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The Impact of Roadside Trees on Air Quality in Hot Desert Climates: A Case Study of Dubai

Sıcak Çöl iklimi Koşullarında Yol Ağaçlarının Hava Kalitesine Etkisi: Dubai Örneği

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Abstract

The global warming period, which continues all over the world, has also taken all climates under its influence. In order to be a solution to this problem, every country around the world produces solutions both within itself and with international unions. Plants are among the most important sources of these solutions. The relationship between air quality and plants is quite different. While polluted air quality affects all living things, even plants, plants help to reduce and improve this damage. In order to minimise and improve harmful emissions in the air, plants are the most important design tool of many professional disciplines, especially landscape architects. This study was carried out in Dubai, the most popular and developing city of the United Arab Emirates. Dubai is a model for the world with its environmental policies and a different herd approach. The main purpose of this study is to reveal the effect of highway planting on air quality. For this purpose, 4 routes with different plant material characteristics on an important main boulevard of Dubai were selected as the study area and analysed for air quality. Four road routes were selected on the basis of the presence or absence of vegetated areas. In line with these choices, particulate matter 10 (PM10), particulate matter 2.5 (PM2.5), total volatile organic compounds (TVOC), formaldehyde (HCHO), carbon monoxide (CO) and carbon dioxide (CO2), which are among the harmful emissions affecting air quality, were measured. The effect of plants on road air quality was analysed. As a result of the study, these measurement results obtained from road routes of different character were compared and evaluated according to 'air quality indices' and suggestions were made for future studies.

Keywords: Air quality, Air quality index, Harmful emissions, Dubai.

Özet

Tüm dünyada süren küresel ısınma süresi aynı şekilde tüm iklimleri de etkisi altında almıştır. Bu soruna çözüm olabilmek için dünya çapında her ülke gerek kendi içerisinde gerekse milletlerarası birleşimler ile çözümler üretmektedir. Bu çözümlerin en önemli kaynakları arasında bitkiler bulunmaktadır. Hava kalitesi ve bitkiler arasındaki ilişki oldukça farklıdır. Kirlenen hava kalitesi tüm canlıları hatta bitkileri bile etkilerken, bitkiler bu zararı indirgemek ve iyileştirmek için yardımcı olmaktadır. Havadaki zararlı emisyonları en aza indirgemek ve iyileştirmek için bitkiler başta peyzaj mimarları olmak üzere birçok meslek disiplinin en önemli tasarım aracıdır. Yapılan bu çalışma kapsamında Birleşik Arap Emirliklerinin gelişen ve gelişmekte olan en popüler ili olan Dubai'de gerçekleştirilmiştir. Dubai çevresel politikaları ve farklı bir sürü yaklaşımı ile dünyaya örnek çalışmalar yapmaktadır. Yapılan bu çalışmanın temel amacı karayolu bitkilendirmelerinin hava kaltesi üzerindeki etkisini ortaya koymaktır. Bu amaç doğrultusunda Dubai'nin önemli bir ana bulvarı üzerinde yer alan ve farklı bitki materyali karakterine sahip 4 güzergâh çalışma alanı olarak seçilmiş ve hava kalitesi analizi yapılmıştır. Yol güzergâhları dört adet olmak üzere bitkisel dokunun var olması ya da bitkilendirme yapılmış alanlar var olmaması üzerinden yapılmıştır. Bu seçimler doğrultusunda hava kalitesini etkileyen zararlı emisyonlar arasında olan Partiküler madde 10 (PM_{10}), Partiküler madde 2.5 ($PM_{2.5}$), Toplam uçucu organik bileşikler (TVOC), Formaldehit (HCHO), Karbonmonoksit (CO) ve Karbondioksit (CO_2) ölçümleri yapılmıştır. Bitkilerin kara yolu hava kalitesindeki etkisi incelenmiştir. Çalışmanın sonucunda farklı karakterdeki yol güzergâhlarından elde edilen bu ölçüm sonuçları "hava kalitesi indekslerine" göre karşılaştırılmıştır, değerlendirilmiş ve gelecekte yapılacak çalışmalar için önerilerde bulunulmuştur.

Anahtar Kelimeler: Hava kalitesi, Hava kalitesi indeksi, Zararlı emisyonlar, Dubai.

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1. Introduction

Air pollution is one of the biggest environmental problems of today. Increasing industrialisation, motor vehicle use and fossil fuel consumption cause an increase in harmful particles in the atmosphere. This has a devastating effect on human health and the environment. At this point, many professional disciplines offer solutions in line with their own fields and produce solutions to improve this situation. Plants, which are the most important element of landscape architecture discipline, play a very important role in the struggle with air quality. In this regard, we can call trees "natural air filters". Trees acting as natural air filters help to significantly improve air quality by absorbing and filtering pollutants in the air.

Trees play a very important role in the climate of urban areas. Among these benefits is the improvement of urban air quality (Nowak and Heisler, 2010; Grylls and van Reeuwijk, 2022). In the absence of trees, large increases in the surface temperature of roads can be observed, as hot roads radiate this heat upwards. This affects the comfort of life for pedestrians and cyclists and makes the situation difficult (Vailshery et al., 2013). One of the most important problems threatening human health is air pollution. This problem is an environmental problem of great concern. Excessive traffic, increasing needs have increased the emission of emissions day by day. Plants can absorb gaseous pollutants through stomata in their leaves. Through stomata, particles are also removed from the air by accumulating on leaves and branches. Many studies have studied this effect and examined its effects (Beckett et al., 2000; Freer-Smith et al., 2005; Vos et al., 2013). Many scientific studies focus on plants and their effects on air quality (Jeanjean et al., 2017). Highways are the most important urban links that connect cities and where vegetation character is important (Bekar et al., 2018).

The presence of trees and vegetation in parks has a dual impact on air pollution mitigation. On one hand, they actively diminish pollutants by directly capturing them and lowering air temperatures, consequently decreasing energy consumption in park vicinity. These actions ultimately curtail emissions and the formation of pollutants. Conversely, park flora may indirectly escalate certain pollutants by releasing volatile organic compounds, which aid in ozone and carbon monoxide production. Additionally, emissions from vegetation maintenance activities, such as chainsaw operation and fuel usage, can further contribute to air pollution (Novak and Heisler, 2010).

PM_{10}, which is among the particulate matter examined within the scope of the study, is emitted by biogenic and anthropogenic effects. This emission adversely affects the respiratory tract (Karimi et al., 2019) This value reflects the measurement of particles with a diameter of 10 micrometres and smaller (Kocak, 2023). Another particulate matter analysed in this context is PM2.5. It can be stated that PM2.5 includes organic compounds, particles formed by the combustion process and particles with a size of 2.5 microns or less. These pollutants can be formed as a result of chemical interaction of substances in the atmosphere as well as direct emission from a certain source (Kocak, 2023).

TVOC is the sum of all volatile organic compounds in indoor air. It is higher indoors than outdoors. HCHO is a subcategory of TVOC that has a higher vapour pressure and mixes with the air faster and is generally harmful to health.

CO is among the hazardous emissions that reduce the oxygen level in the human body (Saxena and Naik, 2019). Carbon dioxide (CO_2), especially the increase in fossil fuel consumption, threatens cities and the world on a global scale. It has a high capacity to dissolve in water and retain heat (Singh et al., 2009). In line with this problem definition; the main purpose of this study is to reveal whether "road afforestation" on the road route of the same character has an effect on air quality in hot climates. Another sub-objective of the study is to reveal how this effect is quantitatively if it has an effect on air quality and to set an example for future studies. In line with this purpose, the main and sub-objectives of the study are as follows;

- Does road afforestation have an effect on air quality on a road route with the same sensitivity?
- How does road afforestation affect air quality on a road route in hot climate conditions?
- If it has an effect on air quality, what is the air quality index result.

2. Material and Method

2.1. Material

This study was conducted in Dubai, one of the most developed cities of the UAE. When the climatic characteristics of Dubai are examined, desert climate is observed. Dubai receives very little precipitation throughout the year. According to Köppen-Geiger, the climate is BWh (Climate Data, 2024) (Figure 1).

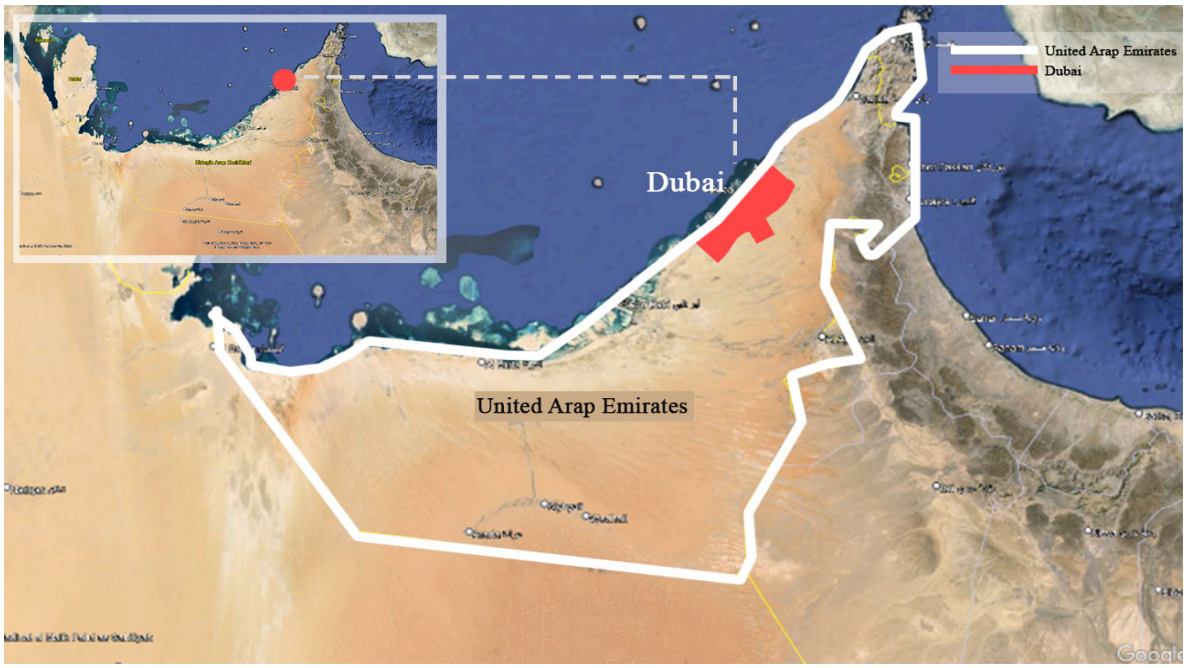

Figure 1. Location of Dubai (Image © Google, Map data, Data SIO, NOAA u.s. Navy NGA gebco Image Landsat/Copernicus).

"D94 King Salman Bin Abdulaziz Al Saud Street Al Sufouh 2" route in Dubai was selected as the main material of the study. This selected road route is one of the most active roads leading to important education, tourism and trade centres of Dubai. The opening of the road to the harbour area and passing over the city's tram line are among the important characteristics of the road (Figure 2).

Measurements were made on this road route. In order to have the same character of the selected study area and to increase the sensitivity more, measurements were made on the same road route. The selected road route surrounds a very large coastal line. The road is divided into main and side roads (Figure 2).

The study area was analysed in 4 sections to allow the measurement of different characters. The first study area is the road route where there is no tree cover ares. The second study area is the second route that continues with the same character as the first study area. In this route, there are trees in the refuge application. The third study point is another reference point with no vegetative character. The fourth area, which is the last measurement point of the study area, has vegetative character. The study areas were selected as two with vegetative character and two without vegetative character. Sensitivity was increased by following the same route. In this way, they are exposed to the same noise, traffic intensity, etc.

Figure 2. Study areas (Image © Google, Map data, Data SIO, NOAA u.s. Navy NGA gebco Image Landsat/Copernicus).

2.2. Method

Air quality measurements were carried out at four measurement points selected within the scope of the study, 3 times a day for 1 month with measurements of 10 minutes in total. Measurements were made with a measuring instrument that measures PM2.5, PM10, HCHO, TVOC, humidity and temperature all together and produces "avarege air quality" results. In total, 90 measurements were carried out in 4 study areas and 360 measurement results were obtained. These measurements were compared with the characteristics of the study area. As a result of the measurements, graphs were obtained according to the average data and these results were discussed (Figure 3).

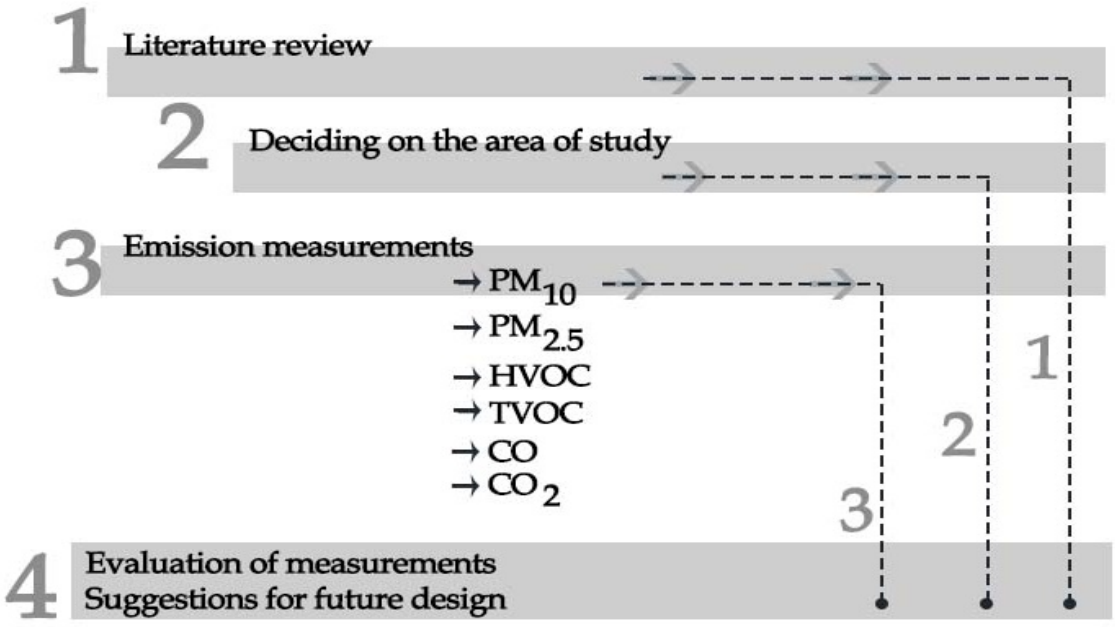

Figure 3. Method flow diagram.

3. Findings

3.1. Findings On Particulate Matter Measurements

The measurement findings obtained within the scope of the study are given in tables and graphs. While evaluating these measurement results, Airnow's AQI metrics and metric range were used. Airnow is a working partner of the U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration (NOAA), National Park Service, NASA, Centers for Disease Control (Airnow, 2024a). In these measurement values, 0-50 index range is "Good", 51-100 index range is "Moderate", 101-150 index range is "Unhealthy for Sensitive Groups", 151-200 index range is "Unhealthy" for everyone, 301-500 index range is "Hazardous". Airnow defines sensitive group as individuals with heart disease, lung disease, pregnant, etc. (Airnow, 2024b).

When the measurement results of particulate matter are analysed, hourly average emission graphs were made in accordance with the data obtained from the first measurement point during the measurement month. This measurement point is a measurement point without trees. For this reason, more intense emission results were obtained compared to the roads with trees. Since the road is both an important road and has a role intersecting many points, intense emission results were obtained on Monday, the first working day of the week, and the last working day of the week. In the results obtained, PM2.5 is 158 µg/m³-, PM10 is 150 µg/m³, HCHO is 0.011 ppm and TVOC is 0.009 ppm. The average air quality index was determined as 152. When we look at the results of the first measurement point, although there is not a big difference, it is seen that the points with vegetation are lower (Figure 4).

Hourly average emission graphs in accordance with the data obtained from the second measurement point during the measurement month are given in Table 3. This measurement point is a measurement point with trees. For this reason, the measurement emission results were lower than the other roads. According to the results obtained, it was determined that trees affect the air quality. Although higher results were obtained on the first working day and the last working day of the week compared to other days, low results were still obtained. In the results obtained, $PM_{2.5}$; 125 µg/m³-, PM_{10}; 112 µg/m³, HCHO; 0,008 ppm, TVOC result; 0,012 ppm. The average air quality index was determined as 111 (Figure 5).

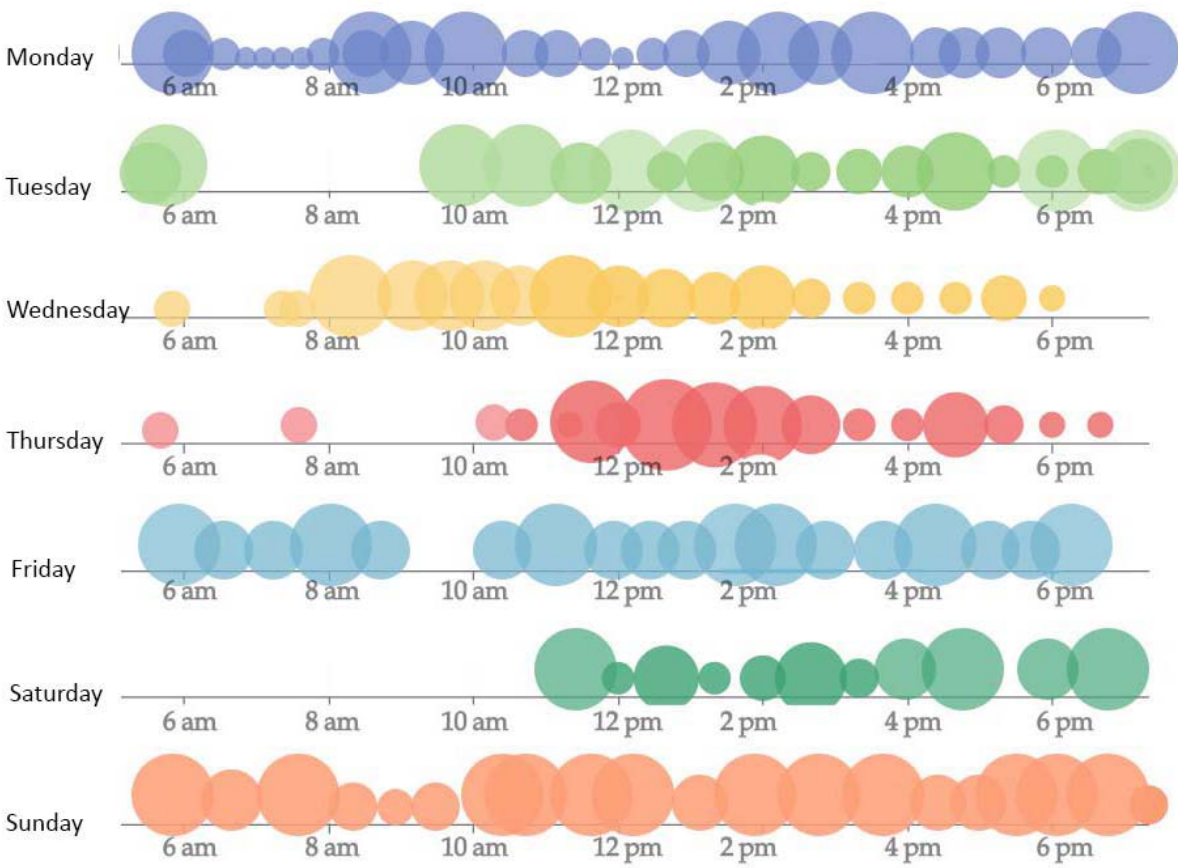

Figure 4. $PM2_{.5}$, PM_{10}, HCHO, TVOC measurement results from the first measurement point.

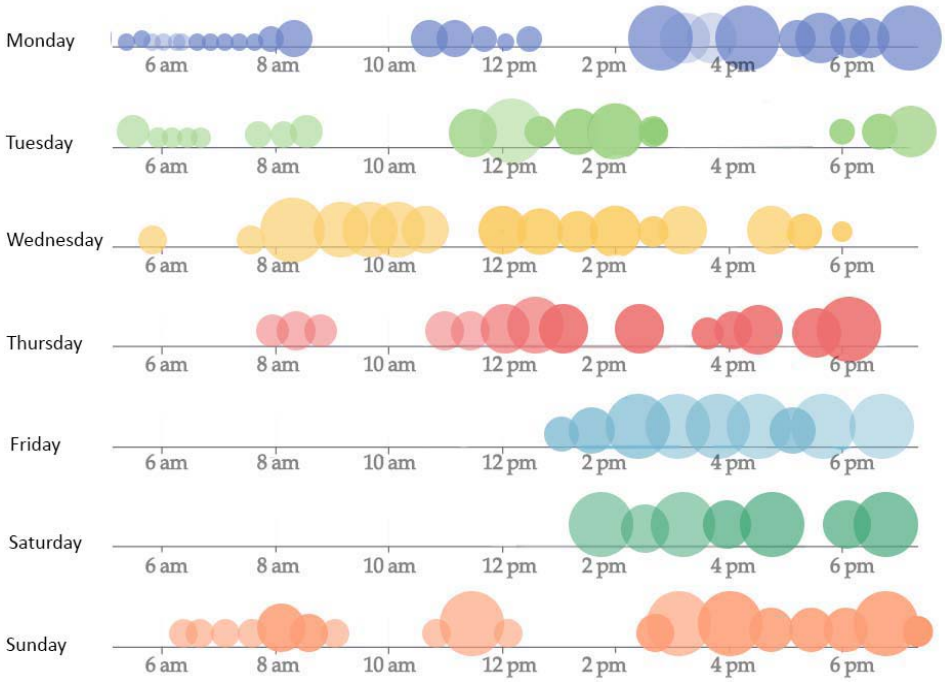

Figure 5. PM2.5, PM10, HCHO, TVOC measurement results from the second measurement point.

The third measurement point is the road route without vegetation. The weekly averages of the measurements made on this road route are expressed graphically in Figure 6. This graph shows that all days of the week are high in terms of emissions.

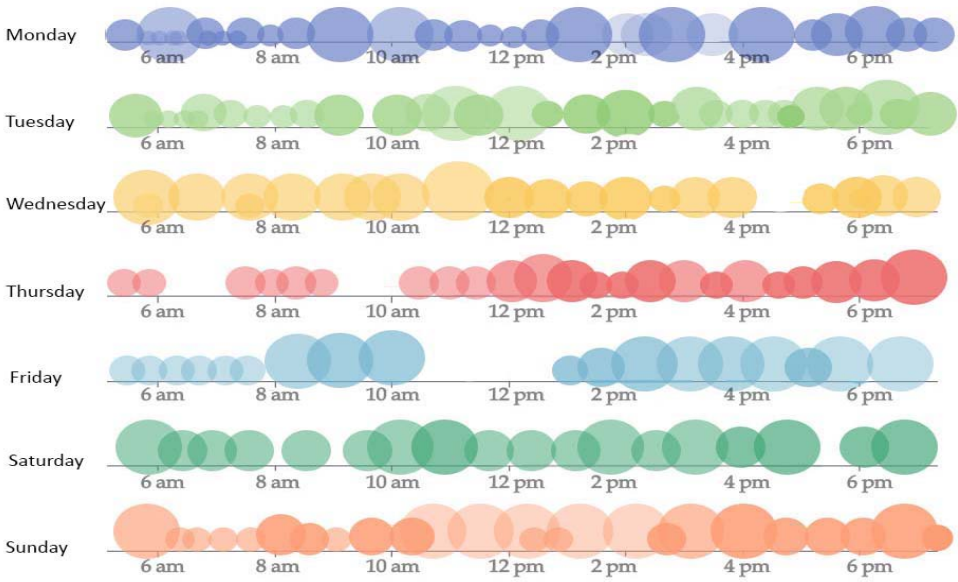

Figure 6. PM2.5, PM10, HCHO, TVOC measurement results from the third measurement point.

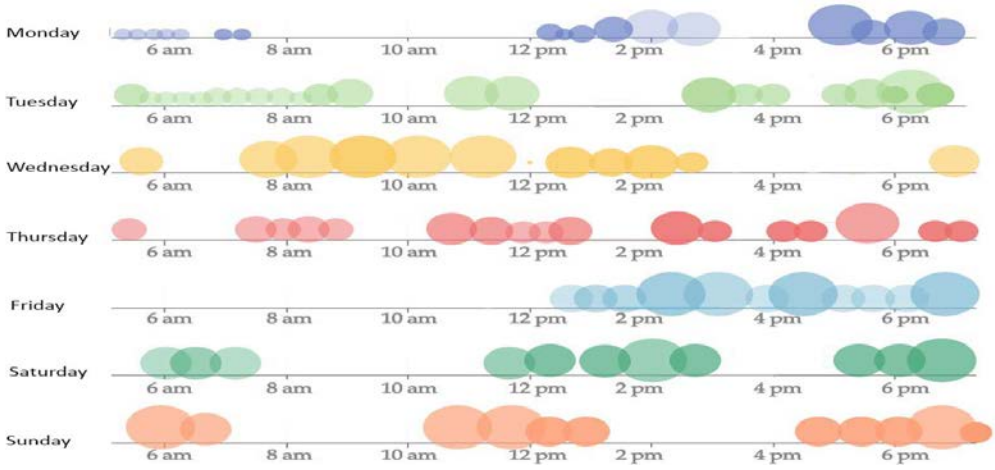

Figure 7. $PM_{2.5}$, PM_{10}, HCHO, TVOC measurement results from the fourth measurement point.

When the data obtained from the fourth measurement point are analysed, PM2.5 was 115 µg/m³, PM10 was 139 µg/m³, HCHO was 0.011 ppm and TVOC was 0.014 ppm. In line with this determination, it was relatively higher at this point, just like the other treeless road (Figure 7). In all measurements, no very low AQI was obtained on treeless roads. This is because Dubai has many environmental policies to improve air quality and many other

environmental policies. When all these are combined, a successful result is obtained. The measurement results of all points are given in Table 1.

Table 1. Average index findings for measurement points

	Measurement Points			
Particulate Matter	**Point: 1**	**Point: 2**	**Point: 3**	**Point: 4**
PM 2.5	158 µg/m³	125 µg/m³	162 µg/m³	115 µg/m³
PM 10	150 µg/m³	112 µg/m³	153 µg/m³	139 µg/m³
HCHO	0,011 ppm	0,008 ppm	0,019 ppm	0,011 ppm
TVOC	0,009 ppm	0,012 ppm	0,021 ppm	0,014 ppm
CO	2	1	2	1
CO_2	407,00 ppm	401,00 ppm	412,00 ppm	413,00 ppm
Avarage AQI	152	111	163	114
Arboriculture status	No trees	•	No trees	•

The ranges of emissions measured within the scope of the study were created by evaluating the ranges of the World Health Organization, American Society of Heating, Refrigerating and Air-Conditioning Engineers and Environmental Protection Agency (WHO, 2010, 2021; ASHRAE, 2021; EPA, 2021).

Table 2. Assessment range of pollutants.

Pollutant	Category	WHO Limit Values
$PM_{2.5}$	Safe	0 - 5 µg/m³ (annual)
	Moderate	5 - 15 µg/m³ (annual)
	Hazardous	> 15 µg/m³ (annual)
	Safe	0 - 15 µg/m³ (24 hours)
	Moderate	15 - 25 µg/m³ (24 hours)
	Hazardous	> 25 µg/m³ (24 hours)
PM_{10}	Safe	0 - 15 µg/m³ (annual)
	Moderate	15 - 45 µg/m³ (annual)
	Hazardous	> 45 µg/m³ (annual)
	Safe	0 - 45 µg/m³ (24 hours)
	Moderate	45 - 75 µg/m³ (24 hours)
	Hazardous	> 75 µg/m³ (24 hours)
HCHO	Safe	0 - 0.08 ppm (30 minutes)
	Hazardous	> 0.08 ppm (30 min)
TVOC	Safe	WHO has not specified, but generally 0 - 0.3 mg/m³
	Moderate	0.3 - 0.6 mg/m³
	Hazardous	> 0.6 mg/m³
CO	Güvenli	0 - 87 ppm (15 minutes)
	Tehlikeli	> 87 ppm (15 minutes)
	Safe	Safe 0 - 30 ppm (1 hour)
	Moderate	0 - 30 ppm (1 hour)
	Hazardous	0 - 8.7 ppm (8 hours)
	Safe	> 8.7 ppm (8 hours)
	Moderate	0 - 6 ppm (24 hours)
	Hazardous	> 6 ppm (24 hours)
CO_2	Safe	0 - 1000 ppm
	Moderate	1000 - 2000 ppm
	Hazardous	> 2000 ppm

4. Conclusion and Recommendation

It is a well-known fact that trees take Carbon Dioxide (CO2) and produce oxygen through the process of photosynthesis. CO2, one of the most important particulate matter in air quality, is part of the life forms of trees. Even this basic function increases oxygen levels in the atmosphere and fulfils a basic requirement for the survival of humans and other living organisms. The United Arab Emirates has a number of ecological policies that are still in progress today, with sustainable studies being carried out. Within all these policies, efforts are made to improve air quality (Jung and Awad 2021). Estidama Pearl Rating System (PRS, 2010), the Dubai Integrated Energy Strategy 2030 (DIES, 2020), the Dubai Clean Energy Strategy 2050 (DCES, 2020), and the Dubai's Green Building Regulations and Specifications (GBR&S, 2011), Al Sa'fat rating system (Al Sa'Fat, 2020), the Ras Al Khaimah Energy Efficiency & Renewable Energy Strategy 2040 (RAKEES, 2018), the Barjeel Green Building Regulations (BGBRİ 2019) are among these studies.

The most important data of the study area is that it is in "hot climate" conditions. Since trees are effective in reducing air temperature, they also help to increase air quality. Looking at the results of the study, although the air quality is not in a risky situation where there are no trees, the air quality is higher where there are trees. The results obtained from the study are as follows;

- The "air quality index" value on the roads with vegetation was better than the other measurement points.

- The lowest values of PM2.5 were obtained at the second and fourth measurement points. Both measurement points are examples where vegetation is present.

- PM10 value is among the most important emissions affecting outdoor air quality. The highest value was found at the first measurement point and the lowest value was found at the second measurement point.

- Although PM10 was 150 µg/m³ at the first measurement point, it was determined that this point was the measurement point with the lowest HCHO value.

- TVOC emission value was found to be the lowest at the first measurement point and the highest at the third measurement point.

- When we look at the results of the CO value, 2ppm was found in places where there is less tree tissue and 1ppm in other places.

- CO2 was 407.00 ppm at the first measurement point, 401.00 ppm at the second measurement point, 412.00 ppm at the third measurement point and 413.00 ppm at the fourth measurement point.

Considering the results obtained, emission measurements were low at the points where there was vegetation or tree presence. The ability of plants to clean air pollutants has been proven by measurements and many previous studies. Improving air quality is beneficial for the city and the whole world, and clean air reduces stress and improves cognitive and physical functions. It helps to create a more prosperous society. In the future stage of this study, it is foreseen to carry out a study on which plant taxa are more important in improving air quality and which species would be better to choose.

References

AirNow (2024a). What is AirNow? Retrieved from https://www.airnow.gov/about-airnow/ Accessed: 15.03.2024

AirNow (2024b). Air quality guide for particle pollution. Retrieved from https://document.airnow.gov/air-Quality-Guide-For-Particle-Pollution.Pdf Accessed: 15.03.2024

Al Sa'Fat (2020). Al Sa'Fat Dubai Green Building System. (2020). Retrieved from https://www.dm.gov.ae/wp-content/uploads/2020/11/Safat-English.pdf. Accessed: 15.03.2024

ASHRAE (2021). American Society of Heating, Refrigerating and Air-Conditioning Engineers Standards and guidelines. Retrieved from https://www.ashrae.org/technical-resources/standards-and-guidelines Accessed: 27.03.2024

BGBR (2019). Barjeel Green Building Regulations. Retrieved from https://mun.rak.ae/Documents/EER/Barjeel%20-%20Green%20Building%20Regulations.pdf. Accessed: 27.03.2024

Beckett, K. P., Freer-Smith, P. H., & Taylor, G. (2000). Particulate pollution capture by urban trees: Effect of species and windspeed. *Global Change Biology*, 6(8), 995-1003. https://doi.org/10.1046/j.1365-2486.2000.00376.x

Bekar, M., Gulpınar Sekban, D. Ü., & Acar, C. (2018). Planting along area sides of highway, Trabzon coastal case. *Journal of Balkan Ecology*, 21, 1-20.

Climate Data (2024). Climate Dubai. Retrieved from https://tr.climate-data.org/asya/birlesik-arap-emirlikleri/dubai/dubai-705/ Accessed: 23.03.2024

DIES (2020). Dubai Integrated Energy Strategy 2030. Retrieved from https://dubaisce.gov.ae/en/about-dsce/ Accessed: 23.02.2024

DCES (2020). Dubai Clean Energy Strategy 2050. Retrieved from https://u.ae/about-the-uae/strategies-initiatives-and-awards/strategies-plans-and-visions/environment-and-energy/dubai-clean-energy-strategy Accessed:13.02.2024

EPA (2021). Environmental Protection Agency Indoor air quality guidelines. Retrieved from https://www.epa.gov/indoor-air-quality-iaq Accessed:13.02.2024

Freer-Smith, P. H., Beckett, K. P., & Taylor, G. (2005). Deposition velocities to Sorbus aria, Acer campestre, Populus deltoides X trichocarpa 'Beaupre', Pinus nigra and X Cupressocyparis leylandii for coarse, fine, and ultra-fine particles in the urban environment. *Environmental Pollution*, 133(1), 157-167. https://doi.org/10.1016/j.envpol.2004.03.031

GBR&S (2011). Green Building Regulations & Specifications. Retrieved from https://www.dm.gov.ae/wp-content/uploads/2018/01/05_ENG_DCL_LawsLegislation_EngineeringSection_GreenBuildingRegulation.pdf. Accessed: 20.03.2024

Grylls, T., & van Reeuwijk, M. (2022). How trees affect urban air quality: It depends on the source. *Atmospheric Environment*, 290, 119275. https://doi.org/10.1016/j.atmosenv.2022.119275

Jeanjean, A. P., Buccolieri, R., Eddy, J., Monks, P. S., & Leigh, R. J. (2017). Air quality affected by trees in real street canyons: The case of Marylebone neighbourhood in central London. *Urban Forestry & Urban Greening*, 22, 41-53.

Jung, C., & Awad, J. (2021). The improvement of indoor air quality in residential buildings in Dubai, UAE. *Buildings*, 11(6), 250-265. https://doi.org/10.3390/buildings11060250

Karimi, A., Shirmardi, M., Hadei, M., Birgani, Y. T., Neisi, A., Takdastan, A., & Goudarzi, G. (2019). Concentrations and health effects of short-and long-term exposure to PM2.5, NO2, and O3 in ambient air of Ahvaz city, Iran (2014–2017). *Ecotoxicology and Environmental Safety*, 180, 542-548. https://doi.org/10.1016/j.ecoenv.2019.05.026

Kocak, Y. (2023). 'Evaluation of air quality in Konya province with deep learning techniques' Master's thesis, Selçuk University, Institute of Science, Konya.

Nowak, D., & Heisler, G. (2010). Air quality effects of urban trees and parks. *National Recreation and Parks Association Research Series Monograph*, 44, 1-44. Retrieved

from https://www.nrpa.org/globalassets/research/nowak-heisler-research-paper.pdf. Accessed: 24.03.2024.

PRS (2010). The Pearl Rating System for Estidama Community Rating System Design and Construction. Retrieved from https://pages.dmt.gov.ae/-/media/DE1617B2A0634AC58B42DB511E18ECF4.ashx?newTab=s1 Accessed:15.03.2024

RAKEES (2018) Ras Al Khaimah Energy Efficiency & Renewable Energy Strategy 2040. Retrieved from https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/strategies-plans-and-visions/environment-and-energy/ras-al-khaimah-energy-efficiency-and-renewable-energy-strategy-2040 Accessed:15.03.2024

Vailshery, L. S., Jaganmohan, M., & Nagendra, H. (2013). Effect of street trees on microclimate and air pollution in a tropical city. *Urban Forestry & Urban Greening*, 12(3), 408-415. https://doi.org/10.1016/j.ufug.2013.03.002

Vos, P. E., 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. https://doi.org/10.1016/j.envpol.2012.10.021

WHO (2021). Global air quality guidelines. Retrieved from https://www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines Accessed:15.03.2024

WHO (2010). World Health Organization guidelines for indoor air quality: Selected pollutants. Retrieved from https://www.who.int/publications/i/item/9789289002134. Accessed: 15.03.2024