Prepublished copy

Nature Environment & Pollution Technology

This is a peer-reviewed prepublished version of the paper to be published in Vol. 25, No. 1, March 2026 issue

Original Research

The Influence of Urban Green Spaces on Airborne Particulate Pollution: A Case Study of Phutthamonthon Park Bangkok Suburb, Thailand

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Key Words	Urban green spaces, Airborne particulates, Health risk, Air pollution, $PM_{2.5}$
DOI	https://doi.org/10.4649/NEPT.2026.v25i01.D1818 (DOI will be active only after the final publication of the paper)
Citation for the Paper	Phonphoton, N. and Jirathananuwat, A., 2026. The influence of urban green spaces on airborne particulate pollution: A case study of Phutthamonthon Park Bangkok Suburb, Thailand. *Nature Environment and Pollution Technology*, 25(1), D1818. https://doi.org/10.46488/NEPT.2026.v25i01.D1818

ABSTRACT

Urban green spaces play a vital role in promoting public health and enhancing the quality of urban environments, particularly through their potential to mitigate air pollution. This study investigated the association between green space and airborne particulate matter (PM) of various sizes, including PM1, PM2.5, PM10, and total dust, within Phutthamonthon Park. Located in Nakhon Pathom province adjacent to Bangkok, Phutthamonthon Park is one of the largest suburban green spaces in the region. The park serves as a significant recreational and cultural hub that supports diverse activities including walking, cycling, and community gatherings, while simultaneously contributing to urban air quality management through its extensive vegetation cover and open spaces. The study also assessed the influence of meteorological factors such as temperature, relative humidity, and time of day on PM concentrations. A cross-sectional survey was conducted in January 2025 using DustTrak DRX Aerosol Monitors across four zones of the park during morning, midday, and evening periods, yielding a total of 144 samples. The results demonstrated a significant reduction in total dust levels within green spaces, with peripheral zones exhibiting 50-100% higher concentrations compared to interior areas. However, no statistically significant differences were observed for PM1, PM2.5, and PM10, which remained elevated during morning hours, likely due to unfavorable atmospheric conditions. These findings underscore the complex role of urban greenery in air quality management, revealing both benefits and limitations. The study offers practical insights for urban planners and policymakers, emphasizing the importance of strategic green space design in reducing air pollution and promoting healthier urban living conditions.

1. INTRODUCTION

Urban expansion in recent decades has led to increasing environmental challenges. In particular, air pollution from fine particulate matter (PM) significantly affects the quality of life in urban areas (Liu et al. 2018). In this context, "urban green spaces" have been recognised as spatial components that can alleviate air pollution problems and promote a long-term, healthy urban environment (Tzoulas et al. 2007). Urban green spaces include parks, gardens, street tree areas, and natural vegetation. They play an important role in absorbing and trapping atmospheric PM through biological mechanisms, such as filtering dust via leaves (Speak et al. 2012) and stems and absorbing pollutants on leaf surfaces (Barwise and Kumar 2020; Nowak et al. 2006). However, the efficiency of dust reduction depends on many factors, including the structure and type of vegetation, the physical characteristics of the area, greenness, vegetation density, and meteorological conditions (Vos et al. 2013).

Previous research suggested that green spaces can significantly reduce levels of large and total PM in some contexts, but their impact on fine PM, such as PM_1 and $PM_{2.5}$, remains uncertain, particularly in the context of tropical or rapidly expanding cities (Barwise & Kumar 2020). Fine PM is considered a primary risk factor for long-term health problems, such as respiratory disorders and cardiovascular disease (Pope Iii & Dockery 2006); this underscores the importance of local pollution control (World Health Organization 2024). Additionally, factors such as temperature, relative humidity, and time of day significantly affect atmospheric PM levels and influence their buoyancy, dispersion, and deposition in open spaces (Zhang 2019). Therefore, studies that consider only green spaces while excluding these environmental factors may not sufficiently explain the phenomenon. Despite growing recognition of the role of green infrastructure in urban air quality, there remains a lack of spatially detailed, real-time assessments within large public parks in Southeast Asia. This study contributes novel evidence by applying a zone-based monitoring design to explore intra-park variation in PM concentrations. By capturing fine-scale spatial dynamics in a tropical peri-urban setting, the findings aim to inform a more context-sensitive understanding of how urban green spaces are associated with airborne PM levels. Given this knowledge gap, this study aims to analyse the relationship between urban green spaces and airborne PM levels, using Phutthamonthon Park, a large green space in the suburb of Bangkok, as a case study. The analysis encompasses four types of PM: PM_1, $PM_{2.5}$, PM_{10}, and total dust, while also considering the influence of temperature, relative humidity, and time of day on PM changes. It is expected that the results of this study will enhance the understanding of the role of urban green spaces in environmental science and support urban design approaches that contribute to the promotion of public health at a fundamental level.

2. MATERIALS AND METHODS

This study is a cross-sectional survey was conducted in January 2025 in Phutthamonthon Park, suburb of Bangkok, Thailand. The Phutthamonthon Park was selected as the study area due to its status as a large public park located in the suburb of Bangkok. This expansive green area has the potential to curb air pollution and is an important component of the urban ecosystem (Jim &Chen 2008). It has an area of 988 acres, with a width and length of approximately 2 kilometres on each side, the park boasts both natural diversity and the capacity to support various activities. Phutthamonthon Park reflects the impact of large urban green areas on air PM. In this study, the area was divided into four zones based on distance from the outer area to facilitate a clearer comparison of PM levels in each zone, The three inner zones (Zones A–C) were delineated by equal radial increments of roughly 333 metres, while Zone D comprised the remaining fringe abutting the park boundary, as shown in Fig. 1. This zoning approach enhances the interpretation of PM distribution by incorporating variation in openness, land use, and surrounding influences, with each zone exhibiting distinct physical, ecological, and anthropogenic features as follows:

Zone A (Central Zone): Located at the park's core, this area features the main Buddha statue and large open lawns interspersed with low- to medium-height trees with sparse canopies. It is the most open zone and is heavily used for physical activities and public gatherings.

Zone B (Intermediate Zone): This zone includes a large pond in the east with minimal tree cover, while the west side contains taller, more densely spaced trees forming shaded jogging paths. Built structures are located in the northeast. The area offers a mixed canopy environment with moderate recreational use.

Zone C (Inner Border Zone): Relatively enclosed, this zone has dense tree coverage in the west and north with taller trees and overlapping canopies, contrasted by open grass space in the east. The southeast includes some built structures. Human activity is limited, and small ponds are scattered throughout.

Zone D (Outer Zone): Located along the park's outer boundary, this zone borders a major road to the east and low-density communities to the north, south, and west. It comprises partially open areas and continuous strips of trees and shrubs, forming a transitional buffer between urban infrastructure and park greenery.

Fig. 1: Study area: Phutthamonthon Park

This research utilized a field-based data collection approach, employing the DustTrak DRX Aerosol Monitors. The DustTrak device is recognized for its precision in measuring fine PM, particularly $PM_{2.5}$, which is considered a critical indicator of air pollution and a key factor affecting human health in urban settings (Sousan et al. 2016). This tool employs light scattering technology to measure the concentration of dust particles in the air. The scattering of light from dust particles is detected and processed into data reflecting dust values of various sizes, including PM_1, $PM_{2.5}$, PM_{10}, and total dust, allowing for real-time data collection and measurement of dust values appropriate for air quality research. The study also collected temperature and relative humidity data. Data were collected over three days, divided into three time periods: morning (05:00–07:00), midday (11:00–13:00), and evening (17:00–19:00). In each round, measurements were conducted across the four designated zones, with four samples taken per zone corresponding to the north, south, east, and west directions. This approach yielded 16 samples per round, resulting in 48 samples per day and a total of 144 samples throughout the study period. Temperature and relative humidity were also recorded alongside PM measurements to support data interpretation.

Descriptive data were analysed using mean and standard deviation. The relationship between various factors, including location within the garden area, temperature, relative humidity, and the effects of different times of day, on PM concentrations were analysed using regression analysis. In addition, the study compared the average PM levels across different locations using ANOVA at a statistical significance level of 0.05

3. RESULTS

3.1. PM, Temperature, and Relative Humidity across Time Periods

PM_1, $PM_{2.5}$, and PM_{10} concentrations were highest during the morning, with significant reductions by midday and evening ($p < 0.001$). Morning hours also recorded the highest relative humidity (91.79%), while midday showed the highest temperature (33.36°C). All temporal variations in PM levels, temperature, and relative humidity were statistically significant (Table 1).

Table 1: Average of PM concentrations, temperature, and relative humidity across time period

Parameter	Morning Mean ± SD (95% CI)	Midday Mean ± SD (95% CI)	Evening Mean ± SD (95% CI)	Significance
PM_1 (mg/m³)	0.09 ± 0.02 (0.08−0.09)	0.05 ± 0.01 (0.05−0.06)	0.04 ± 0.01 (0.04−0.05)	< 0.001
$PM_{2.5}$ (mg/m³)	0.09 ± 0.02 (0.08−0.09)	0.05 ± 0.01 (0.05−0.06)	0.04 ± 0.01 (0.04−0.05)	< 0.001
PM_{10} (mg/m³)	0.09 ± 0.02 (0.09−0.10)	0.06 ± 0.02 (0.06−0.07)	0.05 ± 0.01 (0.05−0.06)	< 0.001
Temperature (°C)	21.81 ± 1.85 (21.28−22.35)	33.36 ± 1.95 (32.79−33.93)	30.49 ± 1.69 (30.00−30.98)	< 0.001

Relative humidity (%)	91.79 ± 3.51 (90.77−92.81)	47.63 ± 11.57 (44.27−50.99)	53.60 ± 8.80 (51.05−56.16)	< 0.001

3.2. Spatial Distribution of Total Dust

Total dust concentrations were significantly higher in Zone D (outside the park) compared to Zones A–C (within the park) ($p = 0.003$). Regression analysis supported this finding, showing a positive association between dust levels and exterior areas (Fig. 2)

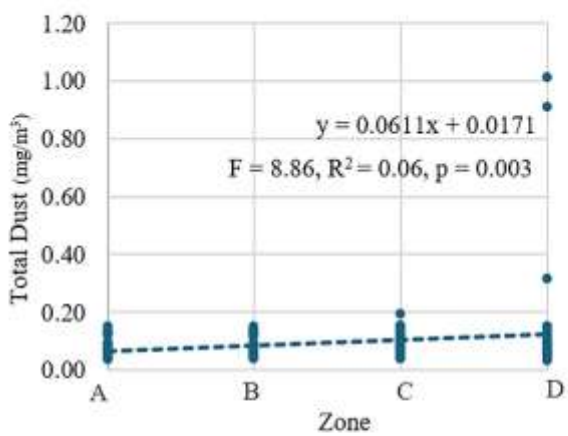

Fig. 2: Distribution of dust particles of different sizes

One-way ANOVA revealed significant differences in total dust concentrations among zones ($F = 2.971$, $p = 0.034$) (Table 2). Duncan's Multiple Range Test was subsequently applied to identify specific pairwise differences. Detailed results are presented in Table 3.

Table 2: Total dust concentration by zone

Parameter	Zone				F	Significance
	A	B	C	D		

	Mean ± SD (95% C I)	Mean ± SD (95% C I)	Mean ± SD (95% C I)	Mean ± SD (95% C I)		
Total Dust (mg/m^3)	0.08 ± 0.03 (0.07−0.08)	0.07 ± 0.03 (0.07−0.08)	0.08 ± 0.04 (0.07−0.10)	0.14 ± 0.21 (0.07−0.21)	2.971	0.034

Post-hoc pairwise comparisons using Duncan's Multiple Range Test confirmed that Zone D (exterior) had significantly higher total dust concentrations than the interior zones (A, B, C), which showed no significant differences among themselves (Table 3).

Table 3: Comparison of mean total dust concentrations (mg/m^3) across zones using Duncan’s Multiple Range Test ($\alpha = 0.05$)

Zone	Mean ± SD (mg/m^3)	Duncan’s Grouping
A	0.08 ± 0.03	b
B	0.07 ± 0.03	b
C	0.08 ± 0.04	b
D	0.14 ± 0.21	a

Note: Means followed by different letters are significantly different at $p < 0.05$ according to Duncan’s Multiple Range Test.

3.3. Effects of Temperature and Relative Humidity

Temperature was inversely related to PM_1, $PM_{2.5}$, and PM_{10} concentrations up to approximately 30°C. Beyond this point, levels of PM increased slightly, while total dust continued to decline (Fig. 3). Relative humidity exhibited a nonlinear association with PM concentrations: levels decreased until ~55% relative humidity, then began to rise. Total dust showed a positive linear relationship with increasing relative humidity (Fig. 4).

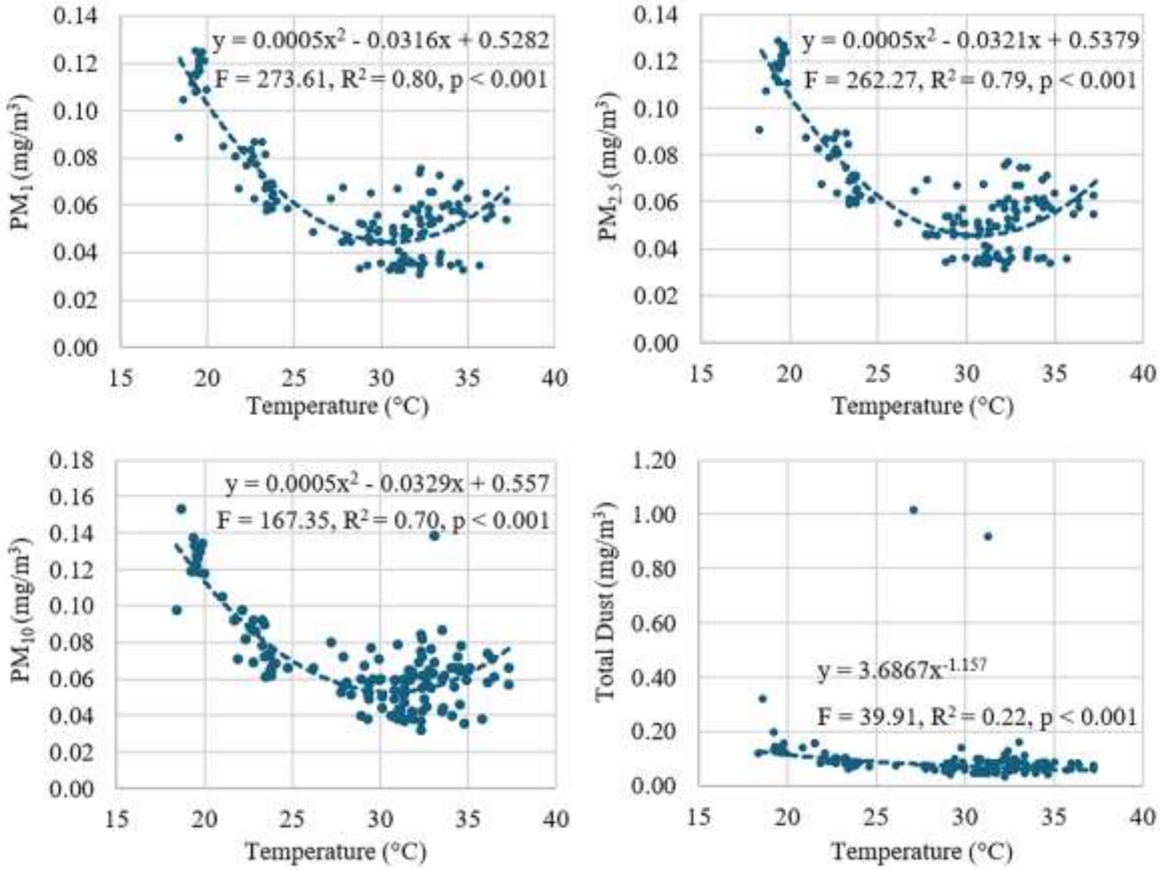

Fig. 3: Influence of temperature on the amount of dust particles of different sizes

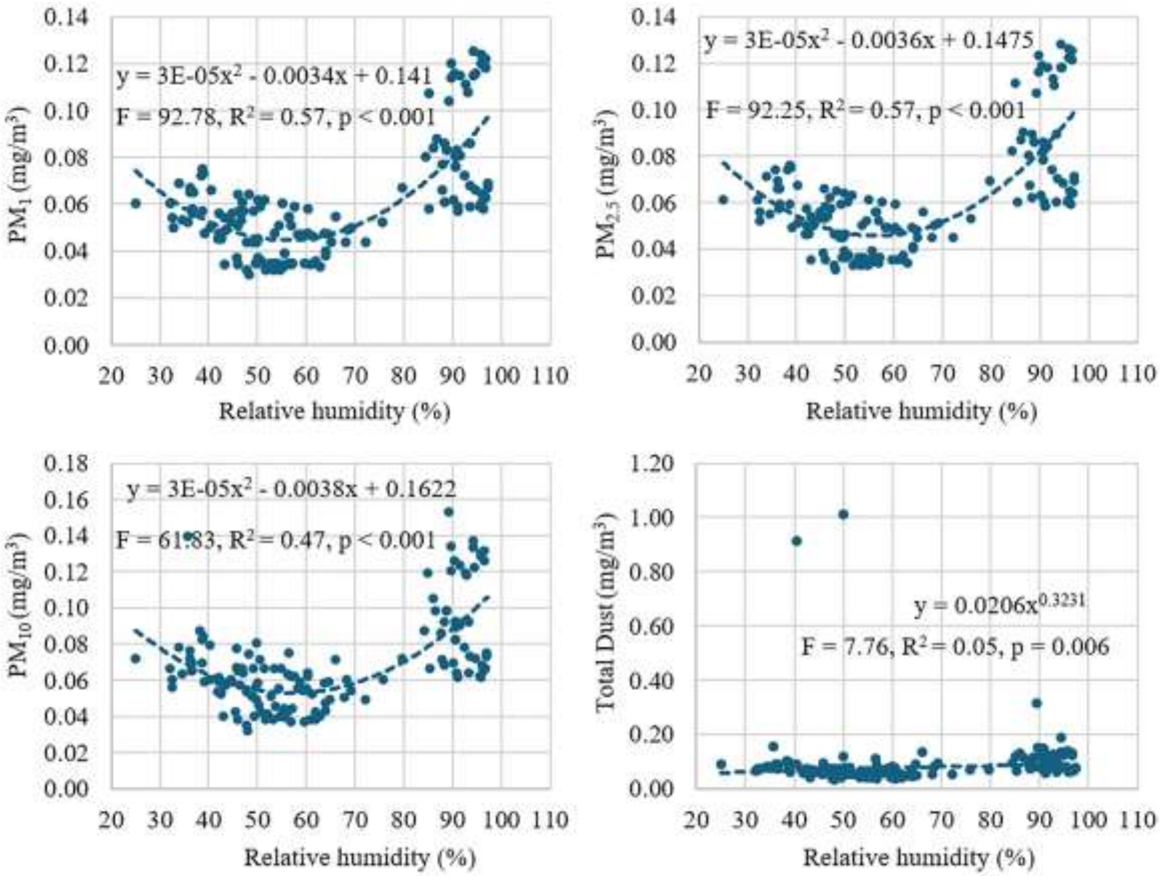

Fig. 4: Influence of relative humidity on the amount of dust particles of different sizes

3.4. Influence of Time of Day

Time of day significantly affected all measured variables. PM levels peaked in the morning and declined throughout the day (Fig. 5). Correspondingly, temperature rose from morning to midday and fell by evening, while relative humidity followed an inverse pattern (Fig. 6 and Fig. 7). A strong inverse relationship was found between temperature and relative humidity.

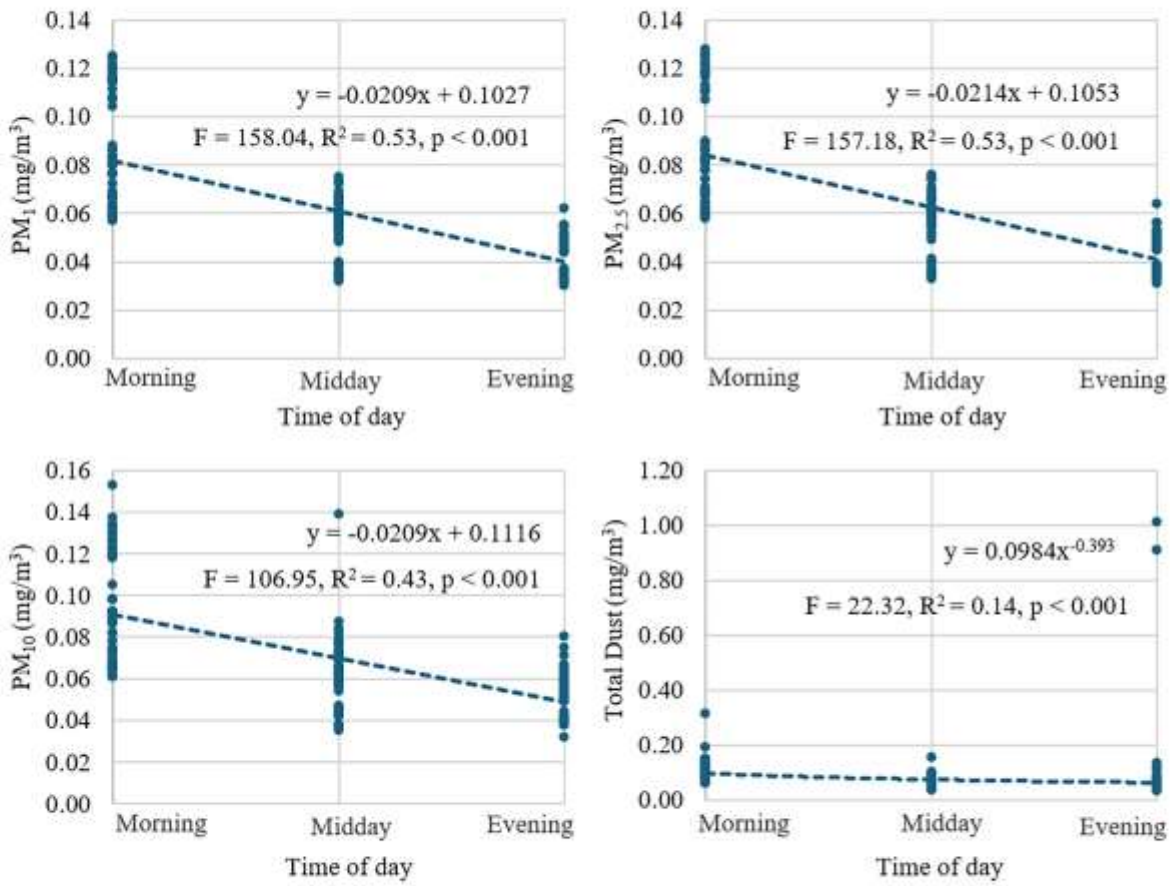

Fig. 5: Influence of time of day on the amount of dust particles of different sizes

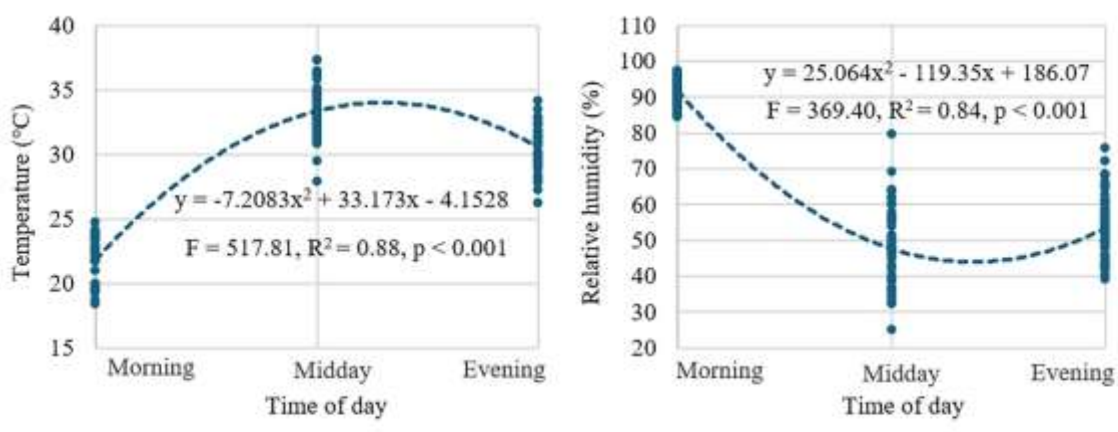

Fig. 6: Influence of time of day on temperature and relative humidity

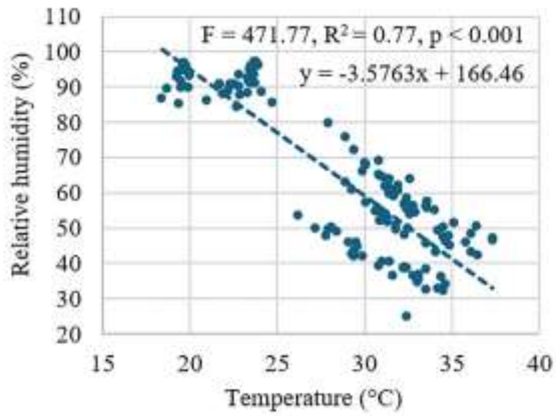

Fig. 7: Influence of temperature on relative humidity

4. DISCUSSION

The findings from this study highlight significant temporal and spatial variations in PM concentrations, temperature, and relative humidity in and around Phutthamonthon Park. These variations have direct implications for human health, especially concerning respiratory and cardiovascular outcomes (World Health Organization 2021).

The significantly higher total dust levels observed in Zone D (outside the park) compared to Zones A–C (inside the park) align with previous evidence that urban vegetation can reduce airborne particulates through interception and deposition mechanisms (Nowak et al. 2006). It is also noteworthy that Zone D exhibited a markedly higher standard deviation compared to other zones, indicating substantial variability in total dust concentrations. Upon inspection of the raw data, two exceptionally high values were identified, likely reflecting transient environmental events or measurement anomalies. These values were retained in the analysis as they fall within plausible environmental limits and represent real-world variability. However, PM1, PM2.5, and PM10 concentrations did not differ significantly between zones. This pattern is likely explained by the buoyancy and prolonged atmospheric suspension of fine particles, which reduce their likelihood of deposition onto surfaces (Janhäll 2015; Nowak et al. 2013). Due to their small aerodynamic diameter and low settling velocity, these particles are less effectively intercepted by plant surfaces. Additionally, although the DustTrak DRX is widely used in air quality monitoring, its detection sensitivity varies by particle size and ambient humidity (Sousan et al. 2016). These factors collectively affect fine PM capture and may have contributed to the observed spatial uniformity.

Interestingly, high total dust concentrations were observed during early morning hours (05:00–07:00), when traffic volumes in the vicinity were likely still relatively low. While traffic emissions may partly account for elevated PM levels near roadside zones, these temporal patterns suggest that other environmental or atmospheric factors may also be at play. Due to the absence of time-resolved traffic data, the influence of morning vehicular activity cannot be confirmed and warrants further study.

Temporal analyses showed that PM levels peaked during morning hours and decreased throughout the day. This pattern corresponds to diurnal changes in temperature and relative humidity, with lower morning temperatures and higher relative humidity favoring PM accumulation through hygroscopic growth, where water vapour condenses onto particle surfaces, increasing their mass and reducing their dispersion in the atmosphere. These observations are consistent with Piyavadee et al. (2024), who found strong correlations between ambient PM concentrations and climatic conditions in Chiangmai, Thailand. Specifically, early morning temperature inversions and high relative humidity were associated with higher pollutant levels. Further support comes from Bhosale et al. (2023), who reported that PM_{10} concentrations varied by location and time of day in Kolhapur City, India. Their findings underscore the role of urban structure and local meteorology in shaping PM distribution, similar to the elevated PM levels found in the outer areas of Phutthamonthon Park.

The non-linear relationships observed in this study between PM levels and meteorological variables (temperature and relative humidity) suggest complex atmospheric interactions. Moderate temperature and relative humidity were associated with reduced PM concentrations, while extremes led to increases—likely due to enhanced suspension or secondary particle formation (Zhang 2019; Zhang et al. 2024). This phenomenon may also be linked to the formation of volatile organic compounds and their subsequent transformation into PM under certain climatic conditions (Han et al. 2014; Jacob & Winner 2009; Seinfeld & Pandis 2016).

The results of this study confirm that green spaces in cities can reduce total dust, but demonstrate limited efficacy in mitigating health-hazardous PM_1, $PM_{2.5}$ and PM_{10}. These findings align with previous research Yli-Pelkonen et al. (2017), which found that urban vegetation primarily reduces larger PM rather than fine particles. The elevated morning concentrations of PM_1, $PM_{2.5}$ and PM_{10}, particularly in areas outside parks, represent a significant public health concern, as fine PM is associated with serious health risks (Brook et al. 2010), including respiratory and cardiovascular diseases. As emphasized by the World Health Organization (2024), long-term exposure to $PM_{2.5}$, even at low concentrations, may increase mortality risk. While this study demonstrates that green spaces contribute significantly to reducing overall dust levels (particularly total dust), their limited impact on PM_1, $PM_{2.5}$ and PM_{10} which poses the most direct health threats - highlights the need for complementary mitigation strategies. Effective reduction of fine dust requires an integrated approach combining source control measures (Setälä et al. 2013) with urban meteorological management. These findings provide valuable evidence to inform sustainable urban planning and park design, while supporting the development of comprehensive environmental and health policies at the city level.

This study measured multiple air quality parameters (PM_1, $PM_{2.5}$, PM_{10}, total dust, temperature, and relative humidity) across different zones and times, providing a detailed analysis of pollution distribution. The comparison between areas inside and outside Phutthamonthon Park offers practical insights into how green spaces influence dust levels in an actual urban environment. However, several limitations must be noted.

First, results from Phutthamonthon Park may not fully represent other urban green spaces with different vegetation types, sizes, or surrounding pollution sources. Second, the study was conducted over only three consecutive days in January, a dry, cool-season period in Thailand. Notably, this season is typically associated with heightened PM levels in Bangkok due to atmospheric inversion and stagnant wind conditions. As such, the findings may reflect peak pollution conditions rather than average year-round patterns. Seasonal factors such as rainfall, wind speed, and temperature inversions can significantly affect PM levels. Likewise, differences in human activity between weekdays and weekends (e.g., traffic volume, park usage) could influence pollution dynamics. Finally, the analysis does not detail park characteristics (e.g., tree density, species, and canopy structure) that might influence dust capture efficiency. Future studies should extend the temporal duration and spatial scope of research to enhance data accuracy. This expansion should include: longer monitoring periods across different seasons and day types, multiple study sites to improve generalizability, and assessment of climate change impacts on PM dynamics. Additionally, researchers should examine how green space design characteristics, particularly vegetation selection in public parks, influence the reduction of health-relevant PM (PM_1, $PM_{2.5}$, and PM_{10}).

5. CONCLUSIONS

This study aimed to analyse the influence of urban green space on airborne PM levels, using Phutthamonthon Park as a case study to examine the patterns of changes in different types of PM, including PM_1, $PM_{2.5}$, PM_{10}, and total dust, as well as the roles of temperature, relative humidity, and time within the context of urban green space. The findings demonstrate that green spaces can significantly reduce total dust concentrations, particularly when comparing interior zones of the park to surrounding urban areas. This highlights the value of vegetation density, distance from pollution sources, and spatial configuration in mitigating airborne particulate matter.

Conversely, PM_1, $PM_{2.5}$, and PM_{10} showed no statistically significant reduction within green zones. These smaller particles, due to their aerodynamic properties and long atmospheric residence times, remain largely unaffected by vegetation alone. Furthermore, PM_1, $PM_{2.5}$, and PM_{10} concentrations were highest during morning hours and declined throughout the day, a pattern influenced by meteorological conditions, particularly temperature and relative humidity. The study also confirmed the non-linear relationship between these environmental factors and PM levels: moderate temperature and relative humidity tended to reduce PM, while extreme values led to increased concentrations. Although the study offers valuable insights, it is based on data collected during only three days in January, a period known for heightened particulate matter levels in Bangkok due to winter meteorological conditions. As such, the findings may reflect peak pollution scenarios rather than year-round averages. Future studies should expand sampling to cover multiple seasons to improve representativeness and capture broader temporal variability.

These findings underscore the complexity of PM dynamics in urban green spaces and point to the need for integrated strategies that combine urban greenery with broader environmental management measures.

5.1. Policy Recommendations

Based on the study's findings, the following policy recommendations are proposed to enhance the role of urban green spaces in air quality improvement and dust pollution control:

1. Promote the development of green infrastructure in high-traffic urban zones, prioritizing areas with elevated pollution levels. While green spaces may have limited impact on fine PM, they contribute to overall dust reduction and support healthier urban environments.

2. Introduce dust control technologies in public spaces, such as misting systems to maintain optimal relative humidity levels and air purification units in high-use zones. These can complement the natural filtration offered by vegetation.

3. Design green spaces to maximize air circulation and pollutant capture by incorporating diverse, pollution-tolerant plant species with high particulate retention capacity. Tree type, canopy structure, and vegetation density should be aligned with air quality goals.

4. Encourage continued research into the interactions between vegetation, climate, and particulate matter. Future studies should explore seasonal variations, vegetation characteristics, and the effects of climate change on PM dynamics across various urban settings.

By integrating these strategies, cities can enhance the effectiveness of green spaces in improving air quality and protecting public health.

Author Contributions: Conceptualization, N.P. and A.J.; methodology, N.P.; software, N.P.; validation, N.P. and A.J.; formal analysis, N.P.; data curation, N.P.; writing—original draft preparation, N.P. and A.J.;

writing—review and editing, N.P. and A.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: No acknowledgments to declare.

Conflicts of Interest: The authors declare no conflicts of interest.

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