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Determining temporal and spatial changes in air quality in the city of Nevşehir

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Abstract

Air pollution, which has notably surged from the Industrial Revolution onwards, has had adverse effects on all forms of life, primarily humans. Factors such as urbanization, intensified industrial activities, growing production and consumption, and the proliferation of vehicular traffic have significantly contributed to the escalating impact of air pollution. This study aimed to evaluate the levels of particulate matter 2.5, particulate matter 10, and carbon dioxide across diverse locations within Nevşehir city center. Sampling was conducted at ten distinct points, utilizing the CEM DT-9880 device for particulate matter and the EXTECH Easyview 80 CO_2 Analyzer device for carbon dioxide. Measurements were taken during both morning and evening hours to discern daily fluctuations, as well as in both summer and winter to identify seasonal variations. Data collected were input into QGIS software and interpolated to delineate the distribution of pollution throughout the city. The findings reveal that pollution levels are significantly elevated across the city, particularly in industrial zones, organized industrial districts, and densely populated residential regions, as well as in areas where coal is extensively utilized for heating. Conversely, parks and green spaces exhibit the lowest levels of particulate matter and carbon dioxide pollution. While complete eradication of pollutants may be unattainable, it is crucial to mitigate pollutant levels to ensure smooth urban living. To achieve this, installing filters on industrial chimneys, expanding natural gas infrastructure, and promoting the use of natural gas in non-infrastructure areas is essential. Should coal be employed for heating, selecting high-quality, low-soot Siberian coals with high energy content is advisable. Enhancing the city's green areas and parks, as well as expanding afforestation initiatives, holds merit. Efforts to curtail vehicular numbers, encourage public transportation, and prioritize carbon emission-free electric vehicles are crucial for fostering a cleaner urban environment.

1. Introduction

In 1950, approximately 30% of the global population (750 million people) resided in urban areas, a figure that expanded to 47% (2.9 billion people) by 2000. Projections suggest that this urban population will rise to 60% by 2030 and further to 68% by 2050 (United Nations, 2018a; United Nations, 2018b; United Nations, 2018c). European countries exhibit an even higher urbanization rate, with over two-thirds of the total population dwelling in urban regions (Cetin et al., 2019; Cetin et al., 2020; Elsunousi et al., 2021; Cesur et al., 2021; Cetin and Jawed 2021; Cetin & Jawed 2022; Cetin et al., 2022a; Cetin et al., 2022b; Cesur et al., 2022;; Sari et al., 2022; Abo Aisha & Cetin, 2023; Cetin & Abo Aisha, 2023). As per data from the Turkish Statistical Institute (TUIK) in 2022, Turkey's overall population stands at 85,279,553. Of this, 93.4% (approximately 79 million) reside in urban locales, while 6.6% (around 6 million) inhabit rural areas (TUİK, 2022). Notably, migration represents a pivotal driver behind urban population accumulation in Turkey. Rural-to-urban migration remains an ongoing phenomenon, portending further urban population growth (Kaya, 2010; Cetin et al., 2017a; Cetin et al., 2017b; Kaya et al., 2018a; Kaya et al., 2018b; Cetin et al., 2020; Cetin & Jawed 2021; Cesur et al., 2021; Elsunousi et al., 2021; Cetin & Jawed 2022; Cetin et al., 2022a; Cetin et al., 2022b; Cesur et al., 2022; Sari et al., 2022; Abo Aisha & Cetin, 2023; Cetin & Abo Aisha, 2023).

This perpetual upsurge in urban populations amplifies the significance of ecological equilibrium, clean environments, and comfortable spaces within urban realms. However, the continual surge in urban residents, coupled with escalating population density, concomitant industrialization, and heightened construction and production activities, engenders a multitude of environmental quandaries (Cetin et al., 2019; Cetin et al., 2020; Cesur et al., 2021; Cetin & Jawed 2021; Elsunousi et al., 2021; Cetin & Jawed 2022; Cetin et al., 2022a; Cetin et al., 2022b;; Cesur et al., 2022; Sari et al., 2022; Abo

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Aisha & Cetin, 2023; Cetin & Abo Aisha, 2023). These environmental challenges entail the degradation of natural ecosystems, air, water, and soil pollution, and the perturbation of ecological harmony (Begum et al., 2008; Kaya, 2010; Brooks & Cetin 2013; Cetin, 2013; Cetin 2015a; Cetin 2015b; Cetin 2016; Kulaç & Yıldız 2016; Deary et al., 2016; Abualqumboz et al., 2017; Cetin et al., 2017a, Cetin et al., 2017b; Sevik et al., 2018; Kaya et al., 2018a; Kaya et al., 2018b; Yucedag et al., 2018).

In urban environments, a spectrum of environmental issues exists, spanning concerns that impact individuals on a personal level to those of mass scale significance. Among these pivotal concerns, air pollution stands out. Air is indispensable for the survival of humans and other living organisms, and its quality must meet certain standards. However, various factors, particularly prevalent in urban settings, lead to a decline in air quality, culminating in the predicament of air pollution (Cetin et al., 2020; Vural, 2021a; Cesur et al., 2021; Elsunousi et al., 2021; Cetin & Jawed 2021; Cetin & Jawed 2022; Cetin et al., 2022a; Cetin et al., 2022b; Cesur et al., 2022; Sari et al., 2022; Abo Aisha & Cetin, 2023; Cetin & Abo Aisha, 2023). At its core, air pollution is a critical environmental challenge arising from the presence of substances (solid, liquid, or gaseous) in the atmosphere that should not be there, or from deviations in the quantities of gases that ought to exist within specific thresholds.

The relentless increase in industrial production, fossil fuel utilization, and vehicular traffic within cities is noteworthy. It is alarming that air pollution levels frequently surpass acceptable thresholds in Turkey, particularly in urban areas (Vural, 2021b). Of the diverse air pollutants, particulate matter emerges as the most recognized and ubiquitous. This pollutant markedly influences human health, as well as the well-being of plants and animals. Carbon Dioxide (CO_2), a greenhouse gas that triggers air pollution and contributes to global warming, has gained significant global attention in recent years. Elevated CO_2 concentrations in urban environments contribute to air pollution. Numerous studies highlight that primary drivers of fluctuating levels in the external environment include traffic density, industrial processes, seasonal shifts, and local weather conditions (Cetin, 2016; Cetin et al., 2017a, Cetin et al., 2017b; Sevik et al., 2018; Türkyılmaz et al., 2018a; Türkyılmaz et al., 2018b; Türkyılmaz et al., 2018c; Türkyılmaz et al., 2018d; Elsunousi et al. Cesur et al., 2021; Cesur et al., 2022a; Cetin et al., 2022b; Cetin et al., 2020; Cesur et al., 2022; Sari et al., 2022; Abo Aisha & Cetin 2023; Cetin & Abo Aisha 2023). Notably, this shift in CO_2 concentrations is predominantly attributable to human activities (Bulgurcu, 2005). Consequently, variations in CO_2 levels manifest in perturbations to people's daily routines and lifestyles. CO_2 concentrations exceeding 1000 ppm result in symptoms such as headaches, fatigue, physical and mental exhaustion, as well as concentration difficulties; surpassing 1500 ppm leads to throat irritation, nasal discomfort, runny nose, coughing, and eye irritation (Ercan, 2012; Cetin et al., 2019; Cetin et al., 2020; Cetin & Jawed 2021; Cesur et al., 2021; Elsunousi et al., 2021 Cetin et al., 2022a; Cetin & Jawed 2022; Cetin et al., 2022b; Cesur et al., 2022; Sari et al., 2022; Abo Aisha & Cetin, 2023; Cetin & Abo Aisha, 2023). Particulate matter presents considerable hazards to human health, the vitality of plants, and the well-being of animals. These substances can incite cardiovascular ailments, respiratory disorders, and allergic responses (Anderson et al., 2012; Adar, 2014; Mukherjee & Agrawal, 2017; Cetin et al., 2020; Elsunousi et al., 2021; Cetin & Jawed, 2021; Cetin & Jawed, 2022; Cetin et al., 2022a; Cetin et al., 2022b; Cesur et al., 2022; Cesur et al., 2021; Sari et al., 2022; Abo Aisha & Cetin, 2023; Cetin & Abo Aisha, 2023).

This study delved into the dynamics of particulate matter and CO_2 pollutants across diverse zones over the course of a day. The investigation of temporal and spatial variations in these pollutants is of paramount significance in terms of comprehending the damages they inflict and devising strategies for mitigation. The research probed the concentrations of particulate matter and carbon dioxide at ten distinct locations within the urban confines of Nevşehir. Data collection occurred twice daily-once in the morning and again in the evening-and spanned select days during both summer and winter seasons, facilitating an analysis of seasonal shifts. The study sought to unravel the fluctuations in polluting agents within the urban landscape, ultimately presenting solutions grounded in the findings.

2. Materials and methods

This study involved the collection of samples from ten distinct locations within Nevşehir city. Particulate matter measurements in both 2.5 and 10 dimensions, as well as CO_2 measurements, were conducted at specific times of the day across these ten selected points. The data collection took place during mornings (08:30-10:30) and evenings (17:00-19:00). Specifically, measurements occurred over a period of four weeks in February (on Mondays, Wednesdays, and Fridays) during the winter season, and similarly for four weeks in May (on Mondays, Wednesdays, and Fridays) during the summer season.

To facilitate these measurements, 6-channel "CEM DT-9880" devices were employed for particulate matter readings, while "EXTECH Easyview 80 CO_2 Analyzer" devices were utilized for CO_2 measurements. These devices have been employed in numerous other studies as well (Cetin, 2016; Aricak et al., 2016; Cetin et al., 2017a, Cetin et al., 2017b).

Subsequent to the measurements conducted in the study area, the collected data were subjected to analysis through the interpolation method utilizing the open-source QGIS software. This software enabled the development of the most precise models that establish correlations between the measurement points. Within the QGIS software, the Kriging method was employed to process the measurement data

The study area was meticulously chosen to include various settings with diverse characteristics. Ten distinct points were selected within the city, each representing different sources of pollution, including residential, industrial, traffic, and natural origins. The specific points chosen are as follows:

In front of the Provincial Gendarmerie: This location features both a green area and pavement. Its proximity to the main road led to its selection, with a focus on identifying transportation-related pollution effects.

Parking Area: Notable for its green spaces, this area was chosen to investigate whether plants absorb pollutants.

Housing Area 1: Selected to assess the environmental impact of pollutants originating from residential sources, particularly in densely populated residential zones.

City Center Area: This high-traffic area experiences significant human density throughout the day. It was chosen to determine the impact of human activities on pollution levels.

Industrial Area: Selected for studying the pollution caused by industrial activities.

Green Area: Chosen to explore how green spaces influence pollution intensity.

Housing Area 2: This area contains residences of individuals with slightly lower income levels. Due to this, coal usage for heating is common. It was chosen to analyze how different heating methods affect pollution levels.

Organized Industrial Zone: This location was chosen because of its 24/7 production operations, larger scale compared to other industrial areas, and higher potential for emitting polluting elements.

Intercity Road: Considering the intense pollutants from transportation sources, this road was selected as a representative location.

Housing Area 3: This dense residential area was chosen to assess the pollution levels in another high-density residential setting (Figure 1).

The diverse characteristics of these selected points offer a comprehensive understanding of pollution sources and patterns within the city.

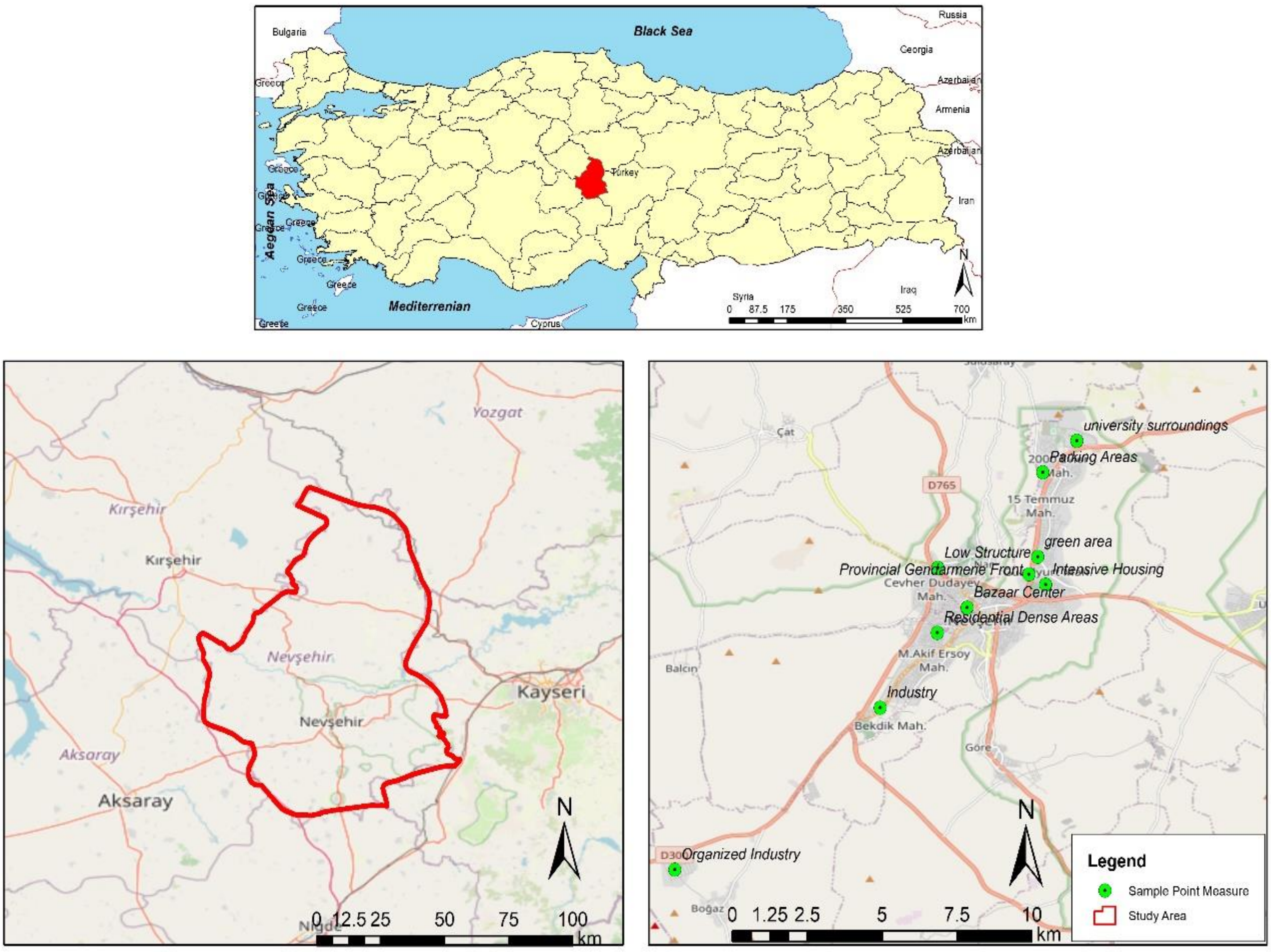

Figure 1. Lokasyon of the study area

3. Results

The averages of measurements conducted during both the morning and evening, as well as across the summer and winter seasons, were computed. The data collected was then subjected to analysis using the QGIS software. These analyses involved interpolation techniques, which in turn were used to generate pollution maps.

Table 1. Averages of the winter season for morning and evening measuring

Measurement Points	Time	CO_2 ppm	2.5 µm	10 µm
Around of University	Morning	621	103	11
Around of University	Evening	570	190	41
Organized Industrial Zone	Morning	760	236	9
Organized Industrial Zone	Evening	710	369	61
City Center	Morning	570	214	13
City Center	Evening	555	361	64
Housing Areas 1	Morning	450	51	5
Housing Areas 1	Evening	420	59	9
Housing Areas 2	Morning	680	241	16
Housing Areas 2	Evening	640	361	76
Industrial area	Morning	801	541	19
Industrial area	Evening	760	638	9
In front of the Provincial Gendarmerie	Morning	496	123	26
In front of the Provincial Gendarmerie	Evening	445	145	8
Parking Areas	Morning	380	36	10
Parking Areas	Evening	360	49	8
Green Areas	Morning	356	42	28
Green Areas	Evening	320	56	26
Housing Areas 3	Morning	593	109	51
Housing Areas 3	Evening	483	135	81

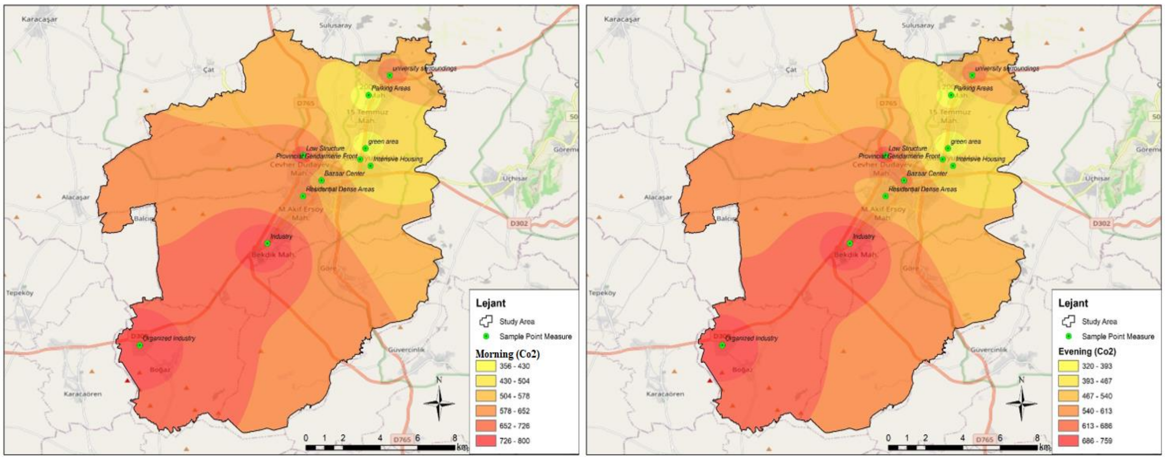

Figure 2. The averages of CO_2 measurement for winter season of morning and evening

In the morning measurement, the highest level of CO_2 was recorded in the industrial zone at a maximum of 801 ppm. This was followed by measurements of 760 ppm in the organized industrial zone and 680 ppm in residential area 2. The lowest CO_2 levels were observed in green areas, with a reading of 356 ppm. Additionally, parking areas displayed relatively low CO_2 levels, registering at 380 ppm. In the evening measurement, similar trends were observed, with the industrial zone displaying the highest CO_2 levels at 760 ppm. Subsequently, elevated CO_2 levels were recorded in the organized industrial zone and residential area 2, with readings of 710 ppm. In contrast, the lowest CO_2 levels were observed in green areas at 362 ppm during the evening measurement, followed by 360 ppm in park areas (Figure 2).

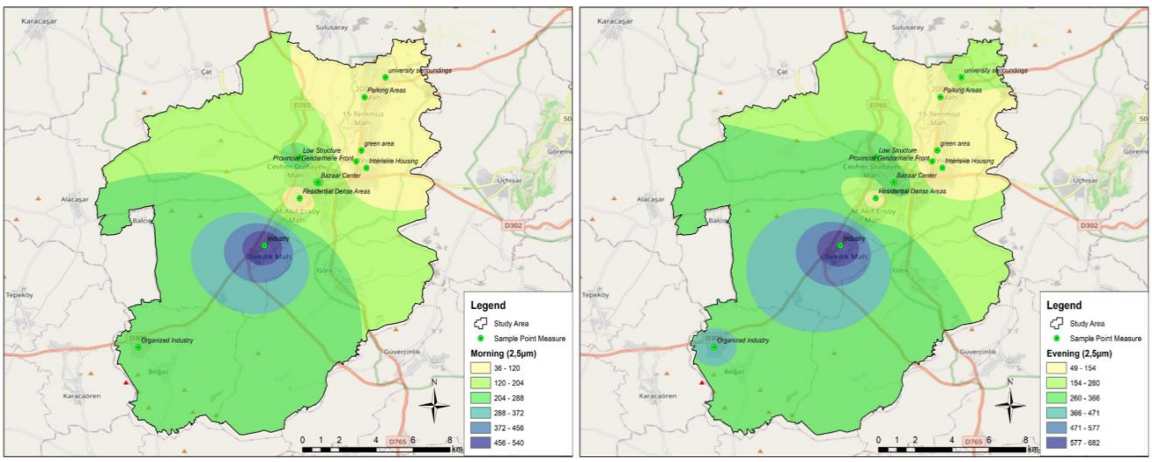

Figure 3. The averages of measurement for winter season of morning and evening 2.5 µm

During the winter measurements, particulate matter with a size of 2.5 µm was measured at the highest levels in the industrial zone, reaching a maximum of 541 µg. Subsequently, elevated levels were observed in residential area 2, recording 241 µg. On the other hand, the lowest concentrations of particulate matter with a size of 2.5 µm were measured in park areas, amounting to 36 µg, followed by 42 µg in green areas.

In the evening measurements, the industrial zone exhibited the highest levels of particulate matter with a size of 2.5 µm, registering 638 µg. Similarly, the organized industrial zone displayed elevated levels, measuring 369 µg. In contrast, the lowest concentrations were observed in park areas (49 µg) and green areas (56 µg) (Figure 3).

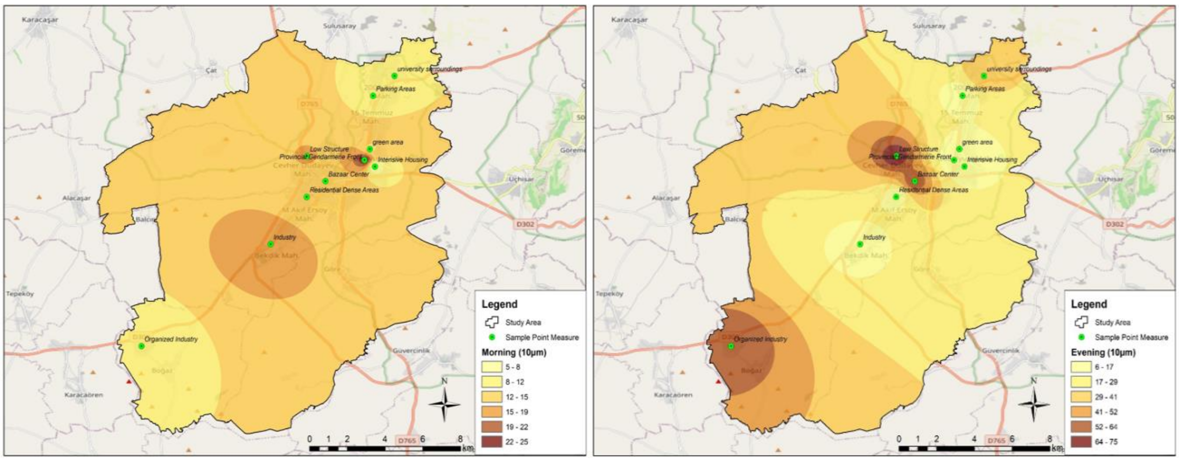

Figure 4. The averages of measurement averages for winter season of morning and evening 10 µm

During the morning measurement in winter, the highest concentration of particulate matter with a size of 10 µm was measured in residential area 3, reaching 51 µg. In contrast, the lowest concentrations were observed in green areas (5 µg) and the organized industrial zone (9 µg).

In the evening measurements, the highest levels of particulate matter with a size of 10 µm were recorded in residential area 3, measuring 81 µg. Conversely, the lowest concentrations were observed in green areas (8 µg) and in front of the provincial gendarme (Figure 4).

Table 2. The averages of measurement averages of the winter season of morning and evening measuring

Measurement Points	Time	CO_2 ppm	2.5 µm	10 µm
Around of University	Morning	560	95	9
Around of University	Evening	550	160	35
Organized Industrial Zone	Morning	720	210	7
Organized Industrial Zone	Evening	695	330	56
City Center	Morning	550	203	10
City Center	Evening	525	306	56
Housing Areas 1	Morning	430	45	2
Housing Areas 1	Evening	410	55	6
Housing Areas 2	Morning	620	235	12
Housing Areas 2	Evening	630	336	65
Industrial area	Morning	741	461	13
Industrial area	Evening	713	550	8
In front of the Provincial Gendarmerie	Morning	490	106	21
In front of the Provincial Gendarmerie	Evening	440	125	6
Parking Areas	Morning	320	26	9
Parking Areas	Evening	310	45	7
Green Areas	Morning	325	36	9
Green Areas	Evening	315	48	8
Housing Areas 3	Morning	510	96	3
Housing Areas 3	Evening	490	110	6

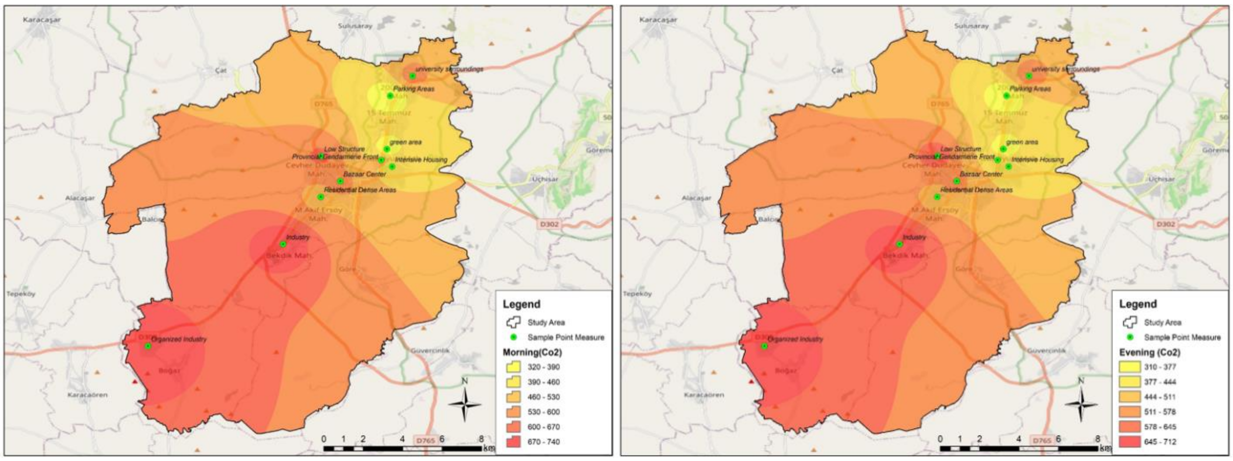

Figure 5. The averages of measurement averages for summer season of morning and evening CO_2

During the morning measurement, the highest concentration of CO_2 was recorded in the industrial zone, reaching 741 ppm. Subsequently, elevated levels were observed in the organized industrial zone, measuring 720 ppm. Conversely, the lowest concentrations of CO2 were measured in park areas (320 ppm) and green areas (352 ppm).

In the evening measurement, similar to the morning measurement, the industrial zone exhibited the highest CO2 concentration, measuring 713 ppm. The lowest CO_2 concentration was measured in parking areas, recording 310 ppm (Figure 5).

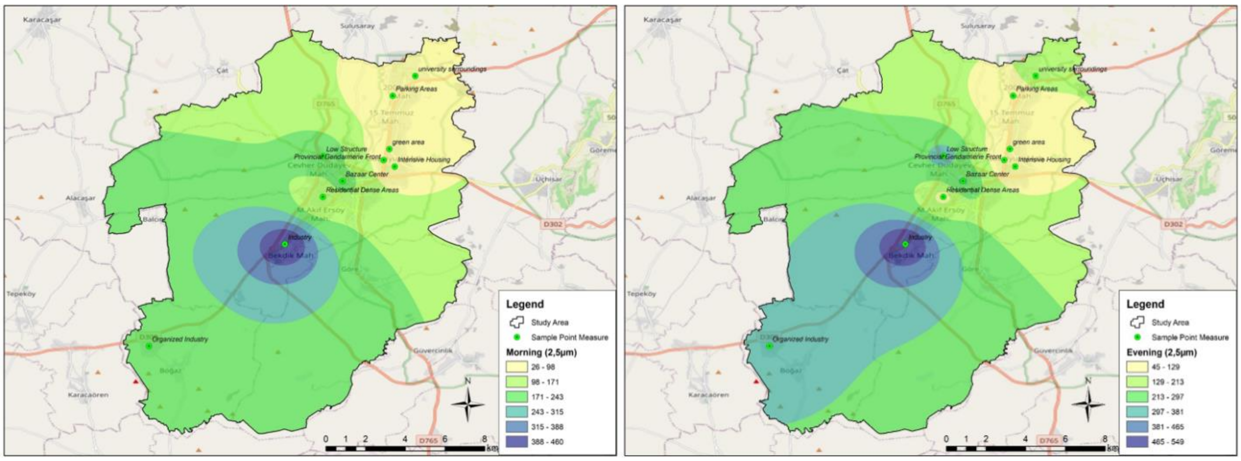

Figure 6. The averages of measurement averages for summer season of morning and evening 2.5 µm

During the morning measurements in the summer season, the industrial zone exhibited the highest concentration of particulate matter with a size of 2.5 µm, reaching 461 µg. Residential areas 2 displayed elevated levels as well, measuring 235 µg. In contrast, the lowest concentration of particulate matter with a size of 2.5 µm was measured in park areas (26 µg) and green areas (36 µg).

In the evening measurements, the industrial zone again recorded the highest concentration of particulate matter with a size of 2.5 µm, measuring 550 µg. Similarly, residential areas 2 exhibited elevated levels, measuring 336 µg. Conversely, the lowest concentrations of particulate matter with a size of 2.5 µm were measured in park areas (45 µg) and green areas (48 µg) (Figure 6).

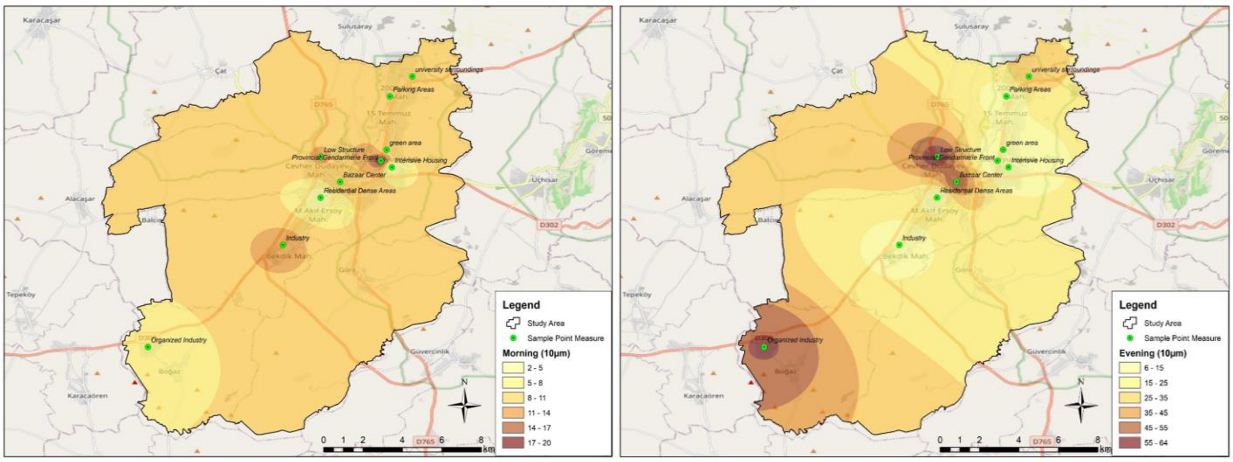

Figure 7. The averages of measurement averages for summer season of morning and evening 10 µm

In the morning measurements during the summer season, particulate matter with a size of 10 µm reached its maximum concentration of 21 µg in front of the provincial gendarmerie. Conversely, the lowest concentrations were measured in residential areas 1 (2 µg) and residential areas 3 (3 µg).

During the evening measurements, the highest concentration of particulate matter with a size of 10 µm was recorded in residential areas 2, measuring 65 µg. On the other hand, the lowest concentrations were measured in residential areas 1, in front of the provincial gendarmerie, and in residential areas 3, all measuring 6 µg (Figure 7).

Throughout the study area, particularly in the industrial zone, organized industrial zone, and residential areas, the levels of CO_2 and particulate matter of sizes 10 and 2.5 µm were observed to be highest. Conversely, the lowest levels were consistently observed in park areas and green areas. The higher concentrations of pollutants in industrial and residential areas can be attributed to the use of fossil fuels for energy and heating. The ability of parks and green areas to absorb pollutants accounts for their reduced pollution levels.

4. Conclusions and recommendations

Air pollution and its impact on air quality have become increasingly significant in recent years. The rise in air pollution levels and the subsequent decline in air quality, primarily driven by human activities, have profound implications for human health as well as the well-being of plants and animals.

Throughout the seasonal and daily measurements conducted within the study area, it was consistently observed that CO_2 levels hovered around 1000 ppm. The recorded maximum values were 796 ppm and 758 ppm, while the minimum values were 385 ppm and 362 ppm. Notably, areas with high human activity exhibited elevated CO_2 levels; Particulate matter concentrations within the study area were particularly high in industrial zones, residential area 2, and the organized industrial zone. Similar to CO_2, human activities are significant contributors to the emission of particulate matter: To mitigate particulate matter and CO_2 levels in urban areas and enhance overall air quality, several measures can be implemented: Install effective filters on factory chimneys within industrial zones and promote the recycling of waste generated from industrial production processes. This will help minimize emissions of pollutants and reduce their impact on the environment for Industrial Filters and Recycling.; Encourage people to use public transportation instead of private vehicles. Reducing the number of vehicles on the road will lead to a relative decrease in pollution generated by traffic and transportation for Promote Public Transportation.; Address pollution caused by solid fuel usage, particularly in areas where low-income individuals reside. Expand the use of natural gas for heating purposes and establish natural gas infrastructure in areas without it. Encouraging the use of higher quality coal for heating can also be beneficial for Improved Heating Practices.

The study indicated that parks and green areas in the city have the ability to absorb air pollutants and act as buffers. Therefore, the city's green spaces should be expanded and the number of parks increased. Afforestation efforts can further contribute to cleaner air and enhanced urban aesthetics for Expansion of Green Areas.

By implementing these strategies, urban areas can take steps towards achieving better air quality and creating healthier living environments for their residents.

Author Contributions

The contributions of the authors of this article is equal.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

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Research and publication ethics were complied with in the study.

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