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Assessment of Particulate Matter Concentrations and Noise Levels Along Dong – Tay Avenue, Ho Chi Minh City

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Abstract: Particulate pollution and traffic noise from the Dong – Tay Avenue created problems in the surrounding areas, especially when traffic volume was very high and vehicles ran at high speeds. Vehicular, dust and noise problems were generated by various kinds of vehicles like trucks, buses, automobiles, and motorcycles. This study aimed to determine the influence of dust and noise generated from traffic activities the Dong – Tay Avenue. Particulate matter concentrations ($PM_{1.0}$, $PM_{2.5}$, $PM_{5.0}$, PM_{10}) and noise levels were measured at 7 sites along the avenue in March and October from 2021 to 2022. The research results showed that the noise levels (73.1 ÷ 84.4 dBA) exceeded the allowable threshold of the National Technical Regulation on noise (QCVN26:2010/BTNMT; noise level < 70 dBA). Additionally, the dust concentrations ($PM_{1.0}$: 6.6 ÷ 18.8 $\mu g/m^3$; $PM_{2.5}$: 9.2 ÷ 35.7 $\mu g/m^3$; $PM_{5.0}$: 11.2 ÷ 47.0 $\mu g/m^3$; PM_{10}: 13.0 ÷ 49.7 $\mu g/m^3$) were lowered the permissible thresholds of the National Technical Regulation on ambient air quality (QCVN05:2013/BTNMT). However, solutions needed to be suggested to improve the air quality for human health and the environment as reducing roadside dust pollution and traffic noise in Ho Chi Minh City. The first priority was the solution of planting trees, which were found along a lane and got different functions. Tree species were suitable for ecological conditions along the roadsides these were applied for green solutions to be planted, including *Hopea odorata, Mimusops elengi, Khaya senegalensis* and *Bougainvillea spectabilis*.

Keywords: Particulate Matter Concentrations, Noise Levels, Vehicles, Air Quality, Roadside

1. Introduction

Air pollution is currently considered to be the world's biggest environmental health threat because economic growth always comes with the risk of pollution. It also had have further consequences on human health, leading in particular to an increasing number of respiratory and cardiovascular diseases [1]. The ambient air pollution was estimated to be responsible for 3.7 million premature deaths in 2012 [2]. Urban areas are characterized by high levels of exposure to environmental stressors, with noise and air pollution being the two most dominant issues. With the continued growth and redevelopment in cities, urban planners are now responsible for designing cities that better reduce noise and air pollution to promote healthier environment [3]. Environmental noise was recognized as a public health and environmental problem that needs to be addressed in modern society. The clear linked between adverse health effects and noise exposure have been identified, and estimates of their increase in the entire population have been established [4]. Excessive exposure to environmental noise could cause annoyance, disrupt sleep cycles, led to cardiovascular disorders, and can even impair cognitive development in children. Noise levels of 65 ÷ 70 dBA outdoors have been considered a threshold related to the adverse health effects of noise [5].

With more than 13 million people living, Ho Chi Minh City (HCMC) was facing the problem of air pollution and noise. Monitoring results in 2017 and now at 12 points in the city showed that dust pollution was up to more than 68% and noise pollution was nearly 100%; both of these factors were far beyond the Vietnam National Technical Regulation on Ambient Air Quality (QCVN 05: 2013). The dust and noise pollution in the city came mainly from major sources, including traffic activities, industrial production, construction and services [6]. Outdoor air pollutants remained the leading environmental risk to humans due to urbanization and industrialization, the concentration of air pollution in some cities, especially in Asia, has far exceeded the safe level of the World Health Organization (WHO) [6]. Besides, indoor air quality also received great attention because people spend most of their time in indoor areas such as factories, companies, schools, and houses. The outdoor air pollution was a dynamic mixture of pollutants with a dynamic mixture of pollutants from both natural and anthropogenic sources, which could penetrate and affect indoor air quality [7]. Vu et al. (2020) showed that the annual average concentrations of NO_2 were higher than that of the QCVN 05: 2013 (40 $\mu g/m^3$) and WHO (40 $\mu g/m^3$). The average annual concentrations of $PM_{2.5}$ were 23 $\mu g/m^3$ and were also much higher than the WHO (10 $\mu g/m^3$) standard by about 2.3 times. In terms of public health impacts, $PM_{2.5}$ was found to be responsible for approximately 1,136 deaths, while the number of deaths from exposure to NO_2 and SO_2 was 172 and 89 deaths, respectively. These numbers required some strict measures from the authorities to be overcome the alarming air pollution in HCMC [8]. The reality of noise pollution in HCMC was really alarming. Noise measurement resulted at 150 monitoring points located on 30 inner city roads at the time of least traffic (from 22:00 to 6:00 the next day) but the measured noise still exceeded the limit. This would have directly affected the daily life and health of the people and needs to be handled quickly by the authorities [9]. In Vietnam, according to the national technical regulation on noise, for specific areas (these far away from the fence of medical centers, libraries, kindergartens, schools, churches, temples, pagodas, and areas that have other specific rules), the allowed sound from 6 to 9 o'clock is 55 dBA, from 9 pm to 6 am another 45 dBA. For normal areas (apartment buildings, houses in the alley, resorts, motels, administrative offices), from 6:00 to 21:00 was 70 dBA; from 21:00 to 6:00 was 55 dBA. In reality, however, we have had to live with sounds beyond our limits [10].

To assess the level of air pollution emissions in HCMC, two methods were commonly used to evaluate pollution or ambient air quality, including (1) applying GIS for the pollutant diffusion model and (2) using integrated methods of data collection, analysis, and evaluation. The assessment of pollution level on the basis of analysis and statistics of environmental monitoring data was only approximate but was a basic and feasible method. To control air from the stationary sources, the following measures could be applied separately or simultaneously: control emissions at the source, dilution of pollutants before being discharged into the environment [11]. Nguyen Tan Hoi (2020) analyzed the general pollution situation in HCMC, and based on previous studies, to review and assess the health impacts of air pollution. The paper also discussed the reciprocal relationship between researchers and policy makers in monitoring air quality and protecting human health. From the comparison with other countries, several proposals were discussed to assess the pollution risk and to strengthen research and possible policies to improve the health of the people in the city [12]. Kesten et al. (2020) developed an acoustic optimization method to generate an optimum dimension of a noise barrier. As a result, a complete glazed noise barrier design could be further examined. Due to the transparent nature, the thermal and aesthetic consequences along with the resilience against traffic accidents of a full glass design also need to be studied in detail [13]. After that, Huertas et al (2021) evaluated the impact of the use of solid barriers on the dispersion of air pollutants emitted by the vehicular traffic on roads located over flat areas were quantified, aiming to identify the geometry that maximizes the mitigation effect of air pollution near the road at the lowest barrier cost. Results showed that, in all barrier configurations, the pollutant concentration normalized to the downwind of the barrier was highly correlated ($R^2 > 0.86$) with the concentrations observed without the barrier. The most cost-effective configuration was observed with a quarter ellipse barrier geometry with a height equivalent to 15% of the road width and located at the edge of the road, where pollutant concentrations were 76% lower than configuration was observed without any barrier [14].

Due to of the importance of air pollution control, this study established the case study at the Dong – Tay Avenue, HCMC to find out the feasible solutions for minimizing impacts on human health and air quality. This article could also provide useful information for governments in implementing a strategic plan that focused on emphasizing the reduction of multi-pollutant emissions and the overall risks associated with air pollution.

2. Materials and Methods

2.1. Study Area

Data with 15.0 km of the Dong – Tay Avenue were used as a representative example for study areas. The samples of $PM_{1.0}$, $PM_{2.5}$, $PM_{5.0}$, PM_{10}, noise, and transport vehicles (trucks, buses, automobiles, motorcycles) at 7 sites were collected for 4 periods in March and October from 2021 to 2022 (Figure 1; Table 1).

Table 1. *Coordinates and locations of the sampling sites in study area.*

Sites	Local Names	Longitude	Latitude
DT1	Vo Van Kiet Street, An Lac Ward, Binh Tan District, Ho Chi Minh City	10^0 43’30”N	$106^0$36’23”E
DT2	Vo Van Kiet Street, Ward 16, District 8, Ho Chi Minh City	10^0 43’40”N	$106^0$37’15”E
DT3	Vo Van Kiet Streets, Ward 5, District 5, Ho Chi Minh City	10^0 46’02”N	$106^0$42’05”E
DT4	Vo Van Kiet Streets, Ward 1, District 1, Ho Chi Minh City	10^0 44’59”N	$106^0$40’31”E
DT5	Mai Chi Tho Streets, Thu Thiem Ward, District 2, Ho Chi Minh City	10^0 46’19”N	$106^0$43’01”E
DT6	Mai Chi Tho Streets, An Loi Dong Ward, District 2, Ho Chi Minh City	10^0 46’49”N	$106^0$46’06”E
DT7	Mai Chi Tho Streets, An Phu Ward, District 2, Ho Chi Minh City	10^0 47’10”N	$106^0$44’51”E

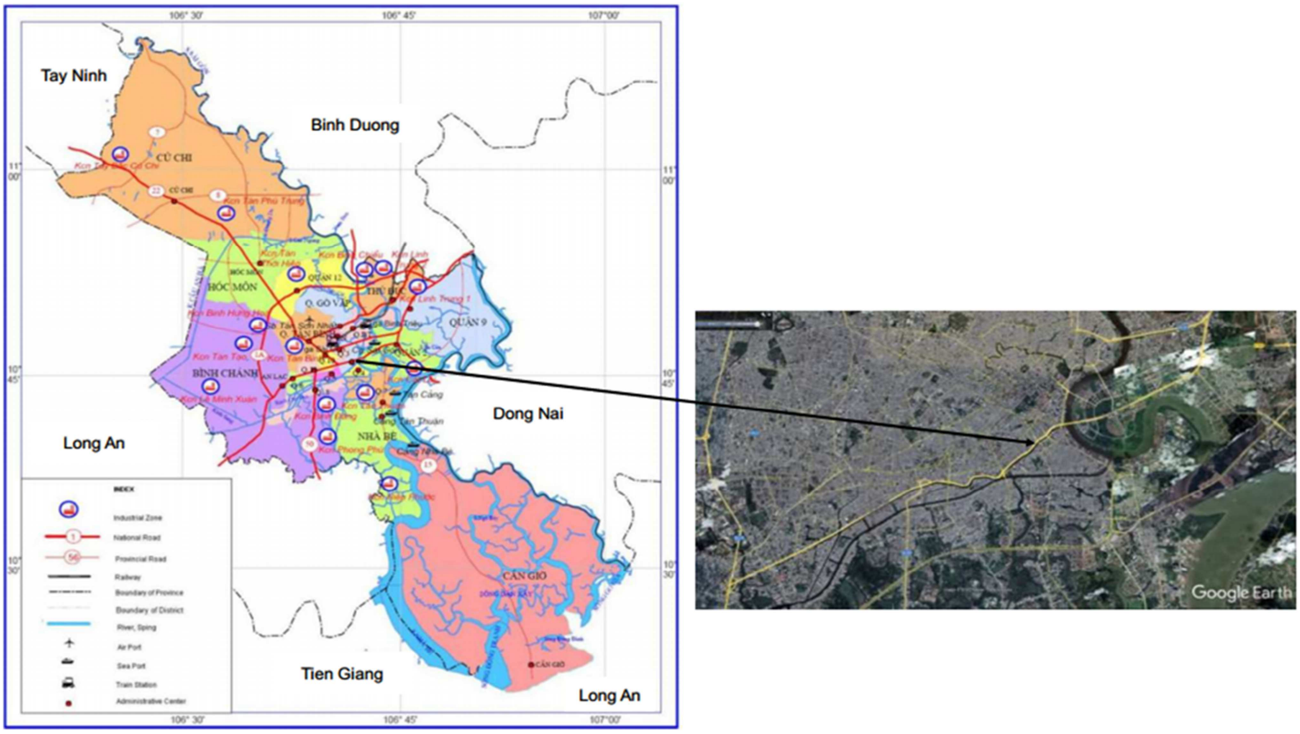


Figure 1. Study area of water quality parameters with 5 sampling sites (DT1–DT7).

2.2. Sampling Process and Analytical Methods

The sampling process and analysis of air quality variables in the Dong – Tay Avenue were taken in 04 periods from March 2021 to October 2022 (Table 2, Figure 2).

Table 2. *Sampling process and analysis for air quality variables.*

Parameters	Units	Methods	QCVN05:2013/BTNMT	QCVN26:2010/BTNMT
Noise	dBA	TCVN 7878-2:2010		70
$PM_{1.0}$	$\mu g/m^3$	TCVN 5067: 1995		
$PM_{2.5}$	$\mu g/m^3$	TCVN 5067: 1995	50	
$PM_{5.0}$	$\mu g/m^3$	TCVN 5067: 1995		
PM_{10}	$\mu g/m^3$	TCVN 5067: 1995	150	

Notes: Compare with environmental standards including QCVN 02:2019/BYT (National Technical Regulation on Dust – Permissible exposure limit value of dust at the workplace); QCVN24:2016/BYT (National Technical Regulation on Noise – Permissible exposure levels of noise in the workplace).

(a) (b)

Figure 2. *Sampling methods for particulate pollution and noise level. (a) $PM_{1.0}$, $PM_{2.5}$, $PM_{5.0}$, PM_{10}; (b) noise.*

2.3. Vehicle Classification Survey

To understand the correlation between dust concentrations and transport activities, the density of vehicles on the road at the monitoring sites was counted. There were many kinds of vehicles circulating on the road at the same time, so they were divided into 4 types of vehicles, including trucks, 24 ÷ 50 seat buses, 4 ÷ 16 seat automobiles, and motorcycles. The number of vehicles at the monitoring locations was averaged over 3 counts, for a period of 5 minutes each time.

2.4. Data Analysis

The obtained data were subject to statistical analysis to test the analysis of variance (ANOVA) and the Pearson correlation among all the parameters using R-statistical software. Significant or highly significant positive or negative correlations were assumed when the p-calculated value was < 0.05, respectively. The nine metrics were tested for their potential as indicators of air quality assessment by regressing values for 2021 and 2022 (28 sampling events for 7 sites).

3. Results and Discussion

3.1. Air Quality Variables Along Dong – Tay Avenue

The air quality parameters and transport activities at 7 sites collected for 4 periods in March and October from 2021 to 2022 were summarized in Table 3.

The concentrations of PM_{10}, $PM_{5.0}$, $PM_{2.5}$, and $PM_{1.0}$ fluctuated between 13.0 µg/m^3 to 49.7 µg/m^3, 11.2 ÷ 47.0 µg/m^3, 9.2 ÷ 35.7 µg/m^3, and 6.6 ÷ 18.8 µg/m^3, the values had not been recorded in excess of the permissible exposure limit of dust concentration in ambient air quality. According to Daellenbach et al. (2020), particulate matter was a component of ambient air pollution that was linked to millions of premature deaths annually globally. Assessments of the chronic and acute effects of particulate matter on human health tended to be based on the mass concentrations, with particle size and composition also thought to play a role. Oxidative potential had been suggested to be one of many factors that could lead to acute health effects of particulate matter, but this association remains uncertain [15]. Meanwhile, the noise measurement results ranged from 73.1 dBA to 84.4 dBA, exceeding the allowable exposure limit for roadside noise. These levels could sometimes be a health risk for people. The stress response has contributed to the development of hypertension (high blood pressure) and atherosclerosis, a condition in which arteries became clogged with fatty deposits called plaque. Hypertension and atherosclerosis were major risk factors for stroke and ischemic heart disease, respectively [16, 17]. Higher blood pressure put strain on the blood vessels and was more likely to cause a stroke due to a blood clot or bleeding. Ischemic heart disease was the term for heart problems caused by narrowed arteries (e.g., heart attacks). The narrowing could be the result of a buildup of plaque or a blood clot or spasm of a blood vessel. Noise-induced stress processes were especially harmful when they persisted for a long time. Therefore, cardiovascular disorders were attributed to long-term noise exposure [18].

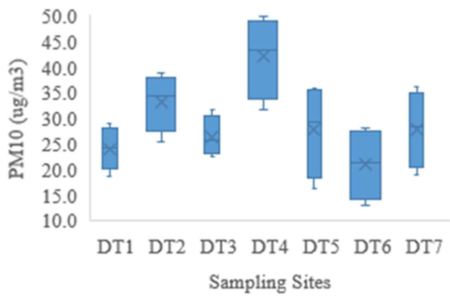
Table 3. *Summary of the air quality parameters and transport density in the Dong – Tay Avenue.*

Parameters	PM_{10} (µg/m^3)	$PM_{5.0}$ (µg/m^3)	$PM_{2.5}$ (µg/m^3)	$PM_{1.0}$ (µg/m^3)	Noise (dBA)	Trucks (units)	Buses (units)	Auto. (units)	Motor. (units)
Min	13.0	11.2	9.2	6.6	73.1	27	19	155	1,250
Median	27.3	23.5	19.2	11.3	79.0	186	49	266	1,,850
Mean	28.9	24.3	20.2	11.8	79.0	167	47	254	2,064
Max	49.7	47.0	35.7	18.8	84.4	329	82	313	3,400
SD	3.2	6.8	8.0	8.8	2.7	108	17	48	709

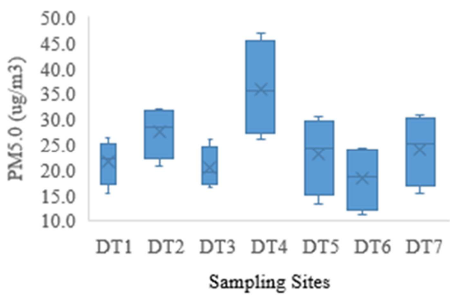
The transport densities of vehicles in the Dong – Tay Avenue ranged between 27 to 329 trucks; 19 ÷ 82 buses, 155 ÷ 313 automobiles, and 1,250 ÷ 3,400 motorcycles. This showed that the transport density in the dry season (March) was higher than this in the rainy season (October). A notable feature, the traffic density recorded in 2021 was lower than this in 2022 because the Covid-19 pandemic has strongly impacted economic activities and goods trade throughout 2021. Besides to the public health crisis, has had a significant impact on the global economy and development. It also led to changes in people's mobility and lifestyle during the COVID-19 pandemic [19]. Due to the implementation of social distance and lockdown during the COVID-19 period, daily travel and related lifestyle habits have changed significantly [20]. In Germany, the lockdown by SARS-CoV-2 caused a significant decrease in mobility, which can affect noise levels. In fact, the so-called traffic barometer of the Federal Highway Research Institute in Germany concluded that a marked decrease in traffic volume was observed on federal highways and federal roads during the lockdown time. In Germany, the lockdown by SARS-CoV-2 had significantly reduced mobility, which could affect noise levels [21].

3.2. Spatial Distribution of Pollutants in Dong – Tay Avenue

The concentrations of different pollutants in the Dong – Tay Avenue were presented in Figure 3. The results showed that all five pollutants had the highest mean concentrations at the site DT4, and the next highest levels of pollution recorded in the sites DTDT2, DT5, and DT7. The lowest mean concentrations were identified at the sites of DT1, DT3, and DT6 (Figure 3).



(a)



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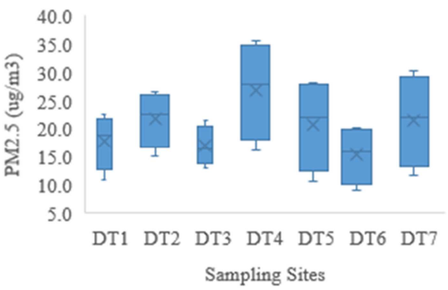
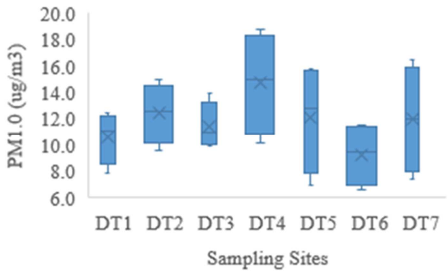
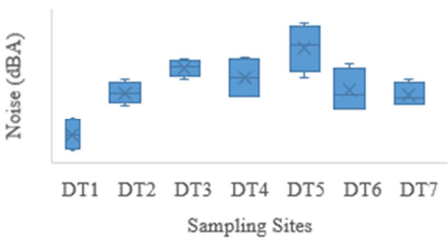


(c)



(d)



(e)

Figure 3. *Dust concentrations and noise levels were measured in the Dong – Tay Avenue. (a) PM_{10} average concentrations; (b) $PM_{5.0}$ average concentrations; (c) $PM_{2.5}$ average concentrations; (d) $PM_{1.0}$ average concentrations and (e) Noise levels.*

In general, the research results on the particulate matters were lowered than the permissible thresholds of the National Technical Regulation on ambient air quality (QCVN05:2013/BTNMT), while the noise levels recorded along the roadsides have exceeded the allowable threshold of the National Technical Regulation on noise (QCVN26:2010/BTNMT). The research results of Ho Q. B. (2017) also showed that the higher traffic density, the more PM_{10} was emitted. Most of the wards in HCMC identified PM_{10} pollution levels exceeding the WHO allowable threshold [2]. In 2019, Luong et al. demonstrated that young children in HCMC were at risk of hospitalization for acute lower respiratory tract infections due to the high concentrations of $PM_{2.5}$ in the city's ambient air [22]. To assess the health impacts on residents through interviews (n = 208), annoyance at home was low (32%), moderate (28%), and high (9%) in comparison with workplace settings of 42%, 43%, and 15%, respectively. Nineteen percent of the interviewees had difficulties in sleeping, while 19.8% experienced stress due to road traffic noise exposures. Furthermore, a strong association ($p < 0.05$) was established between the use and objection of noise barriers. Research revealed high noise levels and the prevalence of discomfort and health effects among the exposed local communities [23].

3.3. Relationships of Number of Vehicles and Air Pollution Parameters

Figure 4 showed that the particulate matter concentrations in Dong – Tay Avenue got strong positive correlations with the number of buses, automobiles, and motorcycles and noise levels (0.45 ÷ 0.77), while these variables were significant positive correlations between the noise (0.32 ÷ 0.50). Similar to the study of particulate pollution and noise in HCMC, Alnawaised et al (2012) indicated that TSP and PM10 remained significantly correlated with traffic count even after controlling for confounding factors (temperature, relative humidity, and wind speed) with TSP (0.726), PM_{10} (0.719) [24]. In 2015, Ahmadi and Nassiri showed daytime and nighttime mean values of 73.34 dBA and 72.59 dBA respectively, which were higher than the WHO outdoor environmental noise guidelines. The highest mean value was recorded as 74.05 dBA. It was found that minibus-vans and truck-buses were mainly responsible for causing of traffic noise on these roads. Using the sound barriers were proposed to reduce traffic noise of the two groups of vehicles on the main roads in Sanandaj city, Iran. [25]. Enembe Oku Okokon et al (2018) observed significantly high particulate air pollution (280 ÷ 489 $\mu g/m^3$) and noise exposures (85 ÷ 92 dBA) during travel in major cities of Africa. Some information was recorded as follows: the highest exposure was observed with car window open and the air conditioners turned off; the major change to modern public transport system would limit passenger exposure; and, the assessment of different size fractions needed to monitor for the exposure identification of Lagos urban commuters [26].

3.4. Measures to Reduce Dust and Noise Pollution

Along with the government's decision to reduce air emissions and noise levels, the citizen needed to protect themselves from fine dust by wearing medical masks that could filter out about 90% of PM_{10}, radically replace fuel. cleaner for vehicles (biofuel E5, gasoline RON95 or electric vehicles). Therefore, solutions to decrease the particulate matters and noise levels included: (i) regulating the circulation period of motorbikes to reduce the number of old motorbikes; (ii) providing technical regulations on emissions for the motorcycle registration; (iii) controlling expired motorcycles strictly; (iv) improving fuel quality by Euro standards; (v) investing in the suitable public transport system in Ho Chi Minh City; (vi) using double-layer fence of trees along two road lanes; and, (vii) upgrading the automatic air quality monitoring system in Ho Chi Minh City to warn people of air pollution levels. In addition, the recommendations proposed by the Government of Vietnam raises standards to address the growing challenges posed by increased pollutant loads, concentrations, and toxicity. Specifically, a series of specific actions could help address four future directions such as (1) public pollution abatement and control expenditure — capital investment; (2) recurrent expenditure — budget allocation; and, (3) recurrent expenditure — budget allocation [27].

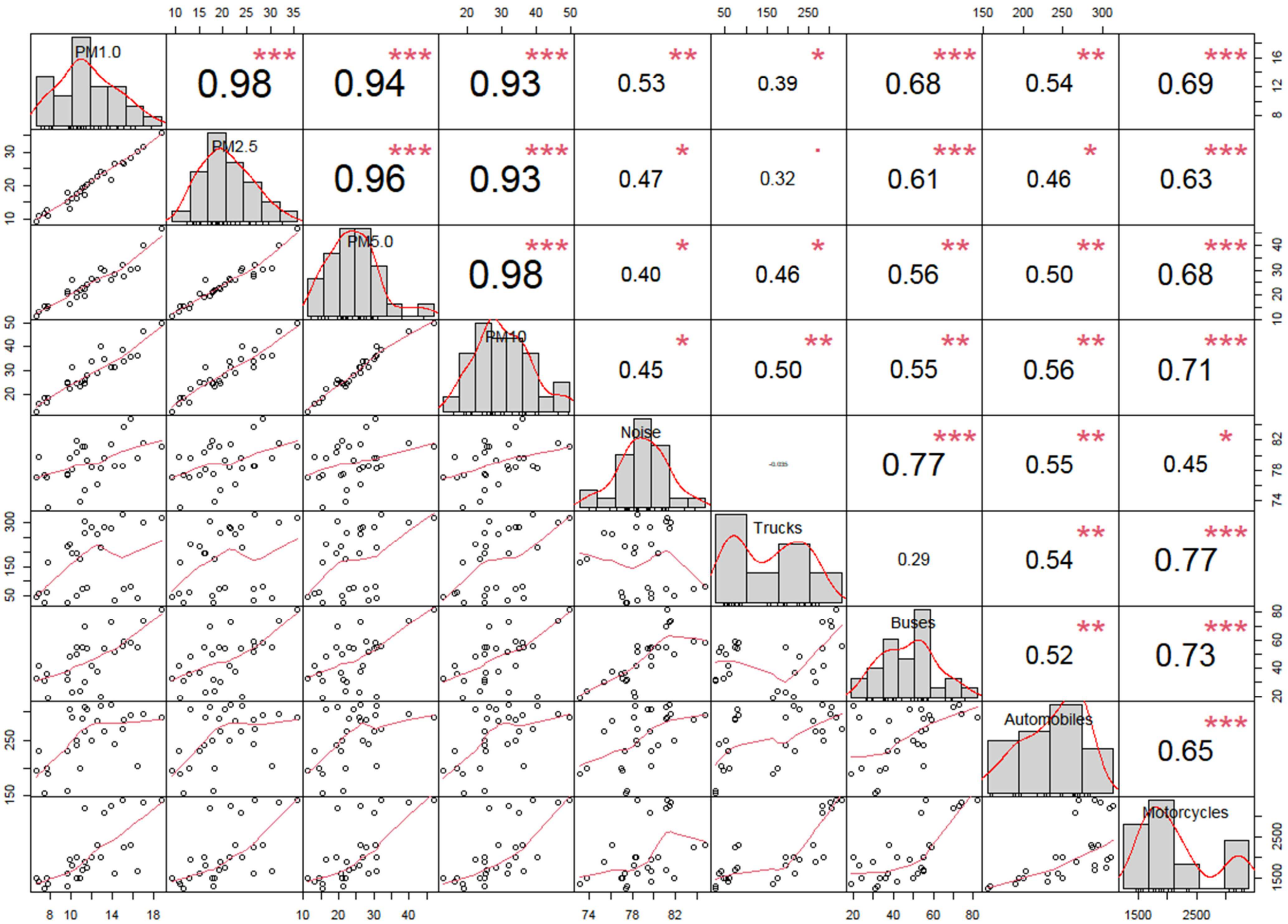


Figure 4. *Relationships between the metrics of number of vehicles and air pollution parameters for sites sampled in the Dong – Tay Avenue during 2021 and 2022.*

4. Conclusion

The findings of this study provided the concentrations of PM10, PM5.0, PM2.5, and PM1.0 ranged from 13.0 μg/m^3 to 49.7 μg/m^3, 11.2 ÷ 47.0 μg/m^3, 9.2 ÷ 35.7 μg/m^3 and 6.6 ÷ 18.8 μg/m^3, these values were not recorded exceeding the allowable limit of dust concentration in ambient air quality. In general, the research results on particles have lowered the permissible threshold on dust concentrations of the QCVN05: 2013/BTNMT, while the noise level recorded along Dong – Tay Avenue has exceeded the allowable threshold on the noise of the QCVN26: 2010 / BTNMT (> 70 dBA).

Traffic density at the Dong – Tay Avenue fluctuated from 27 to 329 trucks, 19 ÷ 82 buses, 155 ÷ 313 automobiles, and 1,250 ÷ 3,400 motorcycles. This showed that the transport density in the dry season (March) was higher than that of the rainy season (October). A notable feature, the traffic density in 2021 was lower than in 2022, as the Covid-19 pandemic has had a strong impact on economic activities and goods trade throughout 2021. It was found that buses and motorcycles were the main sources of particulate pollution problems, while buses and automobiles were the key reasons for traffic noise in the Dong – Tay Avenue.

In summary, the most important factor to reduce the particulate matter concentrations and noise levels on the two main avenues was to apply the pollutant control programs for these groups of vehicles. Trees and other vegetation, known as "roadside vegetation," were found along a lane and have different functions. Apart from the reduction of the particulate matter concentrations and noise levels, they also affected the risk for people involving in the typical ecological functions. It was proposed to use the double-layer fence of trees along two road lanes. The first priority was the solution of planting trees, known as "roadside vegetation," were found along a lane with different functions. Tree species that were suitable for ecological conditions along the boulevards applied for green solutions to be planted, including *Hopea odorata* (ta-khian), *Mimusops elengi* (medlar), *Khaya senegalensis* (khaya wood), *Bougainvillea spectabilis* (great bougainvillea).

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