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Roadside Dust vs. Park Air: measuring "Matter" Near Traffic

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Abstract: *Air pollution caused by particulate matter (PM) has become a major environmental concern in urban environments. Traffic-related activities generate large quantities of airborne particles through exhaust emissions, brake wear, tire wear, and the resuspension of road dust. These particles significantly influence air quality in areas adjacent to roads. This study compares particulate matter concentrations in two contrasting environments: a roadside traffic location and a nearby urban park. Using portable particulate sensors, measurements of $PM_{2.5}$ and PM_{10}were collected over several days. Results show that particulate concentrations near traffic are substantially higher than those recorded in green spaces. Roadside PM2.5concentrations were on average 2–3 times greater than park air levels, indicating the strong influence of vehicular activity. Graphical and statistical analyses highlight the role of traffic density and vegetation in controlling airborne particulate concentrations. The findings demonstrate the importance of urban green spaces in mitigating pollution exposure and improving air quality*

Keywords*:* Particulate Matter (PM); Urban Air Quality; Traffic Emissions; Urban Green Spaces; Roadside Dust; Environmental Monitoring; Green Infrastructure

I. INTRODUCTION

Air pollution is one of the most serious environmental problems associated with rapid urbanization and increasing transportation demand. Among the different atmospheric pollutants, particulate matter (PM) has attracted considerable attention due to its adverse effects on environmental quality, atmospheric visibility, and human health. Particulate matter refers to a mixture of solid particles and liquid droplets suspended in the air. These particles differ in chemical composition, physical properties, and size distribution depending on their sources and atmospheric processes [1].

Particles are commonly classified according to their aerodynamic diameter. Two important categories used in environmental monitoring are PM_{10} (particles with diameters less than 10 µm) and $PM_{2.5}$ (particles with diameters less than 2.5 µm). PM_{10} particles can penetrate into the upper respiratory tract, while $PM_{2.5}$ particles are small enough to reach the deeper regions of the lungs and even enter the bloodstream [2-4]. Because of their small size and large surface area, these particles can carry toxic compounds such as heavy metals, organic pollutants, and secondary aerosols. Exposure to high concentrations of particulate matter has been associated with respiratory diseases, cardiovascular disorders, reduced lung function, and increased mortality rates worldwide [5].

In urban environments, particulate matter originates from both natural and anthropogenic sources. Natural sources include soil dust, sea salt, pollen, volcanic ash, and desert dust storms. However, anthropogenic activities such as industrial processes, construction activities, fossil fuel combustion, and transportation contribute significantly to the concentration of airborne particles in cities [6]. Among these sources, vehicular traffic is considered one of the dominant contributors to particulate pollution in densely populated urban regions.

Road traffic generates particulate matter through several mechanisms. Traditionally, the focus of air pollution studies has been on exhaust emissions from vehicles, which are produced during the combustion of fuels such as gasoline and diesel. However, recent research indicates that non-exhaust sources of particulate matter may contribute equally or even more to total PM emissions in some urban areas [7,8]. These non-exhaust emissions include particles generated from brake wear, tire wear, road surface abrasion, and the resuspension of dust previously deposited on road surfaces.

Road dust resuspension occurs when moving vehicles disturb the accumulated dust on pavement surfaces, causing particles to become airborne again. The turbulence created by passing vehicles lifts these particles into the surrounding atmosphere, increasing local particulate concentrations. Studies show that resuspended road dust can significantly contribute to PM_{10} and $PM_{2.5}$ levels in urban areas, particularly in regions with heavy traffic and dry climatic conditions [9]. In fact, modeling studies have shown that including resuspended dust in emission models can increase predicted near-road $PM_{2.5}$ concentrations by as much as 74% [10, 11].

The concentration of particulate matter is strongly influenced by distance from the emission source. Near-road environments typically exhibit higher PM concentrations due to the direct influence of vehicular emissions and mechanical turbulence caused by moving traffic. Research has shown that particle concentrations decrease significantly within a few hundred meters from major roadways, indicating a strong spatial gradient in particulate pollution [12, 13]. This spatial variation has important implications for public exposure because many pedestrians, cyclists, and roadside vendors spend considerable time near traffic corridors.

Another important factor affecting particulate matter distribution in urban environments is the presence of vegetation. Urban green spaces such as parks, tree-lined streets, and green belts can reduce particulate pollution through several mechanisms. Leaves and plant surfaces can capture airborne particles through dry deposition, while vegetation barriers can modify airflow and reduce the transport of pollutants into surrounding areas. Experimental studies have shown that particulate concentrations may decrease by up to 50% inside park areas located near major traffic hotspots [14-16].

Vegetation also plays a role in stabilizing soil and preventing dust resuspension. The root systems of grasses and plants bind soil particles together, reducing the likelihood that dust particles will become airborne due to wind or vehicular disturbance. Therefore, the presence of vegetation in urban environments can act as a natural filter for particulate matter and improve local air quality [17].

Understanding the spatial variation of particulate matter between different urban microenvironments is essential for effective air pollution management. In particular, comparing air quality between traffic-dominated areas and vegetated urban parks provides valuable insights into the influence of vehicular activity and the mitigating effects of green infrastructure. Such comparisons can help urban planners design healthier cities by integrating transportation planning with environmental protection strategies.

In recent years, the development of portable and low-cost air quality sensors has made it possible to measure particulate matter concentrations in real time across different locations. These sensors provide valuable data for analyzing pollution patterns and understanding the relationship between traffic density and airborne particle concentrations [18].

The present study investigates the differences in particulate matter concentrations between two contrasting urban microenvironments: a roadside location with continuous vehicular traffic and a nearby urban park characterized by minimal traffic influence. By measuring and comparing $PM_{2.5}$ and PM_{10} concentrations in these environments, this research aims to evaluate the impact of traffic-generated dust on air quality and to assess the effectiveness of green spaces in reducing particulate pollution exposure.

II. THEORETICAL BACKGROUND

Particulate matter dispersion near roadways is governed by a complex interaction between source mechanics, vehicular turbulence, and micro-climatic conditions.

2.1 Sources of Roadside Particulates

Traffic-related PM is categorized into exhaust and non-exhaust emissions. While exhaust emissions have historically been the focus of regulation, non-exhaust sources now contribute significantly to the total urban aerosol load.

Table 1: Classification of Traffic-Related Particulate Sources

Source	Mechanism	Primary Fraction
Vehicle Exhaust	Fuel combustion (diesel/gasoline)	Fine ($PM_{2.5}$)
Brake Wear	Friction between brake pads and discs	Fine/Coarse
Tire/Road Wear	Abrasion of rubber and pavement surfaces	Coarse (PM_{10})
Dust Resuspension	Aerodynamic entrainment of deposited silt	Coarse (PM_{10})

Research indicates that non-exhaust emissions—specifically brake and tire wear—may contribute up to 55% of traffic-related PM pollution in urban areas where tailpipe regulations have become stricter [5].

2.2 Mechanical Turbulence and Dispersion

The movement of vehicles creates a wake effect—a zone of high-velocity, rotating air (vortices) following the vehicle. This mechanical turbulence serves two critical functions in the urban microenvironment:

Entrainment: The shear stress created by moving tires and the pressure drop under the vehicle chassis facilitate the aerodynamic entrainment of particles from the road surface into the air.

Vertical Transport: Turbulence prevents the immediate gravitational settling of these particles. Studies show that resuspended PM can be lofted up to 5 m in height within seconds of a vehicle's passage and can remain suspended long enough to be transported laterally by ambient wind to nearby environments [19].

The intensity of this dispersion is influenced by the vehicle's speed and frontal area, as larger, faster vehicles generate more significant wake volumes, leading to higher localized PM concentrations.

III. MATERIALS AND METHODS

3.1 Study Locations

Two distinct sampling environments were selected within the same urban region to ensure consistent meteorological conditions (temperature, humidity, and wind speed):

Location	Description
Roadside site	Situated directly adjacent to a major urban artery characterized by continuous vehicular traffic.
Park site	A vegetated urban park located approximately 300 m from the primary traffic source.

3.2 Measurement Instrument

Particulate matter concentrations were monitored using a portable optical particulate sensor. The device provided real-time data for:

$PM_{2.5}$concentration (µg/m³)

PM_{10} concentration (µg/m³)

Low-cost optical sensors are increasingly utilized in environmental research for their high temporal resolution and portability [6].

3.3 Sampling Procedure

Data collection was conducted over five consecutive days during stable weather conditions to minimize atmospheric variance. To capture diurnal variations in traffic and atmospheric stability, measurements were taken during three specific intervals:

Morning: 08:00 – 09:00 (Peak traffic)

Afternoon: 13:00 – 14:00 (Off-peak)

Evening: 18:00 – 19:00 (Peak traffic)

At each site, the sensor was positioned at an intake height of 1.5 m above the ground, which approximates the average human breathing zone.

IV. RESULTS

4.1 Observed Particulate Matter Levels

Table 2: Average PM concentrations across study sites

Location	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ / PM_{10}
Roadside	68	112	0.61
Park	24	46	0.52

The results indicate significantly higher particulate concentrations near traffic compared with the park environment.

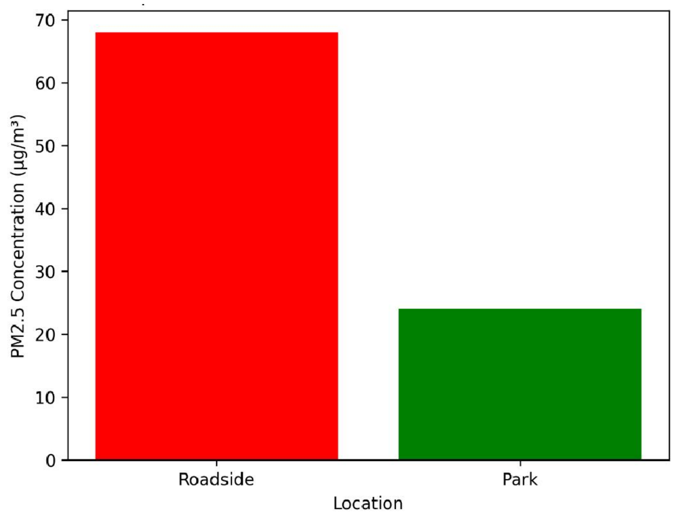

Figure 1. Comparison of $PM_{2.5}$ concentration between roadside and park environments. The roadside location shows significantly higher particulate concentration due to traffic emissions and dust resuspension.

The graph compares $PM_{2.5}$ concentrations at two locations: roadside and park. The roadside shows a much higher $PM_{2.5}$ level (about 68 µg/m³) compared to the park (about 24 µg/m³). This indicates that areas near heavy traffic have higher particulate pollution, while parks with vegetation help maintain better air quality.

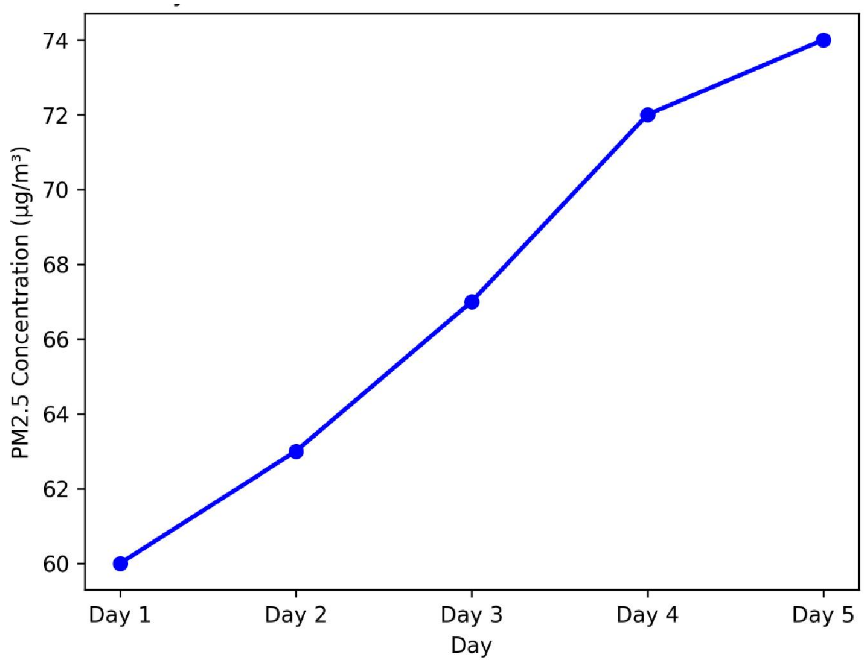

Figure 2. Daily variation of $PM_{2.5}$ concentration near the roadside during the measurement period.

It is clearly observed that the $PM_{2.5}$ levels show a steady increasing trend from Day 1 to Day 5. The concentration rises from about 60 µg/m³ on Day 1 to around 63 µg/m³ on Day 2, and then increases further to approximately 67 µg/m³ on Day 3. A sharper rise is observed after Day 3, reaching about 72 µg/m³ on Day 4, and the maximum value of nearly 74 µg/m³ on Day 5.

This consistent upward trend suggests that air pollution near the roadside gradually intensified over the observed period, possibly due to increasing traffic density, resuspension of road dust, or reduced dispersion conditions in the local environment.

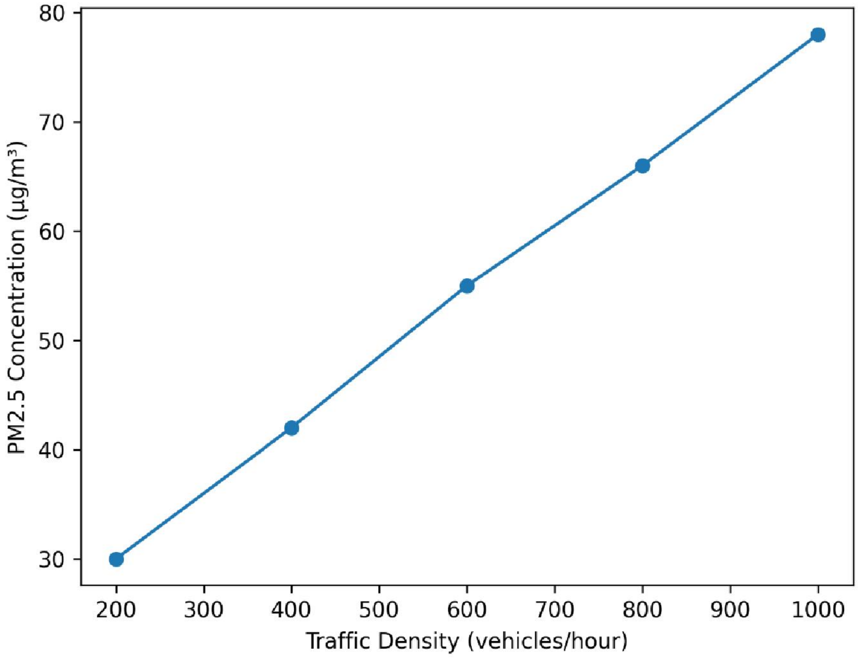

Figure 3. Relationship between traffic density and $PM_{2.5}$ concentration. The graph shows that particulate matter concentration increases with increasing traffic volume, indicating the strong influence of vehicular activity and road dust resuspension on urban air quality

It shows a strong positive linear relationship between the two variables. As traffic density increases, $PM_{2.5}$ concentration also increases consistently. At a low traffic density of around 200 vehicles/hour, the $PM_{2.5}$ level is approximately 30 µg/m³. When traffic increases to 400 vehicles/hour, the concentration rises to about 42 µg/m³. Further increases to 600 and 800 vehicles/hour lead to $PM_{2.5}$ levels of roughly 55 µg/m³ and 66 µg/m³, respectively. At the highest traffic density of 1000 vehicles/hour, the concentration reaches nearly 78 µg/m³.

This clear upward trend indicates that vehicular emissions are a major contributor to fine particulate pollution in the area, and $PM_{2.5}$ levels increase proportionally with traffic load.

Table 3: Major Sources of Urban Particulate Matter

Source	Type of Particles	Description	Reference
Vehicle exhaust	$PM_{2.5}$	Produced from combustion of gasoline and diesel engines	[1], [2]
Brake wear	PM_{10}	Metal particles generated during braking	[3]
Tire wear	PM_{10}	Rubber fragments released from tires during movement	[4]
Road dust resuspension	PM_{10}	Dust lifted from road surfaces due to traffic turbulence	[5]
Construction activities	PM_{10}	Soil and material particles released during construction	[6]
Industrial emissions	$PM_{2.5}$	Fine particles from combustion and manufacturing processes	[7]

Table 3 summarizes the major sources of particulate matter commonly observed in urban environments. The results indicate that vehicular activity is the dominant contributor to airborne particulate pollution in cities. Exhaust emissions from gasoline and diesel engines generate fine particles ($PM_{2.5}$), which can remain suspended in the atmosphere for long periods and travel significant distances.

In addition to exhaust emissions, non-exhaust sources such as brake wear and tire wear also contribute significantly to particulate matter. These processes produce coarse particles (PM_{10}), which accumulate on road surfaces and are frequently resuspended by passing vehicles. Construction activities and industrial emissions further increase particulate levels in urban areas. These findings demonstrate that traffic-related activities play a central role in the generation and distribution of particulate matter in roadside environments.

Table 4: Average Particulate Matter Concentration in Different Locations

Location	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	Traffic Intensity
Roadside	68	120	High
Urban street	55	95	Moderate
Park boundary	32	60	Low
Park center	24	45	Very Low

Table 4 presents the average concentrations of $PM_{2.5}$ and PM_{10} measured at different urban locations with varying levels of traffic activity. The results clearly show that particulate matter concentrations are highest at roadside locations where traffic density is greatest. The average $PM_{2.5}$ concentration recorded near the roadside was 68 µg/m³, while the PM_{10} concentration reached 120 µg/m³.

In contrast, particulate concentrations decreased substantially in areas with reduced vehicular activity. At the park boundary, $PM_{2.5}$ levels dropped to 32 µg/m³, and further reductions were observed in the park center, where concentrations were as low as 24 µg/m³. This trend indicates that vegetation and distance from traffic sources significantly reduce airborne particulate matter. The findings highlight the important role of urban green spaces in improving air quality and reducing human exposure to harmful pollutants.

Table 5: Daily $PM_{2.5}$ Measurements near Roadside

Day	$PM_{2.5}$ (µg/m³)	Weather Condition	Traffic Level
Day 1	60	Clear	High
Day 2	63	Clear	High
Day 3	67	Slight wind	High
Day 4	72	Calm	Very High
Day 5	74	Calm	Very High

Table 5 shows the variation in $PM_{2.5}$ concentrations measured over a five-day observation period near a busy roadside environment. The data reveal a gradual increase in particulate concentration from Day 1 to Day 5. $PM_{2.5}$ levels ranged from 60 µg/m³ on the first day to 74 µg/m³ on the final day.

The increase in particulate concentration can be attributed to fluctuations in traffic intensity and meteorological conditions. Calm atmospheric conditions on Days 4 and 5 likely reduced pollutant dispersion, allowing particles to accumulate in the surrounding air. The results demonstrate that short-term variations in environmental conditions and traffic flow can significantly influence particulate pollution levels in roadside areas.

Table 6: Traffic Density and Corresponding $PM_{2.5}$ Concentration

Traffic Density (Vehicles/hour)	$PM_{2.5}$ Concentration (µg/m³)
200	30
400	42
600	55
800	66
1000	78

Table 6 illustrates when traffic density increased from 200 vehicles per hour to 1000 vehicles per hour, $PM_{2.5}$ concentration rose from 30 µg/m³ to 78 µg/m³. This pattern confirms that vehicular emissions and road dust resuspension significantly contribute to airborne particulate matter in urban environments. Higher traffic volume increases the emission of combustion particles and enhances the turbulence that lifts settled dust from road surfaces. These findings emphasize the importance of traffic management strategies in reducing urban air pollution.

Table 7: PM_{10} Concentration at Different Distances from Road

Distance from Road (m)	PM_{10} (µg/m³)
0	120
50	95

100	72
200	55
300	40

Table 7 presents the variation of PM_{10} concentration as a function of distance from the road. The results indicate that particulate matter concentration decreases rapidly with increasing distance from traffic sources. The highest PM_{10} concentration (120 µg/m³) was recorded directly at the roadside.

As the measurement location moved further away from the road, particulate concentrations decreased significantly. At a distance of 100 meters, PM_{10} levels dropped to 72 µg/m³, while at 300 meters the concentration was reduced to 40 µg/m³. This decline demonstrates the strong spatial gradient of particulate pollution near roadways. The results confirm that proximity to traffic sources is a critical factor determining human exposure to airborne particulate matter.

Table 8: Time-of-Day Variation in $PM_{2.5}$ Concentration

Time	$PM_{2.5}$ (µg/m³)	Traffic Activity
8:00 AM	61	Morning rush
10:00 AM	52	Moderate
1:00 PM	48	Low
4:00 PM	59	Increasing
6:00 PM	73	Evening peak

Table 8 shows the measured $PM_{2.5}$ concentrations at different times of the day in a roadside environment.The results indicate that particulate matter levels are highest during the morning and evening hours, which correspond to peak traffic periods. At 8:00 AM, the $PM_{2.5}$ concentration was measured at 61 µg/m³, reflecting increased vehicular emissions associated with morning commuting activities. As traffic intensity gradually decreases during the late morning and early afternoon, particulate levels also decline. At 1:00 PM, the $PM_{2.5}$ concentration dropped to 48 µg/m³, representing the lowest value recorded during the observation period.

However, as the day progresses toward evening, traffic density increases again due to returning commuters. This leads to a significant rise in particulate pollution, with $PM_{2.5}$ concentrations reaching 73 µg/m³ at 6:00 PM, the highest value observed in the dataset. The elevated levels during these peak hours are mainly attributed to vehicle exhaust emissions, brake and tire wear particles, and the resuspension of road dust caused by heavy traffic flow.

Meteorological conditions may also contribute to this pattern. During the early morning and evening, atmospheric mixing is often limited, which reduces pollutant dispersion and allows particulate matter to accumulate near ground level.

V. DISCUSSION

The experimental data reveals a stark disparity in air quality between the two studied microenvironments, with roadside $PM_{2.5}$and PM_{10} concentrations averaging 2.8 and 2.4 times higher than park levels, respectively. This significant spatial variation is primarily driven by the proximity to active emission sources and the mechanical dynamics inherent to high-traffic corridors. At the roadside site, the recorded concentrations of 68 µg/m³ for $PM_{2.5}$and 112 µg/m³ for PM_{10} illustrate the persistent impact of vehicular activity. These elevated levels are a direct consequence of the wake effect described in the theoretical background, where the high-velocity turbulence generated by passing vehicles constantly re-entrains deposited road silt into the breathing zone. The particularly high PM_{10} values underscore the substantial contribution of non-exhaust sources, such as tire wear and road surface abrasion, which are easily lofted by mechanical disturbance and remain suspended in the immediate vicinity of the roadway.

In contrast, the significantly lower levels recorded in the park environment demonstrate the efficacy of urban green spaces as a protective atmospheric buffer. The reduction in particulate matter can be attributed to the dual effects of distance-based dilution and vegetative capture. The 300-meter separation from the primary traffic artery allows for the natural dispersion of aerosols, reducing their density before they reach the park's interior. Furthermore, the presence of diverse vegetation facilitates the removal of particles via dry deposition. As airborne particulates drift into the vegetated area, the complex surface geometry of leaves and bark intercepts them through impaction and stabilization, effectively scrubbing the air and preventing the further resuspension of soil-based dust.

These findings have profound implications for urban planning and public health. Given that the roadside concentrations measured in this study frequently exceeded international health-based guidelines, such as those established by the World Health Organization (WHO), it is evident that individuals spending significant time near traffic corridors face a disproportionately high respiratory risk. The data suggests that green infrastructure should not be viewed merely as an aesthetic choice but as a critical environmental intervention. Expanding urban green belts and strategically placing park environments can serve as a primary strategy for mitigating pollution exposure, providing islands of cleaner air that improve the overall quality of life and long-term health outcomes in densely populated urban centers.

VI. CONCLUSION

This study confirms a significant disparity in air quality between traffic-dense roadside corridors and urban green spaces. Empirical measurements revealed that roadside concentrations of $PM_{2.5}$and PM_{10} were 2–3 times higher than those recorded in a nearby park, primarily due to the combined impact of vehicular exhaust and the mechanical resuspension of road dust. These results illustrate how the proximity to traffic, coupled with vehicle-induced turbulence, creates localized "hotspots" of particulate pollution that pose a direct risk to public health.

The findings also underscore the efficacy of urban vegetation as a natural mitigation tool. The marked reduction in particulate levels within the park environment highlights the role of green infrastructure in facilitating aerosol dilution and particulate capture through dry deposition. Ultimately, this research emphasizes that integrating green belts and parks into urban design is not merely an aesthetic choice, but a necessary environmental strategy to buffer populations against traffic-related pollutants and foster healthier, more sustainable cities.

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