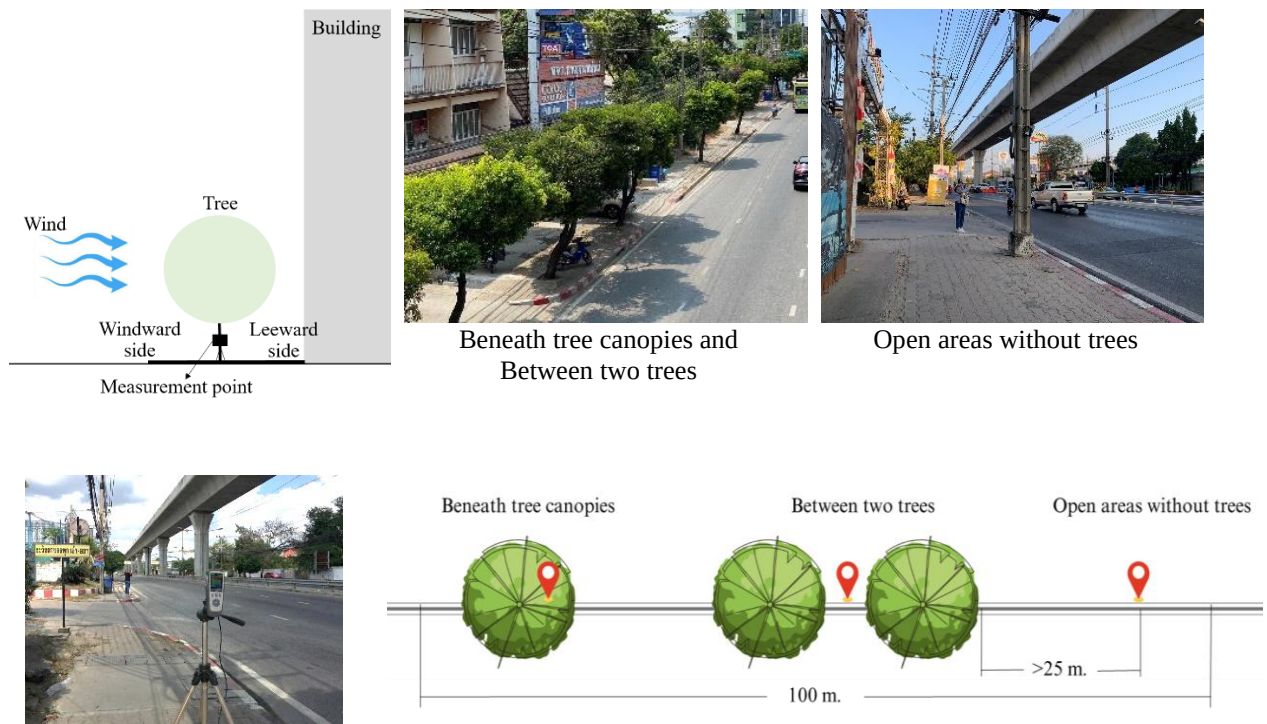


Figure 2 Field measurements were carried out on the three segments of sidewalks with three sampling points per road segment: (1) beneath tree canopy, (2) between two trees, and (3) in open areas without trees

The relative difference in concentration (RDC) was used to quantify the influence of street trees on particle concentrations ($PM_{2.5}$ and PM_{10}) at pedestrian level [20]. RDC was calculated as the difference in particle concentrations between tree-covered and open areas, as shown in Equation (1). Positive RDC values indicate that particle concentrations are higher at tree-covered locations compared to open areas without trees, suggesting an increase in air pollution. Conversely, negative RDC values reflect lower particle concentrations at the tree-covered sites, indicating an improvement in air quality relative to open areas. Statistical analysis was performed using one-way ANOVA and the least significant difference (LSD) test to evaluate the effects of street trees on PM concentrations and microclimatic variables, using SPSS software.

$$RDC = \frac{C_{tree} - C_{ref}}{C_{ref}} \times 100$$

where C_{tree} is the particle concentration at area with tree/between trees ($\mu g/m^3$)

C_{ref} is the particle concentration at area without tree ($\mu g/m^3$)

Results and Discussions

PM Concentration and $PM_{2.5}/PM_{10}$ Ratio

$PM_{2.5}$ and PM_{10} concentrations along Sukhumvit Road were analyzed using hourly field data collected between 7:00 AM and 6:00 PM over a two-week period. The spatiotemporal variability of the $PM_{2.5}/PM_{10}$ ratio was examined based on these hourly measurements to better understand the dynamics of particulate matter distribution throughout the day. The results revealed that peak particulate concentrations occurred during morning rush hours (7:00–9:00 AM) across all sampling points. Beneath tree canopies, $PM_{2.5}$ and PM_{10} peaked at $45.70 \mu g/m^3$ and $73.47 \mu g/m^3$, respectively, at 7:00 AM, before gradually declining to their lowest levels at noon ($35.24 \mu g/m^3$ for $PM_{2.5}$ and $56.00 \mu g/m^3$ for PM_{10} at 12:00 PM). Open areas without tree cover exhibited similar diurnal trends but with slightly higher concentrations, reaching maxima of $47.05 \mu g/m^3$ ($PM_{2.5}$) and $74.96 \mu g/m^3$ (PM_{10}) at 7:00 AM and minima of

$34.80 \mu g/m^3$ ($PM_{2.5}$) and $55.82 \mu g/m^3$ (PM_{10}) at 2:00 PM. The most pronounced variability was observed between trees, where peak concentrations were highest ($48.91 \mu g/m^3$ $PM_{2.5}$ and $77.48 \mu g/m^3$ PM_{10} at 8:00 AM). Across all sites, particulate matter concentrations were consistently lowest during early afternoon hours (12:00–2:00 PM), as illustrated in **Figure 3**.

$PM_{2.5}/PM_{10}$ ratios were subsequently calculated (Figure 3). The results indicate that the ratios across the three sites—beneath tree canopies, between two trees, and in open areas without trees—ranged from 0.620 to 0.657, 0.623 to 0.636, and 0.574 to 0.640, respectively. The highest ratio (0.657) was observed beneath tree canopies, suggesting that street trees may selectively reduce PM_{10} through leaf deposition, thereby increasing the relative proportion of $PM_{2.5}$ [25–26]. In contrast, open areas without trees exhibited a narrower ratio range (0.623–0.636), indicating greater stability, likely due to the absence of vegetation-driven particle filtration [27]. The most variable ratios (0.574–0.640) were recorded between trees, where the lowest value (0.574) suggests intermittent PM_{10} dominance. This variability may result from airflow disturbances in tree gaps, which could promote coarse particle resuspension or uneven pollutant dispersion [28].

PM Concentration and RDC

Figure 4 presents the hourly $PM_{2.5}$ and PM_{10} concentrations along Sukhumvit Road, accompanied by their corresponding RDC values. The results demonstrate that street trees significantly influence particulate matter levels. The highest reduction of $PM_{2.5}$ beneath trees was found at 10:00 AM (RDC_BTC = -12.49%), and at 8:00 AM for between two trees (RDC_BWT = -13.99%). These times correspond with relatively lower $PM_{2.5}$ concentrations at vegetated sites compared to tree-free areas. A similar trend is evident for PM_{10} concentrations, where the most pronounced reductions occurred at 10:00 AM as well, with beneath tree canopies reaching -11.87% and between two trees as low as -14.16%. These values are slightly more substantial than those observed for $PM_{2.5}$ at the same time, suggesting that tree canopies and vegetated areas are particularly effective at capturing larger particulate matter. In addition, as

shows in **Figure 4**, during the early morning hours (7:00–9:00 AM), $\text{PM}_{2.5}$ concentrations beneath trees were occasionally comparable to or slightly higher than those in treeless area (WT), particularly at 9:00 AM. This may be due to limited airflow under the canopy, which can temporarily trap pollutants. This pattern reversed

after 9:00 AM, when PM concentrations at non-vegetated sites exceeded those at vegetated locations. The temporal variations in RDC values reflect dynamic interactions between traffic emissions, wind patterns, and vegetation structure.

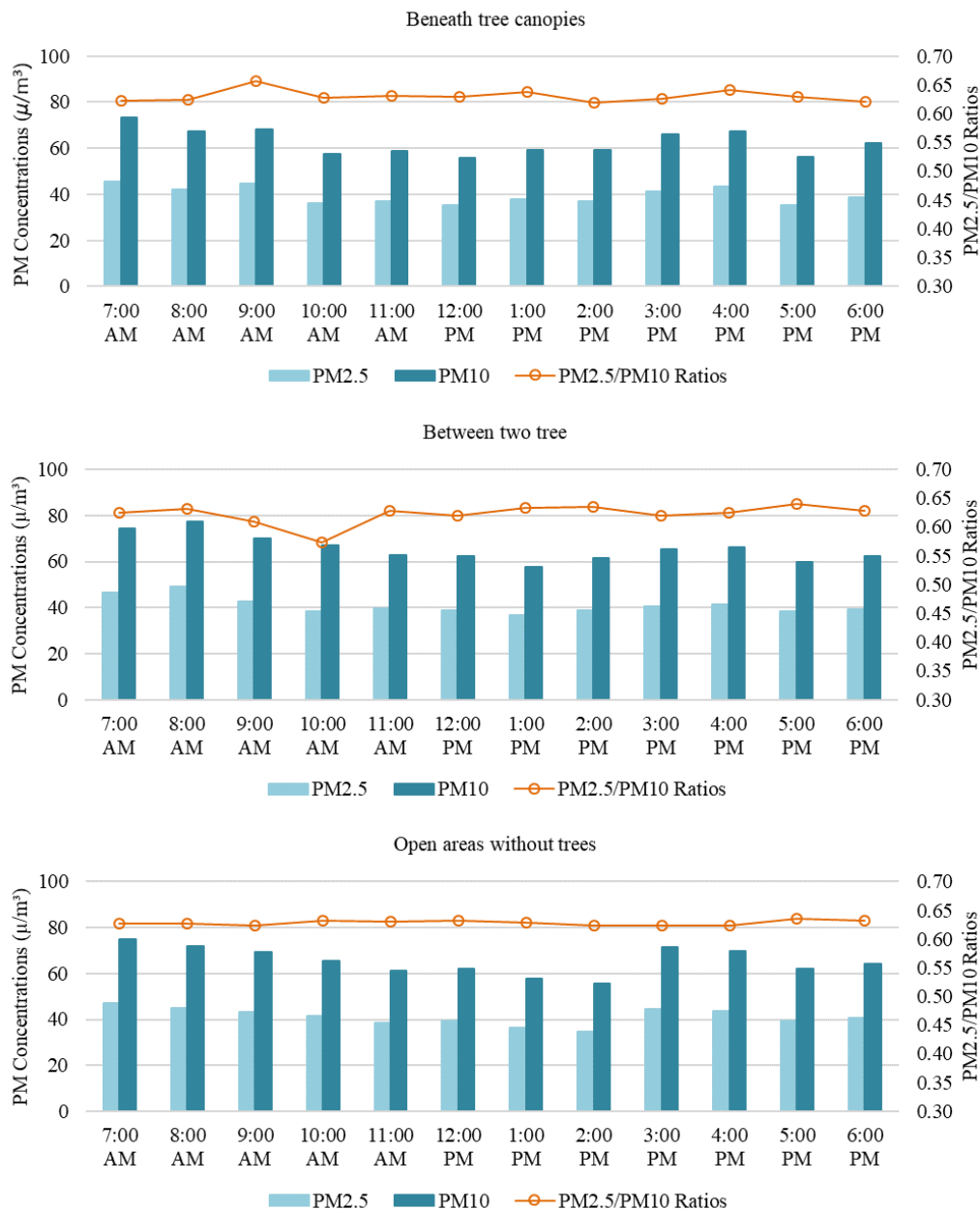


Figure 3 Hourly average PM Concentrations and ratios of the $\text{PM}_{2.5}/\text{PM}_{10}$ on Sukhumvit Road

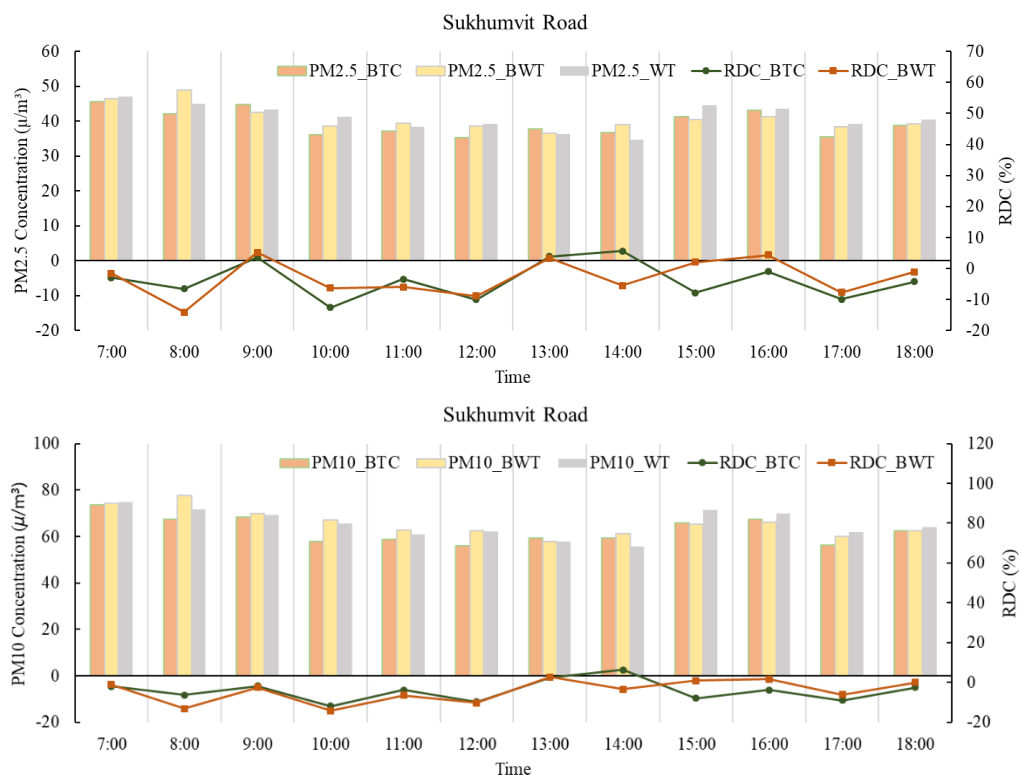


Figure 4 illustrates the PM_{2.5} and PM₁₀ concentration from 7:00 a.m. to 6:00 p.m. on Sukhumvit Road. BTC, BWT and WT represent Beneath Tree Canopy, Between Two Trees, and Without Tree

As illustrated in **Figure 5**, the RDC values for PM_{2.5} and PM₁₀ along Sukhumvit Road were predominantly negative, indicating lower particulate matter concentrations at vegetated locations compared with tree-free areas. Specifically, 17 out of 24 RDC values for PM_{2.5} (9 beneath tree canopies [BTC] and 8 between trees [BWT]) were negative, while 18 out of 24 values for PM₁₀ exhibited the same pattern. On average, PM_{2.5} concentrations decreased by approximately 3.74% beneath tree canopies and 2.99% between trees, whereas PM₁₀ concentrations decreased by about 4.11% and 4.27%, respectively.

These results demonstrate that both fully and partially vegetated areas contribute to particulate matter reduction relative to tree-free zones, with the most pronounced effect observed for PM₁₀. This pattern is consistent with previous studies showing that the particulate removal efficiency of street trees depends strongly on particle size [22, 29]. Coarse particles (PM₁₀) were substantially lower in vegetated areas than in non-vegetated

locations, as they are more readily removed through deposition onto leaf surfaces, whereas fine particles (PM_{2.5}) remain suspended in the atmosphere for longer periods [30]. Overall, the results underscore the efficacy of urban vegetation—particularly tree canopies—in mitigating particulate pollution, with a more substantial effect observed for coarse particles (PM₁₀) than for fine particles (PM_{2.5}).

Microclimatic Conditions under Different Street Tree Configurations

Field measurements of air temperature, relative humidity, and wind speed were conducted across three micro-environments: beneath tree canopies (BTC), between two trees (BWT), and open areas without trees (WT). The results reveal clear variations in microclimatic conditions among the three settings. Beneath tree canopies, the average air temperature was 31.07 °C, relative humidity was 59.79%, and wind speed was 1.55 m/s. In the areas between two trees, the average temperature was slightly lower at 31.02 °C, relative humidity

was 59.20%, and wind speed increased to 2.17 m/s. In contrast, open areas without tree cover exhibited the highest average temperature (31.40

°C), a marginally lower relative humidity (59.11%), and the highest wind speed (2.63 m/s), as shown in **Figure 6**.

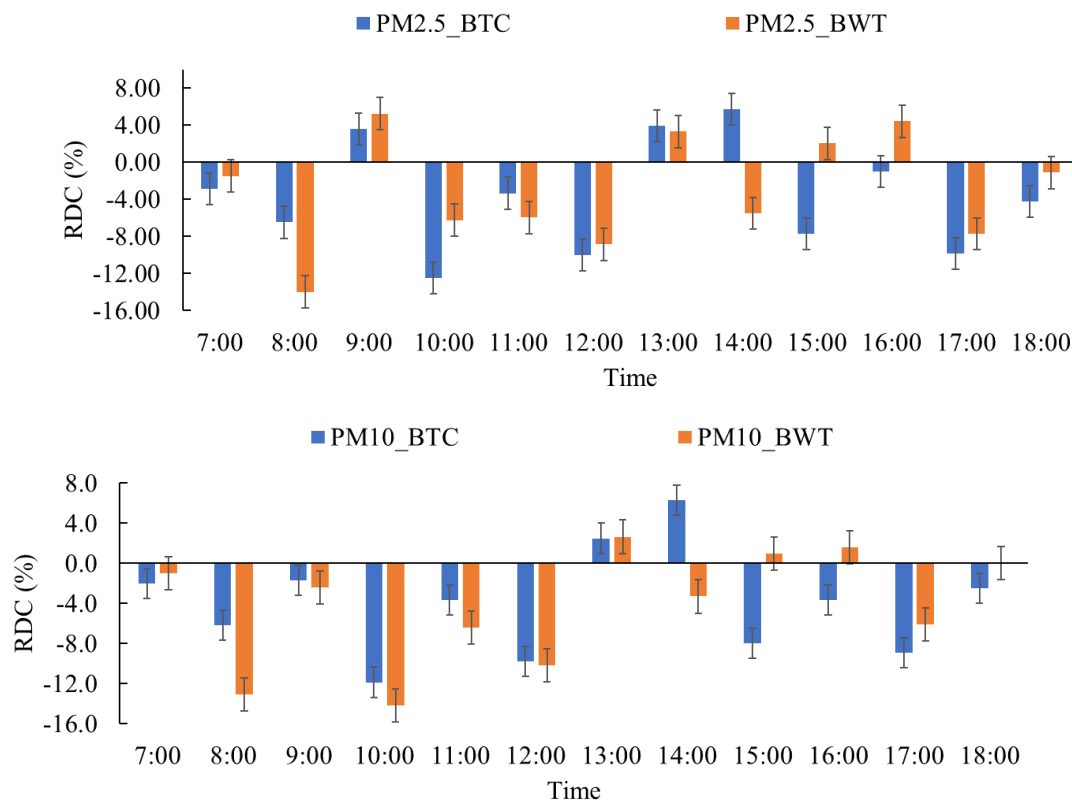


Figure 5 RDC values for PM_{2.5} and PM₁₀ at different times on Sukhumvit Road. Where BTC, BWT and WT represent Beneath Tree Canopy, Between Two Trees, and Without Tree, respectively

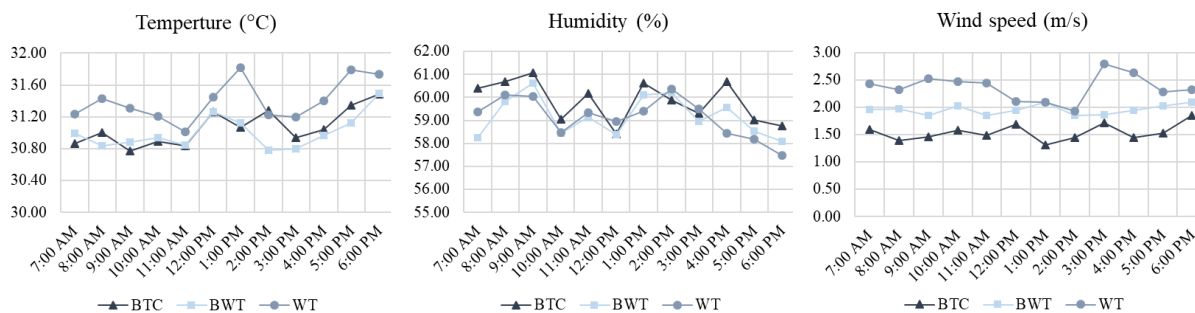


Figure 6 Diurnal variations in air temperature (°C), relative humidity (%), and wind speed (m/s) measured across three micro-environments: beneath tree canopies (BTC), between trees (BWT), and open areas without tree cover (WT) along Sukhumvit Road

Table 1 summarizes the hourly mean values, maxima, and minima of PM_{2.5}, PM₁₀, and associated meteorological parameters across the three micro-environments: beneath tree canopies (BTC), between two trees (BWT), and open areas without trees (WT). Overall, mean PM_{2.5} concentrations ranged from 39.53 µg/m³ under tree canopies to 41.13 µg/m³ in open areas, while PM₁₀ concentrations ranged from 62.69 µg/m³ to 65.59 µg/m³, indicating slightly higher particulate matter levels in non-vegetated and partially vegetated locations. Correspondingly, wind speed was lowest beneath tree canopies (1.54 m/s) and highest in open areas (2.36 m/s), suggesting that reduced airflow under tree cover may limit particulate dispersion. In contrast, air temperature exhibited minimal spatial variation among the three settings; however, marginally higher temperatures in open areas likely reflect increased surface heating and enhanced vertical mixing, conditions that typically favor pollutant dilution.

Effects of Street Trees on Particulate Matter and Microclimate

ANOVA was conducted to determine whether there were variations in PM concentrations and microclimate among the sampling points (beneath tree canopy, between two trees, and open areas without trees). The results revealed differences in particulate matter concentrations (PM_{2.5} and PM₁₀) across the three sampling points. For PM_{2.5}, the mean concentration was lowest under tree canopies (39.45 µg/m³), slightly higher in open areas (41.00 µg/m³), and comparable between trees (40.71 µg/m³). The one-way ANOVA shows

that these differences were not statistically significant at the 0.05 level ($p = 0.058$), indicating that while trees may slightly reduce PM_{2.5} levels, the effect was not strong enough to be conclusive. In contrast, PM₁₀ concentrations showed clearer variation across sites. The lowest mean was observed under tree canopies (62.51 µg/m³), followed by the between trees (64.84 µg/m³), and highest in open areas (65.18 µg/m³). The ANOVA test for PM₁₀ yielded a statistically significant result ($p = 0.030$), suggesting that tree canopies significantly reduce PM₁₀ levels compared to open areas. These findings indicate that street trees are more effective at mitigating larger particles (PM₁₀), possibly due to their capacity to intercept coarse dust particles, while the effect on finer particles like PM_{2.5} may be influenced by additional factors such as wind flow and atmospheric dispersion.

The results revealed significant effects of tree canopies on the urban microclimate. Trees significantly reduced air temperature ($F = 13.168$, $p < 0.001$), with the lowest mean temperature observed under tree canopies (31.07°C), compared to areas without trees (31.40°C, $p < 0.001$). Wind speed was also significantly lower beneath tree canopies (1.54 m/s) than in areas without trees (2.37 m/s, $p < 0.001$) and between trees (2.08 m/s, $p < 0.001$). However, no significant difference was found in relative humidity across the three sampling conditions ($F = 1.873$, $p = 0.154$). Mean differences in microclimatic variables (temperature, humidity, and wind speed) were further examined using LSD post hoc multiple comparisons (see **Table 2**).

Table 1 Hourly summary statistics of PM_{2.5}, PM₁₀, and associated meteorological variables across vegetated and non-vegetated street environments

Area	Parameter	PM _{2.5} (µg/m ³)	PM ₁₀ (µg/m ³)	T (°C)	RH (%)	WS (m/s)
BTC	Average ± SD	39.53 ± 3.71	62.69 ± 5.62	31.07 ± 0.23	59.82 ± 0.93	1.54 ± 0.15
	Max	45.70	73.47	31.49	61.08	1.85
	Min	35.24	56.00	30.77	58.21	1.31
BWT	Average ± SD	40.80 ± 3.58	65.59 ± 5.84	31.77 ± 0.21	59.18 ± 0.87	1.96 ± 0.09
	Max	48.91	77.48	31.50	60.61	2.10
	Min	36.62	57.83	30.79	58.10	1.85
WT	Average ± SD	41.13 ± 3.70	65.48 ± 6.02	31.40 ± 0.26	59.14 ± 0.86	2.36 ± 0.24
	Max	47.05	74.96	31.82	60.38	2.79
	Min	34.80	55.82	31.01	57.49	1.93

BTC, BWT and WT represents Beneath Tree Canopy, Between Two Trees, and Without Tree, respectively.

Table 2 LSD multiple comparison tests for determining the effect of trees on the concentration of PM and Microclimate

Comparison (I - J)	Dependent variables									
	PM _{2.5}		PM ₁₀		Temperature		Humidity		Wind speed	
	M-diff (I-J)	Sig	M-diff (I-J)	Sig	M-diff (I-J)	Sig	M-diff (I-J)	Sig	M-diff (I-J)	Sig
BTC-BWT	-1.25703	0.070	-2.33636	0.016*	-0.33151	0.000*	0.64693	0.106	-0.25846	0.000*
BTC- WT	-1.55095	0.027*	-2.67384	0.008*	-0.39319	0.000*	0.69348	0.083	-0.54061	0.000*
BWT-WT	0.29396	.676	0.33747	0.934	-0.06168	0.088	-0.04655	0.907	0.28214	0.000*

BTC, BWT and WT represents Beneath Tree Canopy, Between Two Trees, and Without Tree, respectively. M-Diff represents the mean difference *The Mean difference is significant at the 0.05 level (P value= 0.05)

The findings confirm that tree canopies significantly reduce PM_{2.5} and PM₁₀ concentrations while simultaneously lowering air temperature and wind speed, highlighting their important role in regulating the urban microclimate. These results are consistent with previous studies demonstrating that urban trees strongly influence local thermal conditions by providing shade and reducing surface and near-ground air temperatures, particularly at the pedestrian level [31]. For example, Zender-Swierz et al. (2024) [32] reported that tree planting can reduce air temperature at a pedestrian height of 1.5 m by approximately 1.83-2.48 °C.

In this study, the presence of trees was negatively correlated with air temperature, which in turn influenced PM_{2.5} and PM₁₀ concentrations within the street canyon. Temperature exhibited a statistically significant relationship with PM_{2.5}, however, the direction of this relationship remains inconclusive. While some studies report lower PM_{2.5} concentrations at reduced temperatures [33-34], others have observed a positive correlation between temperature and particulate matter [17, 35]. This inconsistency suggests that temperature alone does not govern PM variability and that other factors such as wind conditions, street geometry, and vegetation characteristics, play a more dominant role in particulate matter dispersion and accumulation. Additionally, the observed reduction in wind speed is consistent with existing literature describing the role of trees as windbreaks that attenuate airflow and reduce

turbulence within street canyons [36]. Although tree canopies may decrease wind speed, the results highlight a dual effect of urban vegetation, reflecting both aerodynamic modification and enhanced pollutant deposition processes [13, 37]. Along Sukhumvit Road, the presence of medium-height trees (approximately 6-8 m), positioned below the building eave level, appears to preserve ventilation corridors within the street canyon. This configuration allows for sufficient air exchange while promoting particulate deposition on foliage, thereby achieving a balance between aerodynamic performance and pollution removal efficiency.

Although the results indicate that variations in PM concentrations are associated with tree-regulated microclimatic conditions, the overall relationship between humidity and tree presence was weak and statistically insignificant, in contrast to the effects observed for temperature and wind speed. This limited variation can be attributed to the high baseline humidity typical of tropical urban environments, where atmospheric moisture is often near saturation, thereby constraining the potential influence of additional moisture from vegetation through transpiration [38-39]. Moreover, the influence of trees on ambient humidity depends on canopy density, continuity, species characteristics, and soil moisture availability. In roadside planting conditions, where tree cover is often sparse or spatially discontinuous, the evapotranspirative contribution may be insufficient to produce measurable changes in

ambient humidity [31, 40]. These factors likely explain the absence of statistically significant differences in humidity between tree-covered and non-tree scenarios observed in this study.

Conclusions

This study examined the impact of street trees on PM_{2.5} and PM₁₀ concentrations within a high-density street canyon in Samut Prakan. The results indicate that tree-covered locations effectively mitigate particulate matter pollution at the pedestrian level (1.5 m), with the lowest concentrations observed beneath tree canopies, followed by areas between trees and locations without tree cover. The findings further suggest that street trees play a meaningful role in improving urban air quality, particularly through the reduction of PM₁₀. Given the significant reduction in PM₁₀ and the observed mitigation trends for PM_{2.5} under tree canopies, urban policymakers should consider integrating tree planting into air quality management strategies, especially along high-traffic roads. Promoting the use of dense, broad-leaved species with effective canopy coverage may enhance the interception of airborne particles while improving thermal comfort for pedestrians. However, as this study was conducted on a specific stretch of Sukhumvit Road in Samut Prakan Municipality, its generalizability may be limited. To strengthen policy development, future research should expand the geographic scope to include multiple urban districts with varying built environments and vegetation types, and integrate dynamic traffic data across diverse urban contexts to further strengthen the evidence base for tree-based air quality interventions.

References

- [1] World Health Organization. 2021. WHO Global Air Quality Guidelines: Particulate Matter (PM_{2.5} and PM₁₀), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide. Geneva: World Health Organization.
- [2] Thapsaeng, N., Konisranukul, W., and Jirakhajornkul, S. 2019. The influence of urban green spaces on airborne particulate matter pollution. The 6th National and International Academic Conference, Educational Innovation for Sustainable Social Development at Northeastern University (NEUNIC), Thailand on July 20, 2019.
- [3] Yli-Pelkonen, V., Setälä, H., and Viippola, V. 2017. Urban forests near roads do not reduce gaseous air pollutant concentrations but have an impact on particles levels. *Landscape and Urban Planning*. 158: 39-47.
- [4] Chen, M., Dai, F., Yang, B., and Zhu, S. 2019. Effects of neighborhood green space on PM_{2.5} mitigation: Evidence from five megacities in China. *Building and Environment*. 156: 33-45.
- [5] Irga, P.J., Burchett, M.D., and Torpy, F.R. 2015. Does urban forestry have a quantitative effect on ambient air quality in an urban environment? *Atmospheric Environment*. 12(15): 173-181.
- [6] Miao, Y., Zhou, W., Qiu, L., and Liu, H. 2020. How the morphology of urban street canyons affects suspended particulate matter concentration at the pedestrian level: An in-situ investigation. *Sustainable Cities and Society*. 55: 102042.
- [7] Buccolieri, R., Santiago, J.-L., Rivas, E., and Sanchez, B. 2018. Review on urban tree modelling in CFD simulations: Aerodynamic, deposition and thermal effects. *Urban Forestry and Urban Greening*. 31: 212-220.
- [8] Chen, X., Pei, T., Zhou, Z., Teng, M., He, L., Luo, M., and Liu, X. 2015. Efficiency differences of roadside greenbelts with three configurations in removing coarse particles (PM₁₀): A street scale investigation in Wuhan, China. *Urban Forestry and Urban Greening*. 14(2): 354-360.
- [9] Buccolieri, R., Gromke, C., Di Sabatino, S., and Ruck, B. 2009. Aerodynamic effects of trees on pollutant concentration in street canyons. *Science of the Total Environment*. 407(17): 5247-5256.
- [10] Diener, A., and Mudu, P. 2021. How can vegetation protect us from air pollution? A critical review on green spaces' mitigation abilities for air-borne particles from a public health perspective. *Science of the Total Environment*. 796: 148605.

- [11] Setälä, H., Viippola, V., Rantalainen, A., Pennanen, A., and Yli-Pelkonen, V. 2013. Does urban vegetation mitigate air pollution in northern conditions? *Environmental Pollution*. 183: 104-112.
- [12] Brantley, H.L., Hagler, G.S.W., Deshmukh, P.J., Baldauf, R.W. 2014. Field assessment of the effects of roadside vegetation on near-road black carbon and particulate matter. *Science of the Total Environment*. 468-469: 120-129.
- [13] Gromke, C., and Ruck, B. 2012. Pollutant concentrations in street canyons of different aspect ratio with avenues of trees for various wind directions. *Boundary-Layer Meteorology*. 144(1): 41-64.
- [14] Aristodemou, E., et al. 2018. How tall buildings affect turbulent air flows and dispersion of pollution within a neighbourhood. *Environmental Pollution*. 233: 782-796.
- [15] Vos, P.E.J., Maiheu, B., Vankerkom, J., and Janssen, S. 2013. Improving local air quality in cities: To tree or not to tree? *Environmental Pollution*. 183: 113-122.
- [16] Zhu, C., and Zeng, Y. 2018. Effects of urban lake wetlands on the spatial and temporal distribution of air PM10 and PM2.5 in the spring in Wuhan. *Urban Forestry and Urban Greening*. 31: 142-156.
- [17] Li, X., Ma, Y., Wang, Y., Liu, N., and Hong, Y. 2017. Temporal and spatial analyses of particulate matter (PM10 and PM2.5) and its relationship with meteorological parameters over an urban city in northeast China. *Atmospheric Research*. 198: 185-193.
- [18] Wang, J., Han, J., Li, T., Wu, T. and Fang, C. 2023. Impact analysis of meteorological variables on PM2.5 pollution in the most polluted cities in China. *Heliyon*. 9(7): e17609.
- [19] Xu, Y., Xue, W., Lei, Y., Huang, Q., Zhao, Y., Cheng, S., Ren, Z., and Wang, J. 2020. Spatiotemporal variation in the impact of meteorological conditions on PM2.5 pollution in China from 2000 to 2017. *Atmospheric Environment*. 224: 117215.
- [20] Chen, L., Liu, C., Zhang, L., Zou, R., and Zhang, Z. 2018. Variation in tree species ability to capture and retain airborne fine particulate matter (PM2.5). *Scientific Reports*. 7(1): 3206.
- [21] Miao, Y., Li, Y., and Zhang, Y. 2017. The impact of urban green spaces on particulate matter pollution in metropolitan areas. *Environmental Pollution*. 229: 186-194.
- [22] Miao, C., Yu, S., Hu, Y., Liu, M., Yao, J., Zhang, Y., He, X., and Chen, W. 2021. Seasonal effects of street trees on particulate matter concentration in an urban street canyon. *Sustainable Cities and Society*. 73: 103097.
- [23] Air and Noise Quality Management Division. 2022. Report on the status and management of air and noise pollution in Thailand for the year 2022. Bangkok: Pollution Control Department.
- [24] Zhan, N., Lyu, G., Li, X., and Zhang, S. 2020. Study on air pollutants distribution in street canyons affected by interaction of hedgerows and trees. *Environmental Science and Technology*. 43(6): 101-107.
- [25] Nowak, D.J., Hirabayashi, S., Bodine, A., and Greenfield, E. 2013. Modeled PM2.5 removal by trees in ten U.S. cities and associated health effects. *Environmental Pollution*. 178: 395-402.
- [26] Jeanjean, A.P.R., Buccolieri, R., Eddy, J., Monks, P.S., and Leigh, R.J. 2017. Air quality affected by trees in real street canyons: The case of Marylebone neighbourhood in central London. *Urban Forestry and Urban Greening*. 22: 41-53.
- [27] Zhang, K., Batterman, S., and Dion, F. 2011. Vehicle emissions in congestion: Comparison of work zone, rush hour and free-flow conditions. *Atmospheric Environment*. 45(11): 1929-1939.
- [28] Morakinyo, T.E., and Lam, Y.F. 2016. Simulation study of dispersion and removal of particulate matter from traffic by urban trees. *Atmospheric Environment*. 132: 120-128.
- [29] Cai, M., Xin, Z., and Yu, X. 2017. Spatiotemporal variations in PM leaf deposition: A meta-analysis. *Environmental Pollution*. 231: 207-218.

- [30] Mandal, M., Popek, R., Przybysz, A., Roy, A., Das, S., and Sarkar, A. 2023. Breathing fresh air in the city: Implementing avenue trees as a sustainable solution to reduce particulate pollution in urban agglomerations. *Plants*. 12(7): 1545.
- [31] Rahman, M.A., Stratopoulos, L.M.F., Moser-Reischl, A., Zölch, T., Häberle, K.H., Rötzer, T., Pretzsch, H., and Pauleit, S. 2020. Traits of trees for cooling urban heat islands: A meta-analysis. *Building and Environment*. 170: 106606.
- [32] Zender-Świercz, E., Galiszewska, B., Telejko, M., and Starczewska, M. 2024. The effect of temperature and humidity of air on the concentration of particulate matter – PM2.5 and PM10. *Atmospheric Research*. 312: 107733.
- [33] Singh, B.P., Singh, D., Kumar, K., and Jain, V.K. 2021. Study of seasonal variation of PM2.5 concentration associated with meteorological parameters at residential sites in Delhi, India. *Journal of Atmospheric Chemistry*. 78: 161-176.
- [34] Danek, T., Weglińska, E., and Zareba, M. 2022. The influence of meteorological factors and terrain on air pollution concentration and migration: A geostatistical case study from Krakow, Poland. *Scientific Reports*. 12: 11050.
- [35] Dawson, J.P., Adams, P.J., and Pandis, S.N. 2007. Sensitivity of PM2.5 to climate in the Eastern United States: A modeling case study. *Atmospheric Chemistry and Physics*. 7(16): 4295-4309.
- [36] Abhijith, K.V., Kumar, P., Gallagher, J., McNabola, A., Baldauf, R., Pilla, F., and Pulvirenti, B. 2017. Air pollution abatement performances of green infrastructure in open road and built-up street canyon environments: A review. *Atmospheric Environment*. 162: 71-86.
- [37] Xing, Y., and Brimblecombe, P. 2019. Role of vegetation in deposition and dispersion of air pollution in urban parks. *Atmospheric Environment*. 201: 73-83.
- [38] Liu, J., Zheng, B., Xiang, Y., and Fan, J. 2022. The impact of street tree height on PM2.5 concentration in street canyons: A simulation study. *Sustainability*. 14(19): 12378.
- [39] Emmanuel, R., and Johansson, E. 2006. Influence of urban morphology and sea breeze on hot humid microclimate: The case of Colombo, Sri Lanka. *Climate Research*. 30: 189-200.
- [40] Bowler, D.E., Buyung-Ali, L., Knight, T.M., and Pullin, A.S. 2010. Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning*. 97(3): 147-155.