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Influence of Industrial Activity and Urban Growth on Noise and Air Quality: A Case Study of Çorlu

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Abstract

Urbanization and industrialization have brought significant environmental challenges, particularly in the form of air and noise pollution. This study analyzes trends and contributing factors to air and noise pollution in the city of Tekirdağ, Turkey, using data from 2017 to 2022. Key pollutants, including particulate matter (PM10, PM2.5), nitrogen oxides (NOx), nitrogen dioxide (NO_2), and ozone (O_3), were examined, along with noise levels. Seasonal variations in pollutant concentrations were observed, with higher NO_2 and PM10 levels during the winter months, likely due to increased heating and reduced air circulation. Notably, NO_2 levels peaked in 2021, despite industrial shrinkage, emphasizing the role of traffic and human activities. A significant drop in air pollution in 2022 suggests that air quality control measures and environmental policies have been effective. O_3 concentrations, driven by sunlight and atmospheric reactions, were higher in spring and summer. Noise levels followed similar patterns, decreasing in 2020 due to pandemic-related restrictions but rising again in 2021 and 2022, with traffic and urban density identified as key factors. A positive correlation was found between vehicle numbers, housing density, and noise pollution, especially in industrial areas. The study highlights the need for targeted urban planning, traffic management, and industrial regulations to mitigate air and noise pollution and improve public health in growing cities.

Keywords: Air quality, Noise level, Industrial area

1. Introduction

The rapid pace of urbanization and industrialization has significantly increased environmental pollutants, particularly air and noise pollution, in densely populated areas. Air pollution is recognized as a major environmental health hazard, posing both short- and long-term risks to human health by affecting multiple organ systems and contributing to respiratory and cardiovascular diseases. Although human activities such as transportation, heating, and industrial emissions are the primary sources of air pollution, natural events like dust storms and forest fires also contribute to the problem. According to the World Health Organization (WHO), outdoor air pollution was responsible for an estimated 3 million deaths worldwide in 2012, accounting for one in every nine global deaths.

The detrimental effects of air pollution are particularly severe in rapidly urbanizing cities. Tekirdağ, Turkey, is one such city where industrial activity, unplanned urban growth, and the widespread use of low-quality fossil fuels have exacerbated pollution levels. Key air pollutants, such as ozone (O_3), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NOx), and particulate matter (PM), are typically used to monitor air quality. In Turkey, urban air pollution is primarily assessed by measuring SO_2 and PM levels in the atmosphere. In Tekirdağ, the prevalence of air pollution has raised significant health concerns, as previous research by the Department of Public Health at Trakya University has identified elevated concentrations of pollutants in the region.

Despite extensive research on the sources and effects of air pollution, gaps remain in understanding how specific pollutants vary across different seasons and how their concentrations are influenced by regional factors such as industrialization, urbanization, and population growth. This study aims to address these gaps by analyzing the variations in PM10, PM2.5, SO_2, and NOx levels measured across Tekirdağ and its districts from 2015 to 2023, with particular attention to seasonal fluctuations. Unlike previous studies that primarily focused on pollutant levels at a single point in time, this study provides a longitudinal analysis over eight years, allowing for a deeper understanding of temporal changes in pollutant concentrations. Additionally, this research explores the interplay between urbanization trends and pollution levels, highlighting the specific impact of rapid urban growth and industrial expansion on environmental quality.

Similar to other cities in Turkey, Tekirdağ experiences heightened levels of air pollution during the winter months due to a combination of factors, including rapid population growth, unplanned urbanization, increasing industrialization, high migration rates, and the continued use of low-quality fossil fuels. Data from the Ministry of Environment and Urbanization, along with WHO guidelines, indicate that air pollution levels, particularly for SO_2 and PM10, frequently exceed acceptable thresholds. Moreover, data from the Turkish Statistical Institute (DIE) reveal that by 1997, the urbanization rate in Tekirdağ's Central District had reached 74.58%, compared to a national rate of 59.21% and a regional rate of 78.3%. These figures highlight the urbanization pressure in Tekirdağ, which parallels trends observed in other parts of the Marmara region.

In addition to air pollution, noise pollution has emerged as a significant environmental issue in urban areas. Identified by WHO as the second most harmful environmental pollutant after air pollution, noise pollution is primarily generated by human activities, including industrial processes, transportation, and urbanization. Prolonged exposure to elevated noise levels has been linked to a variety of health issues, such as hearing loss, headaches, hypertension, irregular heart rhythms, sleep disturbances, and increased stress levels, all of which negatively affect quality of life. Numerous studies have consistently demonstrated that environmental noise has a profound impact on human well-being, reinforcing the need for comprehensive urban strategies to mitigate both air and noise pollution.

This study contributes to the literature by addressing the combined impact of air and noise pollution in a rapidly urbanizing context, specifically focusing on Tekirdağ. Unlike existing research that often treats air and noise pollution separately, this study examines both pollutants concurrently, providing insights into their overlapping effects on public health and quality of life. By analyzing seasonal variations and the influence of urbanization, this research offers a more nuanced understanding of how these environmental factors interact, which can guide policymakers in developing targeted mitigation strategies.

2. Literature Survey

Several studies have examined air pollution and its relation to meteorological factors and industrial activity across various regions in Turkey. Kotan and Erener (2023) conducted a comprehensive analysis of air pollution in Kocaeli province by investigating seasonal variations in PM10 and SO_2 levels using infinite regression models. Their study also explored the relationship between air pollution and meteorological factors, employing artificial neural networks and multiple regression techniques to evaluate these connections.

The effects of air pollution in the Çerkezköy Organized Industrial Zone were explored by Özel et al. (2021), who analyzed changes in air quality over time using the air quality index (AQI). Their study focused on the period between April and May of 2019-2020, comparing air quality changes with electricity and natural gas consumption data from the Çerkezköy Organized Industrial Zone (ÇOSB). Their findings indicated that the COVID-19 pandemic in 2020 led to reduced industrial activity, resulting in decreased electricity and natural gas consumption, which, in turn, significantly influenced air pollution levels.

A broader investigation into the Marmara Region's air quality was conducted by Yener and Demirarslan (2022), who examined the spatial and meteorological factors affecting air pollution. Their study covered a wide geographic area, including the industrial hubs of the region. The results demonstrated that industrialization and increased traffic density have contributed to rising pollution levels. Furthermore, the study found that air quality is strongly influenced by rising temperatures and declining precipitation in the region.

Another study by Cindoruk (2018) focused on NO and NO_2 levels across the Marmara Region, using data from the Marmara Clean Air Center. The study, which spanned multiple cities including Istanbul, Kocaeli, Balıkesir, Bursa, Tekirdağ, Kırklareli, and Çanakkale, revealed that NO and NO_2 concentrations are closely linked to population density, industrial activity, and traffic volumes, with higher concentrations recorded in areas with greater urbanization. In Edirne, Gül et al. (2019) assessed air quality between 2014 and 2016, focusing on PM10 and SO_2 levels. The study found that air pollution exceeded WHO-recommended limits, particularly during the winter months. This seasonal variation was attributed to increased heating activity and higher vehicular traffic during peak hours.

A study by Aydınoğlu et al. (2022) examined the relationship between NO_2 pollution and mortality rates in Konya province between 2016 and 2019. The research found a significant number of deaths attributed to NO_2 pollution, with 1,141 deaths in 2016, 2,038 in 2017, 2,043 in 2018, and 1,041 in 2019. The authors emphasized the need for effective mitigation strategies to reduce NO_2-related mortality. In the context of smart city applications, an example of air quality analysis using big geographic data management was conducted in Istanbul. The study utilized air and traffic monitoring sensors to calculate the air quality index within a MongoDB environment. The findings demonstrated a clear relationship between traffic density and deteriorating air quality, highlighting the importance of integrating real-time data into smart city frameworks to improve air quality management.

Lastly, Özdemir et al. (1999) investigated noise pollution in the center of Konya, revealing that architectural features significantly influence noise levels. The study found that noise levels exceeded the 65 dBA threshold in all regions surveyed. The sources of noise included vehicles, construction materials lacking proper insulation, machinery, and project or material failures in highway construction. The study concluded that the most cost-effective solution for noise pollution control is managing the noise at its source and providing recommendations for noise reduction strategies.

3. Results and Discussion

3.1 Air Quality

In this study, air quality index (AQI) data were analyzed over a period of 2,190 days, spanning from January 1, 2017, to December 31, 2022. The daily AQI values were obtained from the Çorlu station, part of the Marmara Clean Air Center, using data sourced from the World's Air Pollution database. The Çorlu station is strategically located at the entrance of the city, adjacent to residential settlements, making it an ideal site for capturing a range of urban, industrial, and traffic-related air pollution.

Due to its location, the station is subject to multiple sources of pollution, including urban emissions, industrial activities, and vehicular traffic. The proximity of these pollution sources ensures that the station's data provides a comprehensive reflection of the overall air quality in the region. The AQI values represent concentrations of different pollutants, including particulate matter and gases, with each pollutant's concentration range corresponding to a specific AQI level.

Table 1. Air quality values

NO_2	SO_2	CO	O_3	PM10	Classifi.
0–24	0–24	0.0–0.9	0–32	0.0–9.9	very good
25–49	25–49	1.0–1.9	33–64	10.0–19.9	good
50–99	50–119	2.0–3.9	65–119	20.0–34.9	satisfying
100–199	120–349	4.0–9.9	120–179	35.0–49.9	sufficient
200–499	350–999	10.0–29.9	180–239	50.0–99.9	poor
≥500	≥1000	≥30	≥240	≥100	very poor

The AQI values, measured in mg/m³, are categorized into six levels of air quality: good, moderate, sensitive, unhealthy, very unhealthy, and hazardous. As shown in Table 1, these categories provide an indication of the potential health risks associated with different AQI ranges. The data reveals that Çorlu frequently experiences air quality that ranges from moderate to unhealthy, particularly during periods of increased industrial activity or higher vehicular traffic. The impact of these pollution sources is further exacerbated during certain seasons, with winter months generally showing higher AQI levels, likely due to increased heating emissions and stagnant atmospheric conditions.

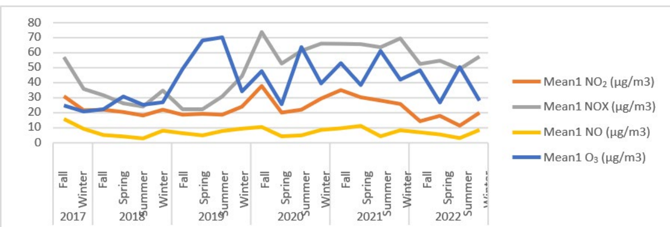

Figure 1. Seasonal changes by year

The analysis of air pollutant levels over multiple years revealed significant variations in nitrogen dioxide (NO_2), nitrogen oxides (NOx), ozone (O_3), and particulate matter (PM10) concentrations, as shown in Figures 1 and 2.

NO_2 levels fluctuated between 2017 and 2022. Higher average NO_2 levels were observed in 2017 and 2018, followed by a noticeable decrease in 2019 and 2022. Seasonal variations were also detected, with elevated NO_2 concentrations typically occurring in autumn and winter, likely due to increased heating activities and reduced air circulation during colder months. An unexpected increase in NO_2 levels during the autumn of 2020 may be attributed to unidentified environmental changes or shifts in factors influencing air quality. The highest levels of NO_2 were recorded in 2021, particularly in autumn and winter, possibly driven by a combination of high traffic volumes, industrial activity, and meteorological conditions. By contrast, a significant reduction in NO_2 levels in 2022 suggests the effectiveness of environmental policies and air quality control measures implemented during that period.

O_3 levels also showed year-to-year variability. Particularly high O_3 concentrations were recorded in 2019, while lower levels were observed in other years. O_3 levels tend to peak in the spring and summer, as ozone formation is closely linked to sunlight and atmospheric chemical reactions, while winter months typically see lower concentrations.

NOx levels followed a similar trend to NO_2, with elevated levels in 2017 and 2018, followed by a decline in 2019. Increases in NOx concentrations were observed again in 2020 and 2021, possibly due to higher energy consumption, industrial activities, and increased transportation. A slight decrease in NOx levels was recorded in 2022, suggesting the impact of air quality improvement initiatives.

Seasonal variations were also evident in NOx levels, with higher concentrations in autumn and winter, likely due to increased heating and less atmospheric circulation during these months. The significant rise in NOx levels in 2020 and 2021 can be attributed to increased industrial and transport-related emissions, as well as the heightened use of energy.

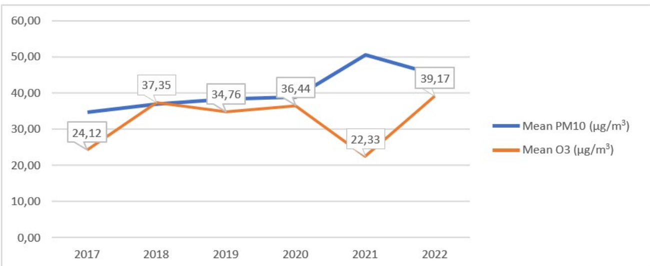

Figure 2. PM10 and O_3 change over the years

PM10 levels demonstrated a clear upward trend between 2017 and 2021. While PM10 levels in 2017 and 2018 were similar, a slight increase occurred in 2019, followed by more substantial increases in 2020 and 2021. These higher levels can be attributed to intensified industrial activities, increased traffic, and unfavorable meteorological conditions during this period. A reduction in PM10 concentrations in 2022 indicates the potential impact of stricter environmental regulations, enhanced air quality policies, and growing public awareness of air pollution's health impacts.

O_3 levels were particularly high in 2018 and 2022, likely due to increased sunlight and warmer weather conditions, both of which promote ozone formation. Conversely, lower O_3 concentrations were recorded in 2017 and 2021, potentially reflecting variations in meteorological factors and pollutant precursors that affect ozone generation.

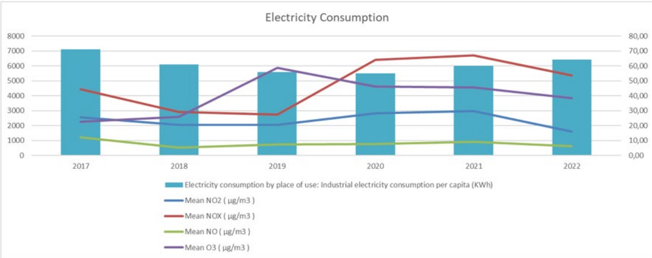

Figure 3. Electricity consumption over the years

Figure 3 shows no significant correlation between NO_2, NOx, or NO levels and industrial electricity consumption. For instance, while NO_2 concentrations were high in 2017, electricity consumption in the industrial sector was lower in 2019 despite decreased pollutant levels. This lack of correlation suggests that other factors, such as traffic and localized emission sources, may have a more direct influence on air pollutant concentrations than industrial electricity usage alone.

Figure 4 highlights the relationship between vehicle numbers and NO_2, NOx, and NO levels. The increase in vehicular traffic appears to correlate with higher concentrations of these pollutants, reinforcing the well-established link between transportation emissions and nitrogen oxide pollution. However, no clear relationship was found between O_3 levels and vehicle numbers, suggesting that other environmental factors, such as sunlight and temperature, play a more critical role in ozone formation than traffic emissions.

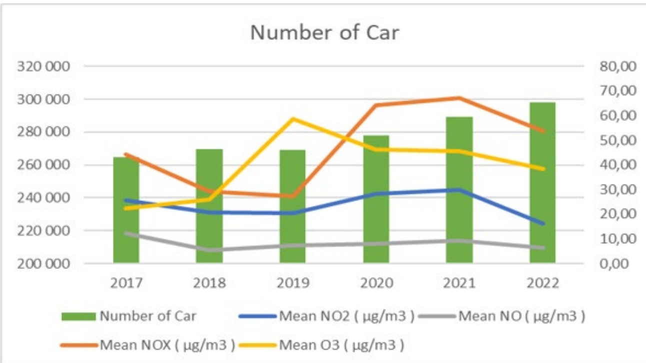

Figure 4. Number of cars and pollutants

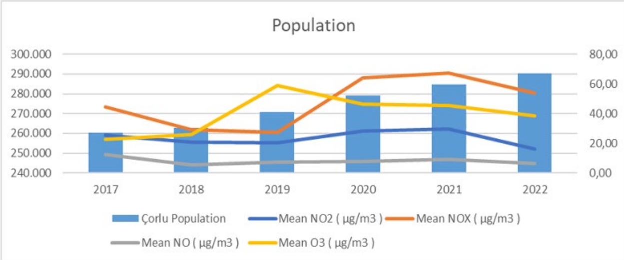

Figure 5. Population changes over the years

Figure 5 indicates that population growth does not have a clear impact on NO_2, NOx, NO, or O_3 levels, suggesting that other sources, such as industrial activity and transportation, are more significant contributors to air pollution in the region.

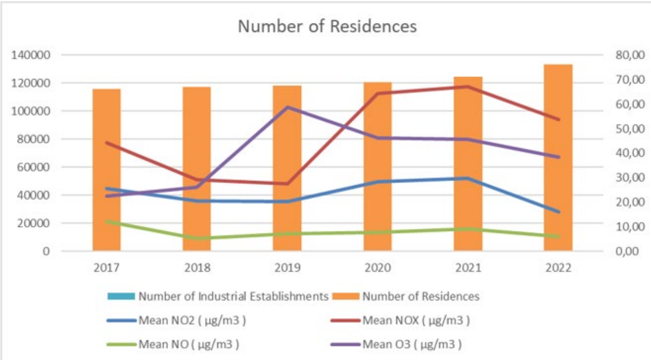

Figure 6. Number of residences changes over the years

Finally, Figure 6 shows no substantial relationship between NO_2, NOx, and NO levels and the number of industrial facilities or residential buildings. This suggests that other factors, such as transportation emissions and energy production, may play a more dominant role in influencing air quality. However, a correlation between ozone levels and industrial activity, as well as the number of residences, was noted, indicating that these factors may contribute to the region's overall ozone concentration.

In summary, the results suggest that while industrial and traffic emissions significantly contribute to air pollution in the study area, the relationship between various pollutants and environmental or human activities is complex. The effectiveness of recent environmental measures and the adoption of air quality improvement strategies are reflected in the overall reduction of pollutant levels, particularly in 2022.

3.2 Noise Level

The rapid pace of urbanization and industrialization has significantly increased environmental pollutants, particularly air and noise pollution, in densely populated areas. Air pollution is recognized as a major environmental health hazard, posing both short- and long-term risks to human health by affecting multiple organ systems and contributing to respiratory and cardiovascular diseases. Although human activities such as transportation, heating, and industrial emissions are the primary sources of air pollution, natural events like dust storms and forest fires also contribute to the problem. According to the World Health Organization (WHO), outdoor air pollution was responsible for an estimated 3 million deaths worldwide in 2012, accounting for one in every nine global deaths.

The detrimental effects of air pollution are particularly severe in rapidly urbanizing cities. Tekirdağ, Turkey, is one such city where industrial activity, unplanned urban growth, and the widespread use of low-quality fossil fuels have exacerbated pollution levels. Key air pollutants, such as ozone (O_3), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NOx), and particulate matter (PM), are typically used to monitor air quality. In Turkey, urban air pollution is primarily assessed by measuring SO_2 and PM levels in the atmosphere. In Tekirdağ, the prevalence of air pollution has raised significant health concerns, as previous research by the Department of Public Health at Trakya University has identified elevated concentrations of pollutants in the region. Noise levels are typically categorized into three main groups based on their intensity:

- Very Noisy: Leq > 65 dBA
- Moderately Noisy: 65 dBA > Leq > 55 dBA
- Low Noise: Leq < 55 dBA

The noise level data used in this study were estimated for the years 2017-2019, using the Holt-Winters method to forecast daily and evening noise levels. The results of this analysis provide valuable insights into the temporal trends and intensity of noise pollution during this period. It is important to note that the highest noise levels were classified as "Very Noisy," exceeding 65 dBA, which poses significant health risks if sustained over long periods. The moderate and low noise categories also have implications for quality of life, particularly in urban areas where exposure to noise is frequent and persistent.

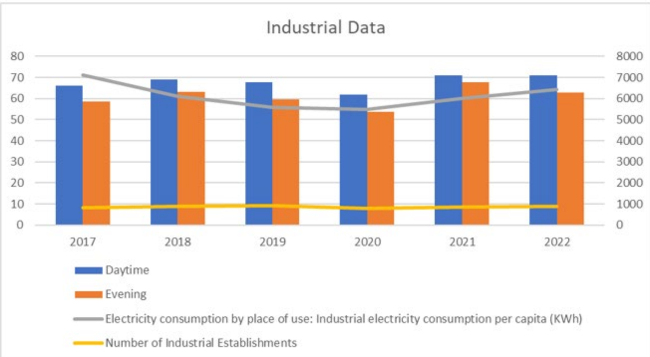

Figure 7. Noise level and industrial data

The analysis of noise level data indicates that the city experiences consistently high noise levels. However, a notable decrease in noise pollution was observed in 2020, coinciding with the industrial slowdowns and restrictions imposed during the COVID-19 pandemic. This temporary reduction in noise levels can be attributed to reduced industrial activities, traffic, and human movement during periods of lockdown. Despite the industrial shrinkage continuing into 2021 and 2022, noise levels increased during these years, suggesting that factors beyond industry—such as traffic and human activities—play a significant role in noise pollution.

Similar to other cities in Turkey, Tekirdağ experiences heightened levels of air pollution during the winter months due to a combination of factors, including rapid population growth, unplanned urbanization, increasing industrialization, high migration rates, and the continued use of low-quality fossil fuels. Data from the Ministry of Environment and Urbanization, along with WHO guidelines, indicate that air pollution levels, particularly for SO_2 and PM10, frequently exceed acceptable thresholds. Moreover, data from the Turkish Statistical Institute (DIE) reveal that by 1997, the urbanization rate in Tekirdağ's Central District had reached 74.58%, compared to a national rate of 59.21% and a regional rate of 78.3%. These figures highlight the urbanization pressure in Tekirdağ, which parallels trends observed in other parts of the Marmara region.

In addition to air pollution, noise pollution has emerged as a significant environmental issue in urban areas. Identified by WHO as the second most harmful environmental pollutant after air pollution, noise pollution is primarily generated by human activities, including industrial processes, transportation, and urbanization. Prolonged exposure to elevated noise levels has been linked to a variety of health issues, such as hearing loss, headaches, hypertension, irregular heart rhythms, sleep disturbances, and increased stress levels, all of which negatively affect quality of life. Numerous studies have consistently demonstrated that environmental noise has a profound impact on human well-being, reinforcing the need for comprehensive urban strategies to mitigate both air and noise pollution.

The relationship between noise levels and the number of houses and cars was also examined. Figure 8 illustrates that while the pandemic of 2020 led to an increase in the number of cars, the general restrictions did not lead to a significant reduction in noise levels. This indicates that while industrial activity was curtailed, the noise generated by traffic and human activities persisted, counteracting the expected reduction in overall noise pollution.

Additionally, a positive correlation was observed between the number of houses, the number of cars, and noise levels. The increasing urban density, coupled with the region's proximity to industrial zones, has contributed to elevated noise levels. This suggests that urban expansion, particularly in residential areas close to industrial sites and traffic routes, amplifies noise pollution. The findings underscore the importance of considering both human and industrial factors when devising noise mitigation strategies for urban areas.

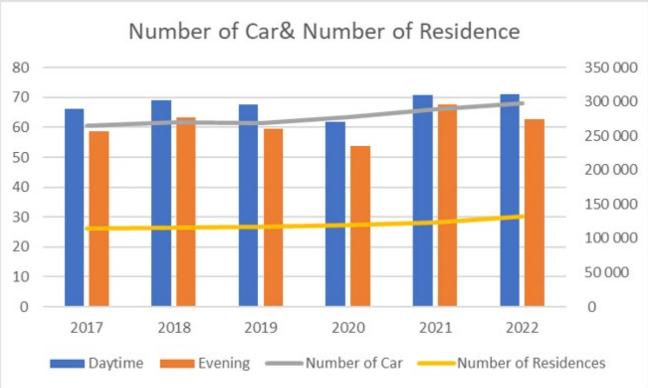

Figure 8. Number of cars and residences

This study contributes to the literature by addressing the combined impact of air and noise pollution in a rapidly urbanizing context, specifically focusing on Tekirdağ. Unlike existing research that often treats air and noise pollution separately, this study examines both pollutants concurrently, providing insights into their overlapping effects on public health and quality of life. By analyzing seasonal variations and the influence of urbanization, this research offers a more nuanced understanding of how these environmental factors interact, which can guide policymakers in developing targeted mitigation strategies.

To enhance the practical relevance of the study, we propose several concrete mitigation strategies based on our findings. For noise pollution, urban planners should consider establishing noise barriers along major traffic routes and encouraging the use of noise-reducing construction materials in residential buildings, particularly those located near industrial zones. Green buffers, such as tree belts, can also be strategically planted to reduce noise levels and improve air quality. Implementing traffic management measures, such as limiting heavy vehicle access during peak hours and promoting public transportation, could further alleviate noise pollution. Additionally, creating designated industrial zones away from residential areas and enforcing stricter noise regulations for factories and businesses are essential steps in minimizing noise exposure. By integrating these strategies into urban planning, municipalities can effectively mitigate the adverse effects of noise pollution, thereby enhancing the quality of life for city residents.

4. Conclusion

Based on the WHO and EU limit values, the Çorlu district of Tekirdağ province experiences significant air pollution caused by SO_2, PM10, and NOx, particularly during the winter period. The primary contributors to increased pollution during winter are urban traffic and domestic heating. Therefore, promoting public transportation is crucial for reducing air pollution.

Air pollution in Tekirdağ's Çorlu district shows distinct seasonal characteristics, with increased levels during winter, late autumn, and early spring. This indicates that heating is a major source of pollution, while emissions from motor vehicles also contribute, particularly during peak traffic hours in the morning and evening.

Measures taken to reduce air pollution have led to notable improvements in air quality. Future initiatives could include visualizing data from weather observation stations and issuing public warnings based on adverse weather indices, aligning with smart city objectives.

When considering both noise levels and air pollution, seasonal and daily variations are evident. Managing noise within the framework of sustainable development policies remains important for public health. Developing detailed maps and road maps can guide future measures to improve environmental quality and public well-being.

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