

EVALUATION OF THE CORRELATION BETWEEN AMBIENT AIR POLLUTION LEVELS, TRAFFIC DENSITY, AND MICROCLIMATE PARAMETERS IN THE SOUTHERN KEY ECONOMIC ZONE

Nghia Nguyen Van^{1*}, Long Le Ba², Huyen Dong Thi Thu¹, Son Nguyen Thanh³

¹*Dong Nai Technology University*

²*Industrial University of Ho Chi Minh City*

³*Ho Chi Minh City University of Culture*

*Corresponding author: Nghia Nguyen Van, nguyenvannghia@dnvu.edu.vn

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ABSTRACT

This study examined the intricate relationship between air quality, traffic density, and microclimatic elements within the Southern Key Economic Zone (SKEZ), where air pollution poses a significant environmental challenge. Using data from the Southern Center for Environmental Monitoring, we applied variance analysis and multivariate normal distribution methods to quantify these relationships. Our findings suggest that environmental quality parameters are affected by a plethora of factors, including vehicle type and microclimate. Noteworthy observations are as follows: (1) Total Suspended Particles: TSP concentrations are primarily influenced by temperature (1.99% contribution to variance), wind speed (2.66%), and the operational frequency of trucks and coaches (4.17%) and heavier trucks and buses (9.13%); (2) Nitrogen Dioxide and Sulfur Dioxide: NO₂ and SO₂ levels exhibit a strong correlation with wind speed, with respective contributions to variance of 4.47% and 6.12%; (3) Noise Pollution: Noise levels are directly affected by the operational frequency of motorcycles, trucks, coaches, and buses. Notably, trucks and buses had the most significant impact on the noise variance, accounting for 10.88%. These results highlight the multifaceted nature of environmental degradation in the Southern Key Economic Zone. Further research is necessary to develop targeted mitigation strategies that address the interplay among traffic patterns, vehicle emissions, and local meteorological conditions

1. INTRODUCTION

The Southern Key Economic Zone was established using Decision No. 44/1998/QĐ-TTg, issued on February 23, 1998, by the

Prime Minister, and encompasses Ho Chi Minh City and the provinces of Dong Nai, Binh Duong, and Ba Ria - Vung Tau. Recently, rapid socioeconomic development in

the Southern Key Economic Zone (SKEZ) has given rise to serious environmental pollution issues (Thien & Bien, 2012). The primary sources of pollution in the study area are anthropogenic activities, including industrial activities, transportation, and urban infrastructure development. The concentrations of dust parameters, including fine dust and total suspended dust, tend to remain at high levels, particularly in traffic axes and main roads in large urban areas. Emissions from road motor vehicles contribute significantly to the total emissions that cause air pollution, particularly in urban areas. These emissions primarily consisted of SO₂, NO₂, CO, and dust. Notably, motorcycles and scooters account for the largest proportion of vehicles and are also the largest source of pollution emissions (Tong Cuc Moi Truong, 2016). This presents a unique opportunity to investigate the impact of traffic patterns on the dispersion, concentration, and eventual impact of pollutants when intersected with local microclimatic factors, such as temperature, humidity, wind speed, and atmospheric pressure. Seasonal variations, daily temperature fluctuations, and changing wind patterns can influence the dispersion and concentration of pollutants, resulting in variable exposure levels throughout the year. Therefore, understanding and quantifying the impact of each factor on air pollution levels is crucial. This study aims to investigate the correlation and quantify the specific effects of various factors, including traffic density and microclimate parameters, on air pollution levels

2. METHODOLOGY

2.1. Study area

Study area is in the southern key economic zone (SKEZ)

2.2. Data collection

This study utilizes data collected from the Southern Center for Environmental Monitoring, as part of the national air and water monitoring program assigned by the General Department of Environment. The survey was conducted at 19 observation points across the provinces of Dong Nai, Ba Ria - Vung Tau, Tay Ninh, Binh Duong, Binh Phuoc, Ho Chi Minh City, and Long An. These observation points were categorized into three research areas: interprovincial traffic axes, urban traffic intersections, and economic and industrial zones.

2.3. Data processing steps

To evaluate the relationship between air pollution levels, traffic frequency, and microclimate factors, simple and multivariate regression analysis techniques were applied to each environmental quality parameter. These methods allow the examination of the relationship between dependent variables (changes in environmental quality) and one or more independent variables (traffic frequency of motor vehicles, categorized into four groups, and microclimate factors, including temperature, humidity, wind speed, and pressure). Data processing was performed using JMP 13.0, employing analysis of variance (ANOVA) to assess the impact of each factor and Tukey's post-hoc test to evaluate the differences between treatments. The data processing steps were as follows:

Step 1: Normalizing the data to reorganize the dataset and remove outliers to improve the accuracy of the statistical model.

Step 2: Performing one-way ANOVA to examine the effect of one independent variable (air quality parameters, traffic frequency, and microclimate factors) across the three classified research areas. Tukey's post-hoc test was then used to determine specific differences between the classified groups.

Step 3: Correlation analysis of each environmental quality parameter with traffic frequency and microclimate factors to identify linear relationships between factor pairs.

Step 4: Multivariate regression analysis to determine the contribution of traffic frequency and microclimate factors to the variation in environmental quality parameters.

2.4. Statistical analysis

The relationship between these parameters (air pollution levels, traffic frequency, and microclimate factors) was quantified using linear and non-linear models. The r^2 value (coefficient of determination) was computed, and analysis of variance (ANOVA) was applied to determine the statistical significance of the individual relationship with a 95% confidence level ($p \leq 0.05$). Some data were statistically analyzed, following the ANOVA

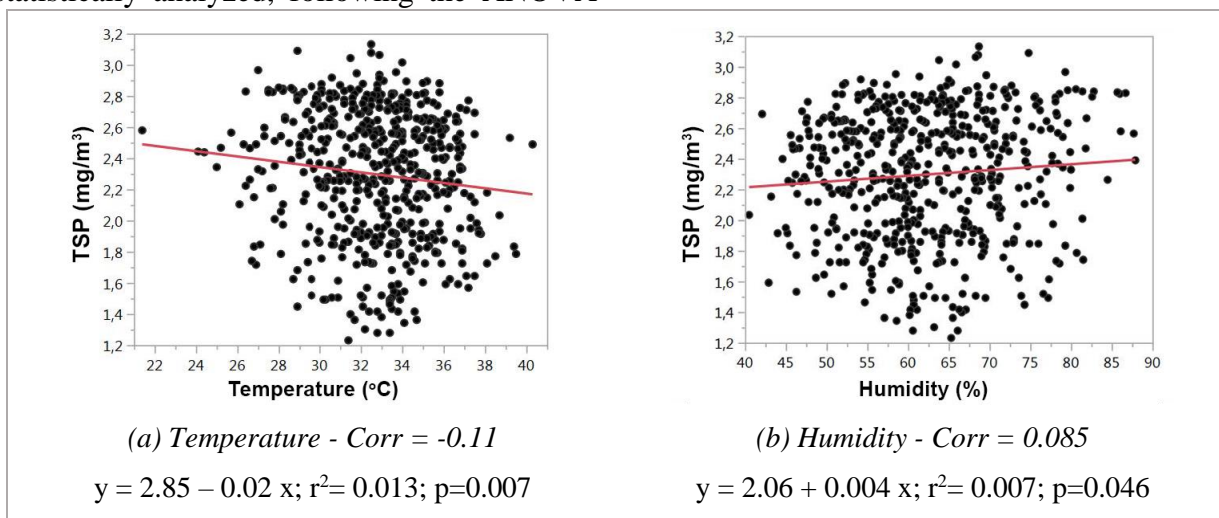
procedure for a completely randomized design, using JMP 13 (SAS Institute Inc, NC, USA). When the ANOVA result showed a significant effect at $p \leq 0.05$, the Tukey's honestly significant difference test was used to classify treatment means.

3. FINDINGS AND DISCUSSION

3.1. Correlation Between Air Quality Parameters, Traffic Frequency, and Microclimate Factors

3.1.1. Correlation Between TSP and Traffic Frequency and Microclimate Factors

The survey findings indicate that Total Suspended Particles (TSP) exhibits a significant relationship with several microclimate elements and traffic frequency (Fig.1, Fig.2), except for pressure ($p=0.12$) (Fig. 1d). The concentration of TSP increases as traffic frequency and humidity levels rise, whereas it decreases with increasing temperature and wind speed. The statistical data revealed a robust correlation between TSP, traffic frequency, and wind speed, demonstrating high reliability ($p < 0.0001$). ($p < 0.0001$).



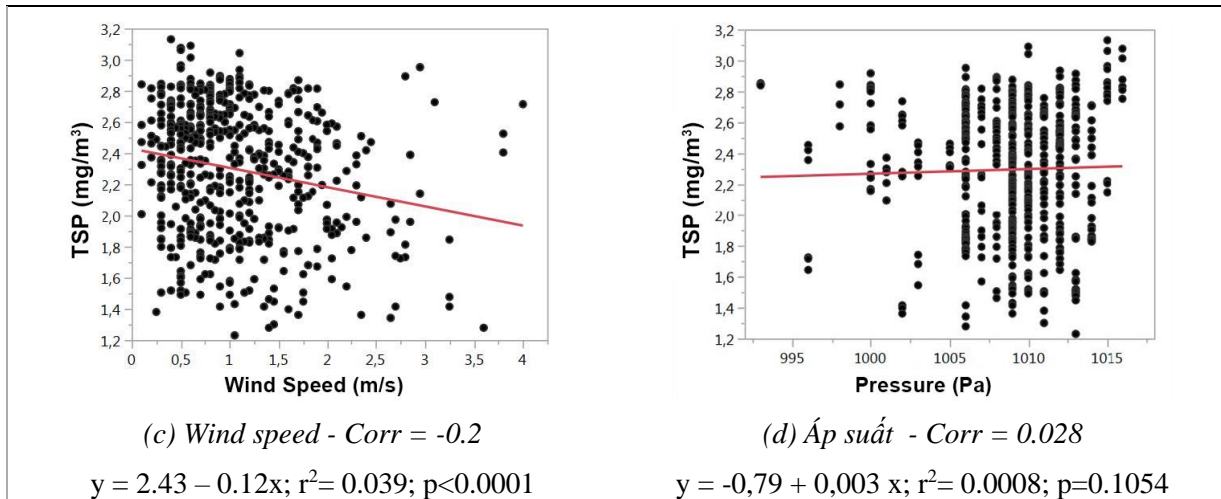


Figure 1. The correlation between TSP and microclimatic factors. r^2 is the coefficient of determination and $p < 0.05$ indicates the relationship is significant following the non-linear regression analysis

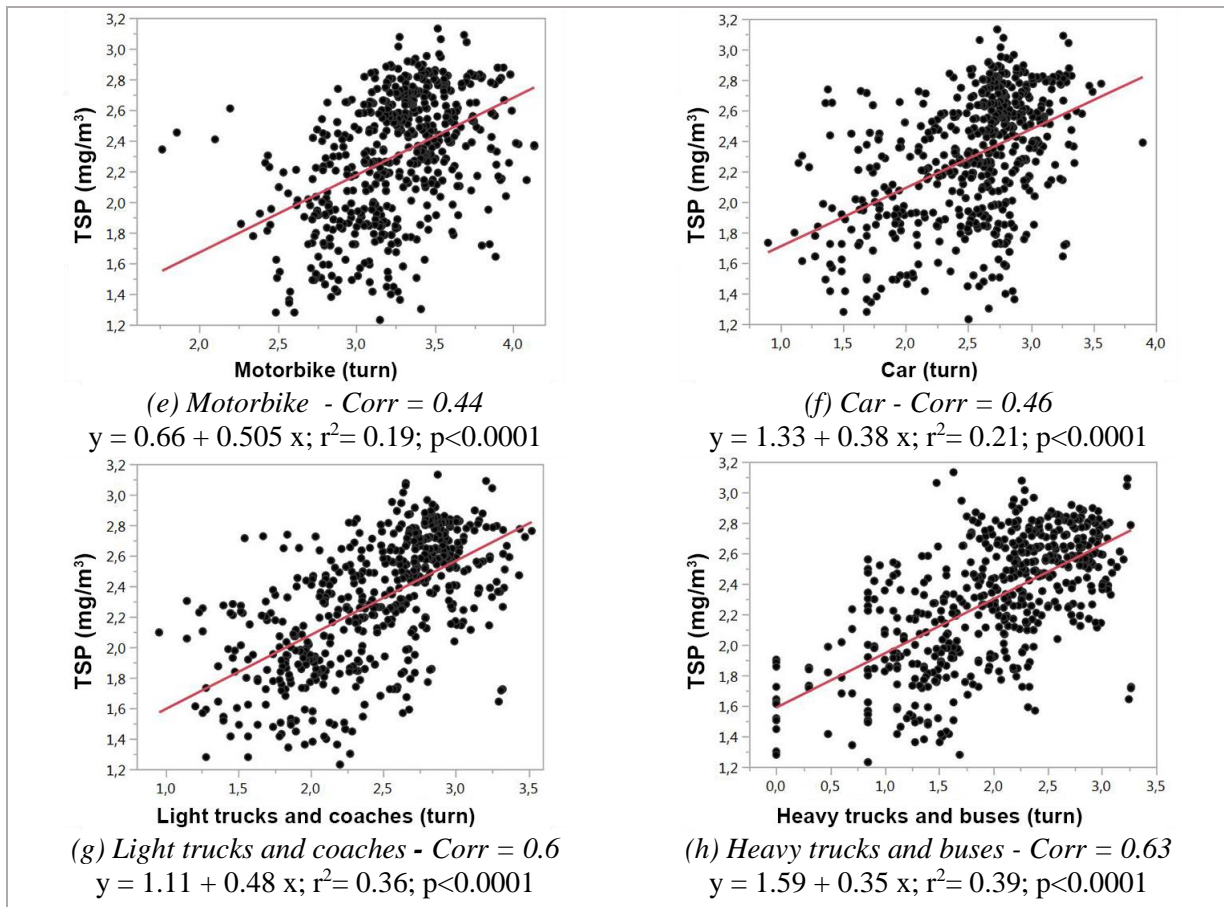


Figure 2. The correlation between TSP and traffic vehicles. r^2 is the coefficient of determination and $p < 0.05$ indicates the relationship is significant following the non-linear regression analysis

3.1.2. Correlation Between NO₂ and Traffic Frequency and Microclimate Factors

The survey findings revealed a strong correlation between NO₂ and microclimate

factors and traffic frequency, except for temperature and humidity, which showed no significant correlation ($p=0.31$ and $p=0.69$, respectively) (Fig. 3a,b). The results indicated that NO_2 concentrations increased with increasing traffic frequency and decreased

with increasing microclimate factors. The statistical values demonstrated a high level of reliability in the correlation between NO_2 , traffic frequency, and wind speed ($p<0.0001$). (Fig. 3c)

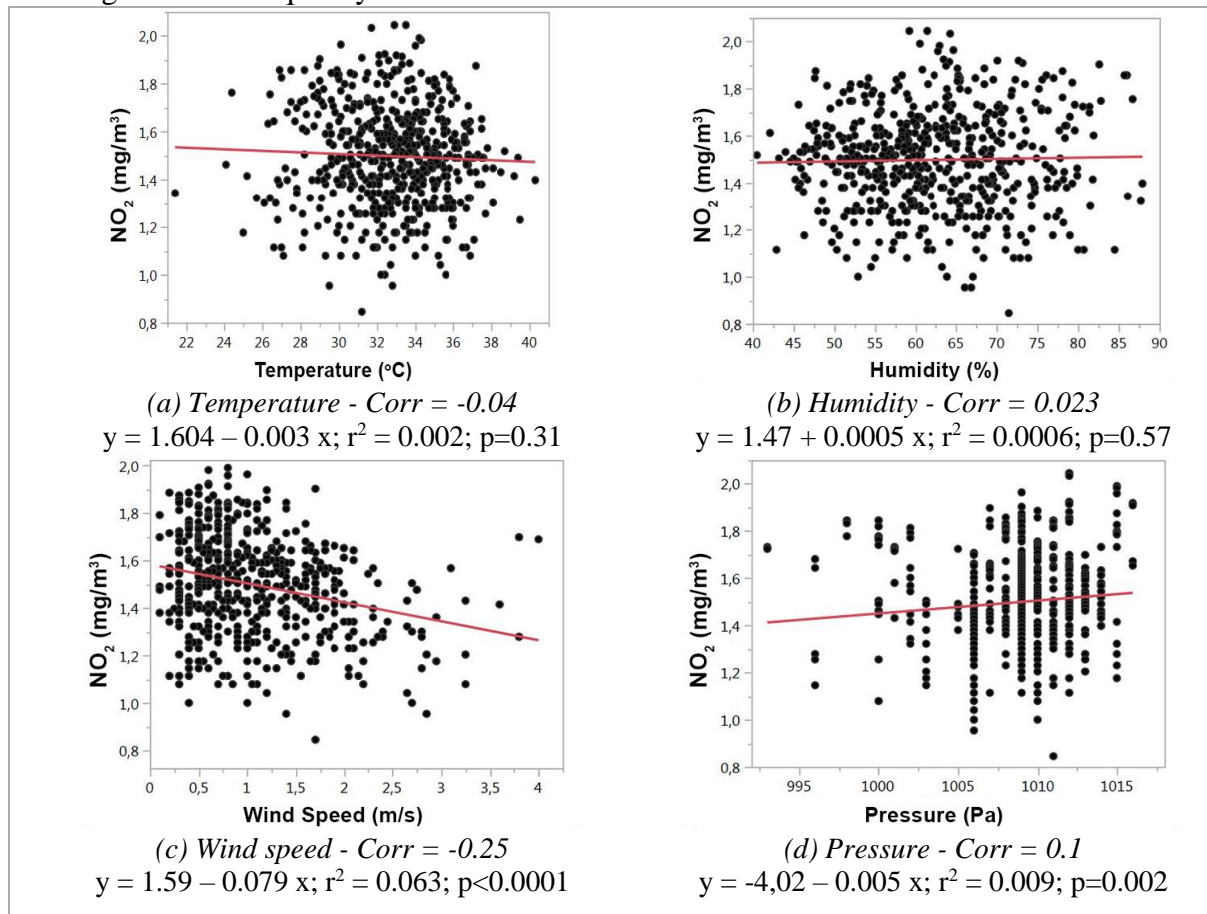
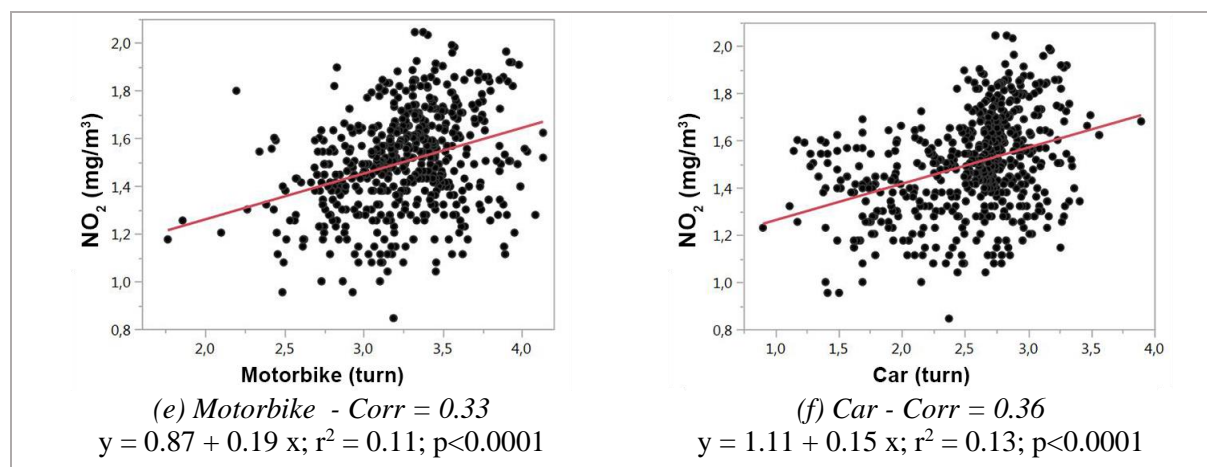


Figure 3. The correlation between NO_2 and microclimatic factors. r^2 is the coefficient of determination and $p<0.05$ indicates the relationship is significant following the non-linear regression analysis



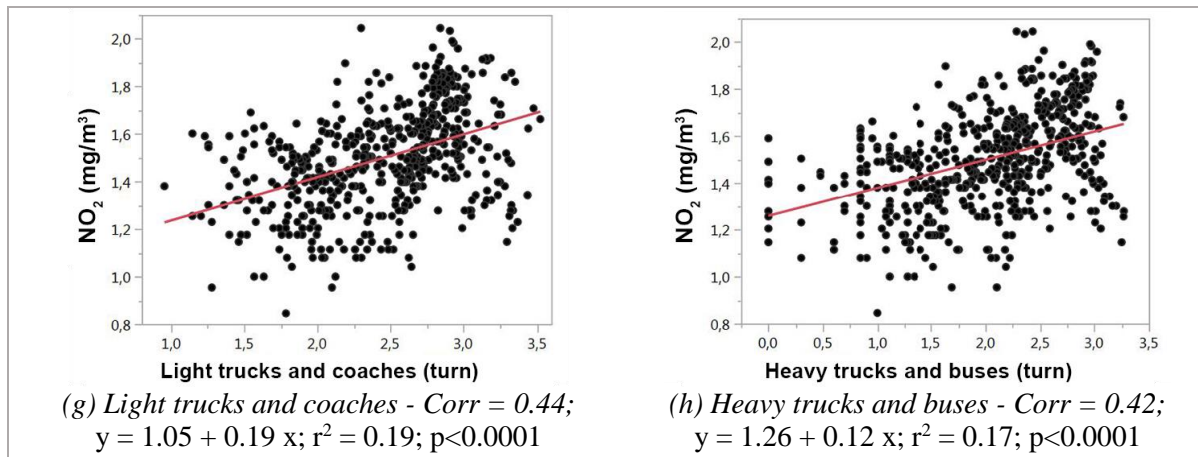


Figure 4. The correlation between NO_2 and traffic vehicles. r^2 is the coefficient of determination and $p < 0.05$ indicates the relationship is significant following the non-linear regression analysis

3.1.3. Correlation Between SO_2 and Traffic Frequency and Microclimate Factors

The survey findings revealed a significant relationship between SO_2 , traffic frequency, and wind speed. The data indicate that as traffic frequency increases, so do SO_2

concentrations; as wind speed increases, SO_2 concentrations decrease (Fig. 4c). Furthermore, statistical analysis demonstrated a robust correlation between these variables, with a high level of confidence ($p < 0.0001$).

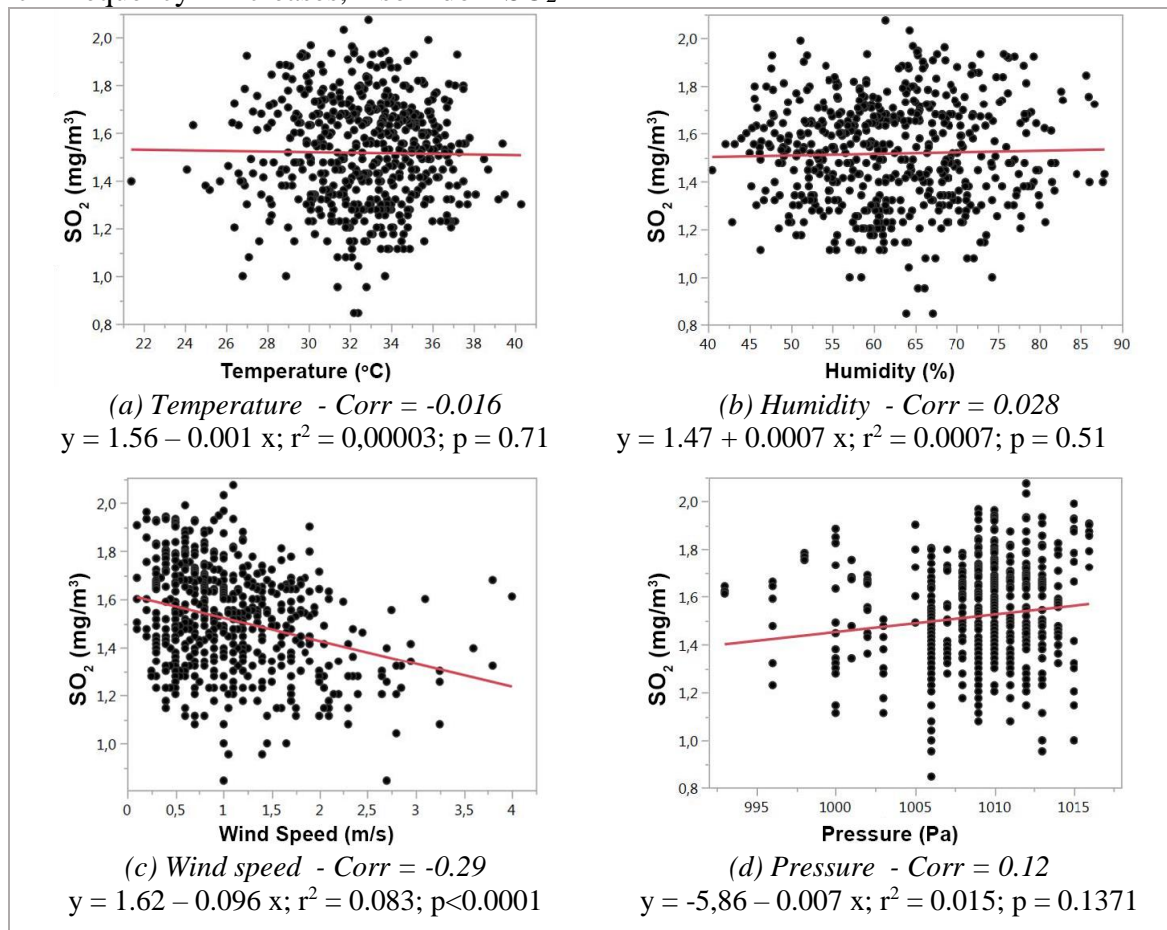


Figure 5. The correlation between SO₂ and microclimatic factors. r² is the coefficient of determination and p<0.05 indicates the relationship is significant following the non-linear regression analysis

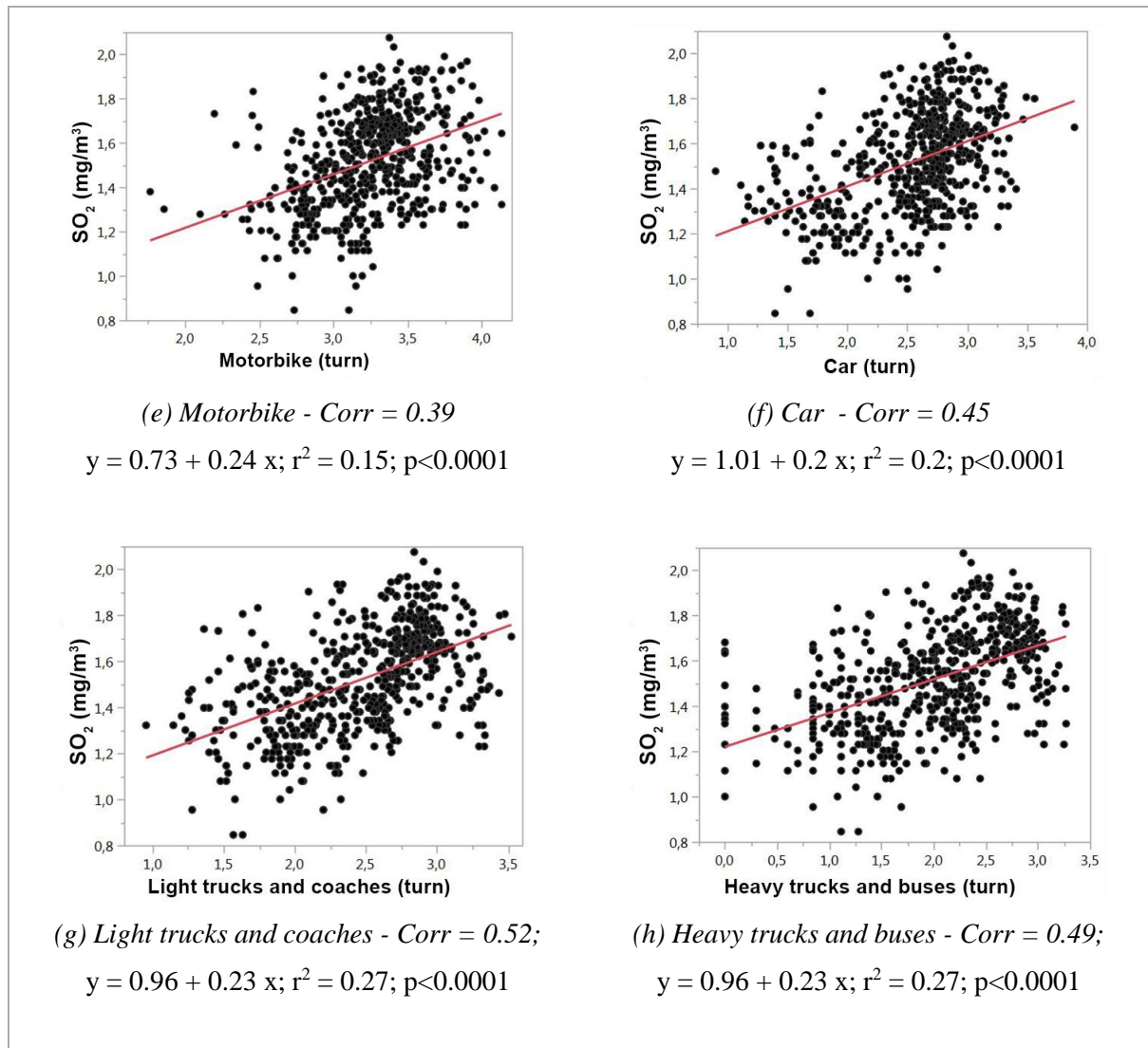


Figure 6. The correlation between SO₂ and traffic vehicles. r² is the coefficient of determination and p<0.05 indicates the relationship is significant following the non-linear regression analysis

3.1.4. Correlation Between Noise Levels and Traffic Frequency and Microclimate Factors

Correlation Between Noise Levels and Traffic Frequency and Microclimate Factors
 The survey results showed that noise levels were influenced by traffic frequency and microclimate factors, except for temperature (p=0.45) (Fig. 7a). It was observed that noise levels increased with higher traffic frequency

and humidity, whereas they decreased with higher wind speeds and pressures. The statistical data suggest a strong and dependable connection between the noise levels, traffic frequency (Fig. 8) and wind speed (Fig. 7c), with a high level of reliability (p<0.0001). The correlation between noise level and humidity was significant, but its reliability was lower (p=0.038).

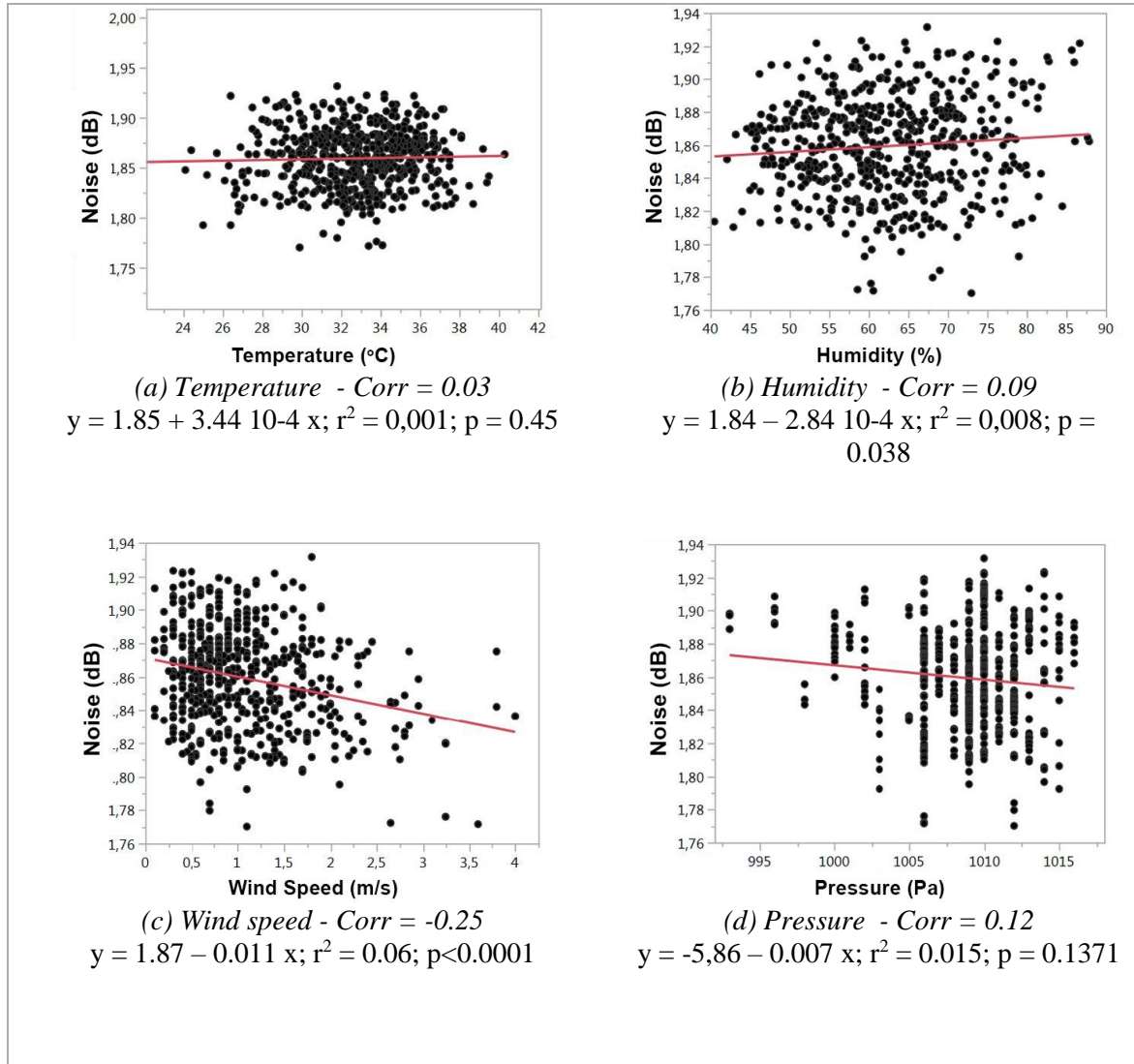
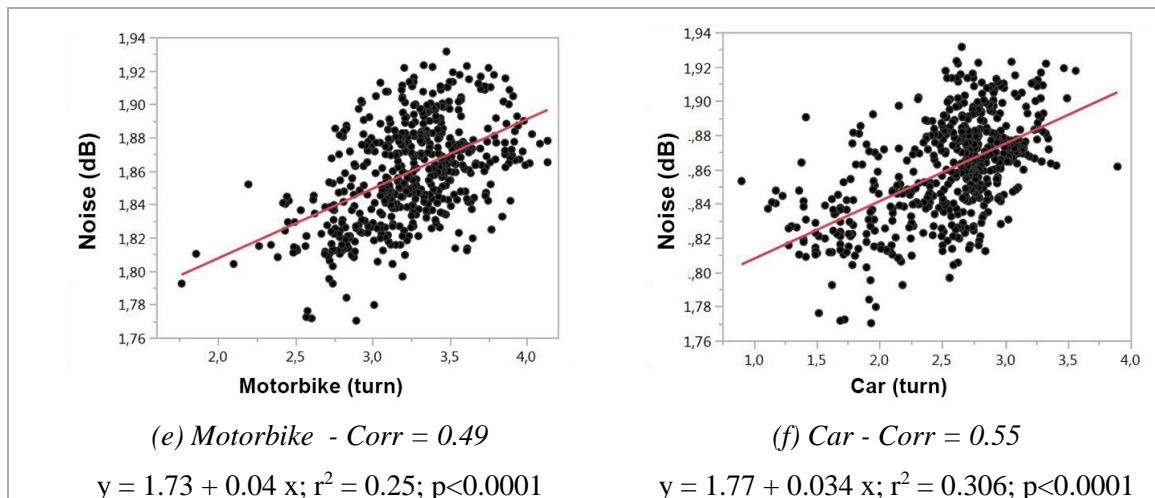


Figure 7. The correlation between Noise and microclimatic factors. r^2 is the coefficient of determination and $p < 0.05$ indicates the relationship is significant following the non-linear regression analysis



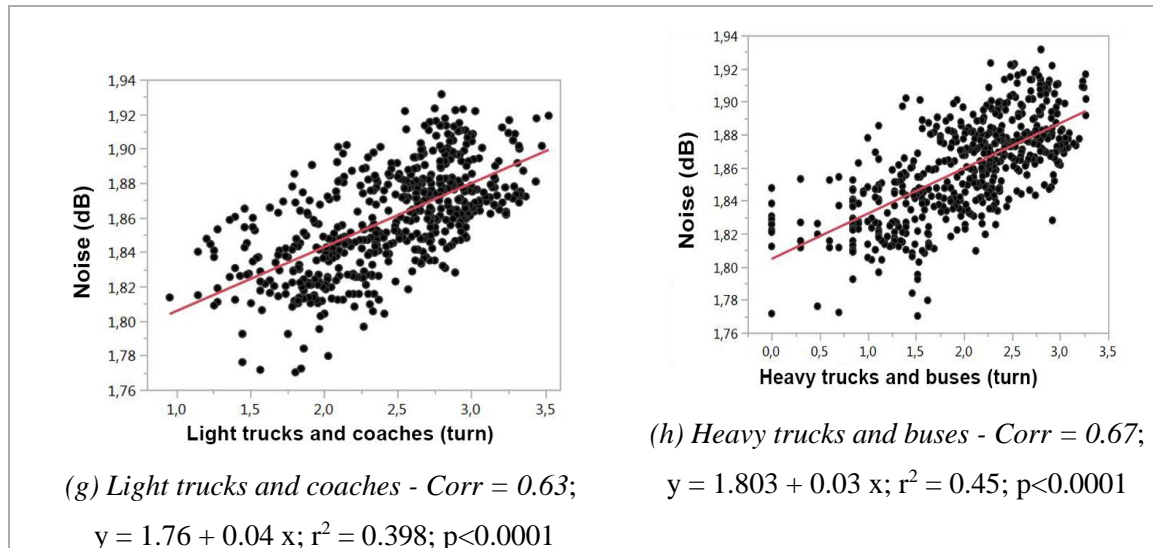


Figure 8. The correlation between Noise and traffic vehicles. r^2 is the coefficient of determination and $p < 0.05$ indicates the relationship is significant following the non-linear regression analysis

Traffic frequency is positively correlated with ambient air quality parameters. An increase in traffic activity leads to higher air pollution levels. The data collected from the monitoring stations indicate that higher wind speeds are associated with lower pollutant concentrations owing to better dispersion. However, other microclimate factors, such as temperature, humidity, and pressure, did not display clear relationships with ambient air quality parameters. Although an individual analysis of each parameter reveals some connections, the statistical significance and reliability of these correlations are limited.

3.2. Quantifying the Relationship Between Air Quality Parameters, Traffic Frequency, and Microclimate Factors

3.2.1. Quantifying the Relationship Between TSP, Traffic Frequency, and Microclimate Factors

Several studies have demonstrated a connection between traffic frequency and air pollution levels (Long, Phong, & Duyen; Phung, Long, Tin, & Phung, 2018; Phung, Tin, & Long, 2017); as well as the relationship between microclimate conditions and air

pollution (Sukojo & Zulfa, 2019). In light of these findings, air quality monitoring data in the SKEZ were analyzed to reconsider the causes of rising air pollution. The correlation analysis results indicated that most environmental quality parameters were correlated with one or more microclimate factors and/or one or more types of vehicles. Further, data processing and statistical analysis quantified the impact of microclimate factors and traffic frequency on the parameters, revealing statistically significant differences with a probability greater than 95%. Specifically,

(1) TSP

The concentration of Total Suspended Particles (TSP) is influenced by various factors such as temperature, humidity, wind speed, and different types of vehicles. Among these factors, heavy trucks and buses made the most significant contribution to TSP variation, accounting for 9.13% of the total variation. This suggests that emissions from these large vehicles, which frequently operate in urban and industrial areas, play a crucial role in elevating the TSP levels. Light trucks and coaches also

have a notable impact, contributing 4.17%, reflecting their considerable presence on roads and their potential for emitting particulates. Wind speed, with a 2.66% contribution, affected TSP levels by dispersing pollutants or spreading them over a larger area, thereby influencing air quality in different ways. Temperature and car traffic contribute similarly to TSP variation, accounting for approximately 2% each, indicating that these factors influence particulate matter through mechanisms such as chemical reactions and the sheer volume of emissions from cars. Humidity and motorbike traffic have relatively minor contributions of 0.64% and 0.59%, respectively, suggesting that while they do play a role in TSP variation, their impact is less significant than that of other factors. However, the high error term of 78.84% indicates that there may be other unaccounted for variables influencing TSP levels or that the model used may not fully capture the complexity of the interactions between these factors. This highlights the need for further research to better understand and manage particulate pollution sources in this region.

Table 1. The percentage contribution of various factors to the variation in TSP concentrations

Source	Sum of Squares	The percentage contribution of variation (%)
Temperature	1,26	1,99
Humidity	0,41	0,64
Wind speed	1,68	2,66
Motorbike	0,37	0,59
Car	1,25	1,98
Light trucks and coaches	2,63	4,17
Heavy trucks and buses	5,75	9,13
Error	49,70	78,84
Total TSP Variation	63,040	100

The analysis of the data indicates that heavy trucks and buses are the most significant contributors to the variation in Total Suspended Particles (TSP) concentrations, accounting for 9.13% of the total variation. This suggests that the emissions from these large vehicles, frequently operating in urban and industrial areas, play a crucial role in elevating TSP levels. Light trucks and coaches also have a notable impact, contributing 4.17%, which reflects their considerable presence on the roads and their potential for emitting particulates. Wind speed, with a 2.66% contribution, affects TSP levels by either dispersing pollutants or spreading them over a larger area, thereby influencing air quality in different ways. Temperature and car traffic contribute similarly to TSP variation, each accounting for around 2%, indicating that these factors influence particulate matter through mechanisms like chemical reactions and the sheer volume of emissions from cars. Humidity and motorbike traffic have relatively minor contributions of 0.64% and 0.59% respectively, suggesting that while they do play a role in TSP variation, their impact is less significant compared to other factors. However, the high error term of 78.84% indicates that there are likely other unaccounted-for variables influencing TSP levels, or that the model used may not fully capture the complexity of the interactions between these factors. This highlights the need for further research to better understand and manage the sources of particulate pollution in the region.

(2) NO_2

The extent of NO_2 fluctuation depends on several variables, including wind speed, pressure, and emissions generated by two types of vehicles: light trucks and coaches, and heavy trucks and buses.

Table 2. The percentage contribution of various factors to the variation in NO₂ concentrations

Source	Sum of Squares	The percentage contribution of variation (%)
Wind speed	0,90	4,47
Pressure	0,49	2,46
light trucks and coaches	0,55	2,74
heavy trucks and buses	0,28	1,39
Error	17,81	88,93
Total NO₂ Variation	20,022	100

The data revealed that wind speed had the most considerable influence on NO₂ levels, accounting for 4.47% of the overall variation. This highlights the role of the wind in dispersing NO₂ and reducing its concentration in specific areas. Pressure also plays a role in NO₂ levels, contributing 2.46%, while emissions from light trucks and coaches accounted for 2.74% of the variation, and heavy trucks and buses contributed only 1.39%. The comparatively lower impact of heavy trucks and buses on NO₂ levels compared to TSP suggests that while these vehicles are significant sources of particulate matter, their influence on NO₂ levels may be mitigated by factors such as emission controls or less concentrated activity in high-pollution areas. It is worth noting that the error term in this analysis was remarkably high at 88.93%, indicating that the model may not fully account for other significant factors affecting NO₂ levels, as demonstrated by the high error in the TSP analysis (78.84 %). These outcomes align with the results of a study conducted by (Capşa et al., 2016) concerning the relationship between air quality aspects in Bacau City. In this study, a variance analysis of nitrogen oxide (NO_x) concentrations was performed in relation to significant climatic factors. This research utilized data collected in 2010 from the Bacau

Meteorological Station and various air quality monitoring stations to establish the relationship between instances of nitrogen oxide (NO_x) concentrations exceeding permissible limits and changes in climatic factors. The climatic factors analyzed included air temperature, atmospheric pressure, humidity, solar radiation, and wind speed and direction. This study found that wind can either enhance pollutant activity or accelerate its dispersion. Additionally, wind direction was found to influence air quality in a specific urban area based on the city's shape and size, the type and distribution of major pollution sources, and its geographical location.

(3) SO₂

SO₂ variation is influenced by microclimatic factors, such as wind speed, pressure, and the presence of different types of vehicles, including light trucks and coaches, and heavy trucks and buses. Among these factors, wind speed had the greatest impact, accounting for 6.12% of the variation. Pressure was the next most influential factor, contributing 4.2%, followed by light trucks and coaches (3.34 %), and heavy trucks and buses (2.03 %).

Table 3. The percentage contribution of various factors to the variation in SO₂ concentrations

Source	Sum of Squares	The percentage contribution of variation (%)
Wind speed	1,23	6,12
Pressure	0,84	4,20
Light trucks and coaches	0,67	3,34
Heavy trucks and buses	0,41	2,03
Error	16,89	84,32
Total SO₂ Variation	20,03	100

(4) Noise

The extent of noise variation depends on several factors, including the frequency of traffic from motorcycles, light trucks and coaches, and heavy trucks and buses.

Table 4. The percentage contribution of various factors to the variation in Noise concentrations

Source	Sum of Squares	The percentage contribution of variation (%)
Wind speed	0,013	4,40
Motorbike	0,002	0,71
Light trucks and coaches	0,004	1,30
Heavy trucks and buses	0,032	10,88
Error	0,245	82,71
Total Noise Variation	0,30	100

Analysis of the data shows that heavy trucks and buses have the most significant influence on noise variation, accounting for 10.88% of the total variation in noise levels. This finding underscores the substantial role that large vehicles play in generating noise pollution, likely owing to their powerful engines and regular operation in urban areas. Wind speed also emerged as an important factor, contributing to 4.4% of the variation, suggesting that environmental conditions can affect noise levels by either dispersing or amplifying sound depending on the circumstances. In contrast, the contributions from motorcycles, light trucks, and coaches are relatively lower, at 0.71% and 1.30%, respectively, indicating that while these vehicles contribute to noise pollution, their impact is less pronounced than that of heavier vehicles.

4. CONCLUSION

This study investigated the microclimate factors, traffic frequency, and air quality

parameters at observation points in the SKEZ in 2018 and 2019. The research findings indicate that the air quality in the SKEZ is primarily influenced by TSP and noise levels. The TSP values ranged from less than LOQ ($<45 \mu\text{g}/\text{m}^3$) to $894 \mu\text{g}/\text{m}^3$, with 36.2% of values exceeding QCVN 05:2013/BTNMT (1-hour average $\leq 300 \mu\text{g}/\text{m}^3$). Noise level values range from 47.2 dBA to 89.7 dBA, with 53.67% of values exceeding QCVN 05:2013/BTNMT (1-hour average ≤ 70 dBA). The study also reveals that the interprovincial traffic axes have the lowest air quality, with 90% of noise and TSP monitoring samples exceeding QCVN 05:2013/BTNMT (1-hour average) and QCVN 26:2010/BTNMT. Furthermore, this study demonstrates that microclimate factors and traffic frequency are closely related to air quality. Specifically, TSP varied with temperature, humidity, wind speed, and all types of vehicles, with the most significant contributions coming from temperature (1.99%), wind speed (2.66%), light trucks and coaches (4.17%), and heavy trucks and buses (9.13%). NO_2 varies with wind speed, pressure, and two types of vehicles: light trucks and coaches and heavy trucks and buses, with the most significant contribution coming from wind speed (4.47%). SO_2 varies with microclimate factors, including wind speed and pressure, as well as with two types of vehicles: light trucks and coaches, and heavy trucks and buses, with the most significant contribution coming from wind speed (6.12%). Noise levels vary with traffic frequency, particularly for motorcycles, light trucks and coaches, and heavy trucks and buses. Additionally, noise levels varied with wind speed (4.4%), with heavy trucks and buses having the most significant impact on noise levels, contributing 10.88%.

The data and analysis show that microclimate factors and traffic frequency are

closely related to air quality in the key southern economic zone. The substantial error margin in the statistical analysis of the research data signifies the intricacy of air pollution and underscores the necessity for additional comprehensive studies to identify and thoroughly understand all contributing elements. Comprehending these relationships presents opportunities to pursue additional in-depth research avenues. Initially, it allowed for the recognition of critical times and locations where air quality is most compromised, thereby allowing targeted interventions. Second, it offers a scientific foundation for policymaking, particularly in the planning and execution of traffic management and urban planning strategies that mitigate the detrimental consequences of vehicular emissions. Lastly, such research can enlighten public health strategies, as air pollution is closely connected to respiratory and cardiovascular diseases, especially in vulnerable populations residing in urbanized areas.

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