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Investigation and Assessment of Road Traffic Noise: a Case Study in Ho Chi Minh City, Vietnam

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Abstract Noise pollution is recognized as a major environmental issue which is significantly related to the risk for the human health. The purpose of this study was to investigate and assess the noise pollution in some typical locations of Ho Chi Minh City (HCMC) due to road traffic. L_{Aeq} values measured at seven representative sites in 2015 and 2016 showed the existence of road traffic noise pollution. The study found that the statistical noise level with traffic noise index (TNI) throughout the studied area in 2015 has an average TNI_{2015} of 95.5 ± 20.78 dB with the range from 66.7 to 125.6 dB. The statistical noise level TNI_{2016} in 2016 showed that the noise levels of all the measured sites were between 49.4 and 103.8 dB and has an average of 70.9 ± 22.38 dB. The maximum value of TNI was recorded at site S2 with 124.9 dB (weekdays) and 122.0 dB (weekends), respectively. Pairwise comparisons showed that there were significant differences between the results of the weekdays and weekends for almost of studying sites ($p < 0.05$). Pearson correlation coefficients were calculated to describe the association between road traffic-related noise and environmental conditions. The effects of environmental factors on TNI showed an important impact of road traffic volumes and wind speeds with standardized coefficients of significance at 0.05. Based on these findings, it could be used for the potential of estimating noise levels and contributing to the sustainable urban development in HCMC.

Keywords Environmental factors · Road traffic noise · Traffic noise index (TNI) · Ho Chi Minh City (HCMC) · Vietnam

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1 Introduction

Traffic noise is known as a major factor of environmental pollution (Marathe, 2012). Noise pollution has been considered as a serious health hazard (Bies & Hansen, 1996; Montes-González et al., 2018), with noise that is harmful to humans from levels of annoyance to health issues (Mato & Mufuruki, 1999; Morrell et al., 1997) and also having negative impacts on urban life (Garg et al., 2007; Wu et al., 2019). Over the past decades, noise pollution has received increasing attention and studies have reported that noise pollution is one of the environmental hazards affecting human (Tetreault et al., 2013; WHO, 2005). A study of Zannin et al. (2013) showed that the environmental noise characterization based on noise measurements and interviews has been addressed in different studies. Also, the analysis of multiple regression model has shown differences in the community reaction related to noise (Trieu et al., 2021). Similar studies have been conducted on noise pollution in Europe, Asia or USA, etc. (Ballesteros et al., 2014; Brainard et al., 2004; Ky, 2014; Lan et al., 2016; Lee et al., 2014; Paiva et al., 2019; Peng et al., 2021; Ristovska & Lekaviciute, 2013; Yano et al., 2002). Previous studies showed motor vehicles and the related traffic means are known as the main sources of the noise pollution in large cities (Bhosale et al., 2012; Liu et al., 2014; Sobotova et al., 2010). Noise pollution emitted by vehicles increases with vehicle speed, acceleration, or traffic frequency (Sandberg & Ejsmont, 2002). In recent years, based on the appropriate reference time intervals, Nguyen et al. (2020) used the noise indicators as useful approach to suggest the implementation of noise control policies. Furthermore, according to researches of air pollution, noise pollution can cause adverse effects on health, behavior, and quality of life (Garg et al., 2007; Liu et al., 2021; Montes-González et al., 2018; Moura-de-Sousa & Cardoso, 2001). Noise pollution is a common problem in most of the cities in the whole world, especially big cities. It could be recognized that road traffic noise can affect health in both directly and indirectly ways (Babisch, 2005). Noise from road traffic is also a serious harmful environmental stressor (WHO, 2011). Nowadays, the road traffic noise has become an issue of global concern (Liu et al., 2021; US.EPA, 2011).

Regarding to Vietnam, located in the tropical monsoon climate zone, Ho Chi Minh City (HCMC), the biggest city of Vietnam, with the area of 2096 km^2 and the population of approximately 10 million, has two different seasons: dry and wet (HCMCSO, 2017). With a megacity characteristic in Vietnam, the strong development process in HCMC has caused the rapid growth of vehicles and road traffic frequency. According to Department of Transport of HCMC, for example, the number of motorcycles has been registered at about 6.3 million and that of passenger cars is 0.6 million (HCMCDOT, 2015). Therefore, the noise pollution due to road traffic is a major concern and impacts on the public life quality (Yen et al., 2010a). However, the researches on road traffic noise pollution in Vietnam in general and HCMC in particular have been very few. Our literature search on the journal of *Water, Air & Soil Pollution* (Electronic ISSN 1573-2932) returns no paper related to this issue while on the journal of *Environmental Monitoring and Assessment* (Electronic ISSN 1573-2959) returns only one paper on this so far. Therefore, this study was conducted to investigate and assess the existing status of road traffic noise level and the associated characteristics at some typical sites in HCMC, a megacity of Vietnam to give scientific findings to the city's air environment management and the public health protection as well as contributing to the world's knowledge on the situation of road traffic noise in a megacity of the Southeast Asian Region (ASEAN).

2 Materials and Methods

2.1 Studied Sites

To assess the road traffic noise effects on the urban to suburban areas in HCMC, seven different sites ranging from less noise zone (suburban) to high traffic zone (central urban) with the potential of high noise pollution including (S1) at Tan Chanh Hiep Street, District 12; (S2) at Dinh Tien Hoang Street, District 1; (S3) at Nguyen Thi Minh Khai Street, District 1; (S4) at Nguyen Van Linh Street, District 7; (S5) at Tran Phu Street, District 5; (S6) at Mai Chi Tho Street, District 2; and (S7) at Xo Viet Nghe Tinh Street, Binh Thanh District were chosen to investigate the noise pollution levels in seasons of years 2015 and 2016. The sampling sites of the study are shown in Fig. 1 and summarized in Table 1.

2.2 Noise Measurement

A-weighted sound pressure levels [L_A (dB)] were measured with sound level meters (RION NL-21 and NL-22). The measurements were continuously conducted at the sampling sites which were at 1.2 m high above the land surface and 2.5–5 m away from the road shoulders (Lan et al., 2016; Yen et al., 2010a, 2010b) during a week of wet season from 12th to 18th in October 2015 and a week of dry season from 11th to 17th in April 2016 to represent two typical seasons (the wet and dry seasons) of a year in the study area. L_{10} and L_{90} were calculated from the obtained L_A levels, in which, L_{10} and L_{90} are the noise levels that exceed for 10% and

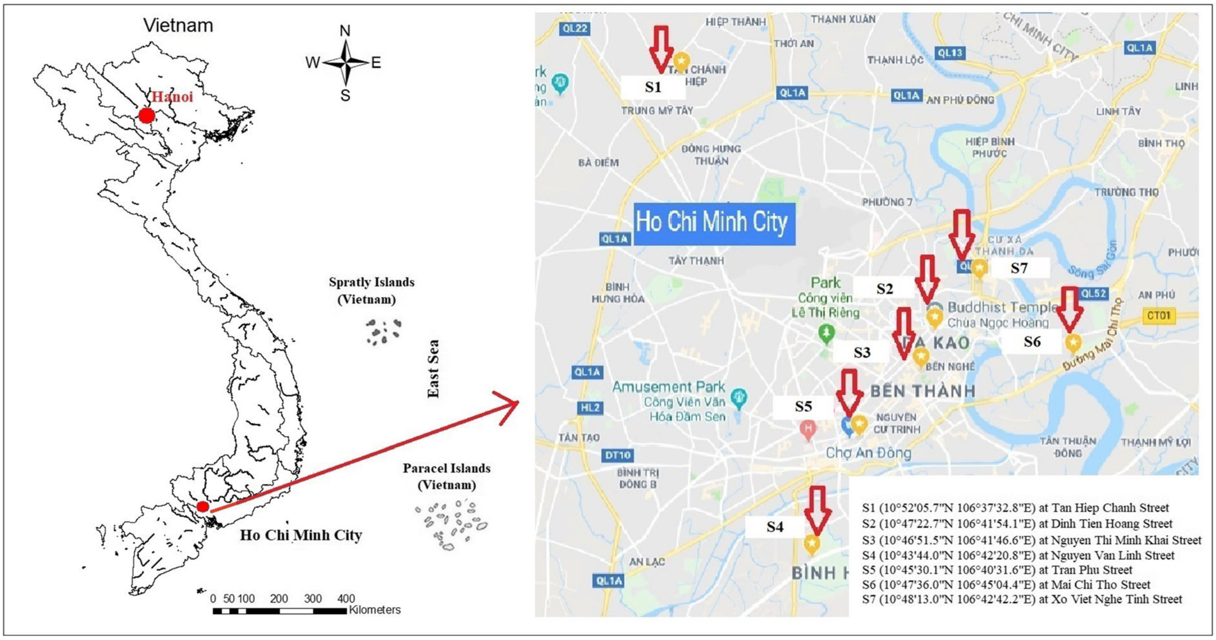

Fig. 1 Overview of the study area in Ho Chi Minh City

90% of measurement period, calculated by statistical analysis (Bazaras et al., 2008). L_{10} indicates peak levels of noise while L_{90} indicates background noise levels. L_{Aeq} is defined as equivalent continuous sound level; the steady sound level over a given period of time has the same total energy as the fluctuating noise (Davis & Masten, 2004). The monitoring device was calibrated to read the sound level in dB(A). For the assessment of noise, several methods have been proposed (Kephalopoulos et al., 2014). In this study, traffic noise index (TNI) was applied. It is defined in term which indicates the degree of variation of annoyance that is caused by traffic noise (Griffiths & Langdon, 1968; Langdon & Scholes, 1968; Parbat & Nagarnaik, 2007). TNI is calculated as follows:

$$TNI = 4(L_{10} - L_{90}) + (L_{90} - 30) \quad (1)$$

The values of L_{10}, L_{90}, and traffic noise index (TNI) have been calculated to specify the characteristics of noise (dB).

2.3 Monitoring of Environmental Factors and Traffic Volume

A monitoring of environmental factors was conducted during the same period of noise measurement. Temperature was simultaneously measured using a portable thermal environment meter (TM-181, Tenmars Electronics Co. Ltd., Taiwan). Other environmental parameters such as wind speed were directly measured by wind direction sensor (WTF-B510). These environmental factors were measured on site at seven monitoring sites.

The traffic volume was quantified during the 24-h period by reproducing video camera recordings (Yen et al., 2010a, 2010b). Traffic flows were grouped into two vehicle categories: light vehicles (Q_L) with loading weight less than or equal to 2.5 tons (such as taxis, private/small cars, and motorcycles) and heavy vehicles (Q_H) with loading weight greater than 2.5 tons.

2.4 Statistical Methods

Paired samples t-test was used to compare L_{Aeq} and TNI at each monitoring site and significance of measurement periods was $p < 0.05$. Descriptive statistical techniques were used to find the average noise level for both weekdays (from Monday to Friday) and weekends (from Saturday to Sunday). Correlations were calculated to examine the relationships between noise levels with wind speed and temperature. All statistical analyses were performed using SPSS version 13.0 (IBM, Chicago, IL, USA) with significance of $p < 0.05$.

Table 1 Characteristics of sampling sites

Site	Address	Characteristics, purposes	Latitude	Longitude
S1	Tan Hiep Chanh Street, District 12	- Characteristics: less noise zone, suburban, quiet area, and less impacted by vehicles - Purposes: human impact and health issue assessment in rural area	10°52′05.7″N	106°37′32.8″E
S2	Dinh Tien Hoang Street, District 1	- Characteristics: high vehicle density, traffic noise pollution zone - Purposes: human impact and health issue assessment in central urban area	10°47′22.7″N	106°41′54.1″E
S3	Nguyen Thi Minh Khai Street, District 1	- Characteristics: high vehicle density, traffic noise pollution zone - Purposes: human impact and health issue assessment in central urban area	10°46′51.5″N	106°41′46.6″E
S4	Nguyen Van Linh Street, District 7	- Characteristics: in the south of the city, medium vehicle density - Purposes: health issue assessment in residential area	10°43′44.0″N	106°42′20.8″E
S5	Tran Phu Street, District 5	- Characteristics: in the south of the city central, crowded area, moderate vehicle density - Purposes: health issue assessment	10°45′30.1″N	106°40′31.6″E
S6	Mai Chi Tho Street, District 2	- Characteristics: in the east of the city, high heavy vehicle density - Purposes: health issue assessment	10°47′36.0″N	106°45′04.4″E
S7	Xo Viet Nghe Tinh Street, Binh Thanh District	- Characteristics: in the northeast of the city, crowded area, high vehicle density - Purposes: health issue assessment	10°48′13.0″N	106°42′42.2″E

3 Results and Discussions

3.1 Monitoring Results of Environmental Factors

The averaged temperature at monitored sites in the wet season 2015 was 31.2 ± 1.18 °C with fluctuation of about 29.6 – 33.3 °C. In the dry season 2016, the temperature ranged about 30.6 – 36.2 °C with the averaged value of 33.4 ± 2.05 °C. The results of detail monitored data on environmental factors (temperature, wind) in the studied area are shown in Table 2.

The results of averaged wind speed at monitored sites were 2.4 ± 2.45 m/s (wet season, 2015) and 1.8 ± 1.48 m/s (dry season, 2016), respectively. The monitoring results showed that the wind velocity trend in the wet season is greater than that in the dry season.

3.2 Assessment of Road Traffic Noise

3.2.1 Variation of Traffic Noise Levels

The noise levels (L_{Aeq}) and traffic noise index (TNI) varied spatially and temporally over the studying periods as shown in Table 3. In this table, hourly traffic volume (veh./h short for vehicle/hour) has been grouped into two vehicle categories (light and heavy vehicles). The maximum number of total light vehicles passing per unit time was observed at site S2 where the number was 9013 (veh./h) in the wet season 2015 and 10,213 (veh./h) in the dry season 2016. Heavy traffic road was seen at site S2, which causes the highest noise level. The hourly averaged number of vehicles from all sites was counted about 40,854 in 2015 and 37,693 in 2016. These traffic flows were higher than those in the previous study of Yen et al. (2010b) in Hanoi and HCMC. It also showed that the minimum and the maximum noise levels were 61.0 dB and 83.6 dB, respectively, in the wet season 2015 (Fig. 2), and they were equal to 54.3 dB and 75.2 dB, respectively, during the dry season 2016 (Fig. 3). The highest noise levels were recorded with 83.6 dB at site S2 (wet season 2015) and 78.2 dB at site S6 (dry season 2016), respectively. WHO has suggested that environmental noise levels should not exceed 50 dB (moderate annoyance level), 55 dB (serious annoyance level) in daytime and evening, and 45 dB outside bedrooms for the human health protection (WHO, 2009).

Table 2 The measured values of environmental factors

Sites	Wet season, 2015		Dry season, 2016	
	Temp. (°C)	Wind (m/s)	Temp. (°C)	Wind (m/s)
S1	30.4	2.2	34.4	3.7
S2	33.3	6.3	36.2	3.5
S3	29.6	0.4	31.3	1.8
S4	31.9	1.0	32.9	0.2
S5	31.3	1.4	33.5	0.9
S6	31.3	5.3	35.4	2.4
S7	30.7	0.1	30.6	0.1
Mean	31.2	2.4	33.4	1.8
SD	1.18	2.45	2.05	1.48
Min	29.6	0.1	30.6	0.1
Max	33.3	6.3	36.2	3.7

However, Figs. 2 and 3 showed that all the measured noise values at all sampling sites exceeded the WHO's suggested values. In other words, the study area was polluted with the road traffic noise, especially at the sampling sites S2 and S6 due to the fact that the sampling site S2 is in the central urban area with high vehicle density (Q_L and Q_H) and the sampling site S6 is in the suburban area with high heavy vehicle density (Q_H and Q_L) (Table 3). In addition, Vietnam National Technical Regulation on Noise (VMONRE, 2010) shows that the maximum allowable limits of noise levels (L_{Aeq}) are 45 dB (from 9:00 PM to 6:00 AM in special sites), 55 dB (from 6:00 AM to 9:00 PM for especial sites and from 9:00 PM to 6:00 AM in usual sites), and 70 dB (from 6:00 AM to 9:00 PM in usual sites). Thus, L_{Aeq} values measured at seven sites in HCMC have shown the road traffic noise pollution at almost of sampling sites.

The noise pollution caused by the increase in the number of vehicles in HCMC is quite similar to the results of studies conducted by Piccolo et al. (2004), Sommerhoff et al. (2004), Paz et al. (2005), and Paoprayoon et al. (2005). In this study, noise levels were found to be high, which is due to the central road passing through the city from urban (sites 2, 6, 7) to suburban areas (sites 1, 3, 5). Thus, total number of vehicles at dense traffic areas increased the high noise level and leading to noise pollution in the area. The noise pollution could affect the urban resident's health. This result is similar to the result published by Stosic et al. (2009).

Regarding to traffic noise index (TNI), the TNI value was highest at site S2 (125.6 dB in 2015) and site S6 (103.6 dB in 2016) corresponding to the sites with high traffic density. This result is similar to the result published by Marathe (2012). The average TNI in wet season (95.5 ± 20.78 dB) was higher than that in dry season (70.9 ± 22.38 dB), and it is a clear confirmation by paired samples t-test ($p < 0.001$). The paired t-test used to compare the wet and dry season TNI results for the monitoring periods is shown in Table 4.

Table 3 The measured values of traffic volumes and noise levels

Sites	Wet season, 2015						Dry season, 2016					
	Q_L (veh./h)	Q_H (veh./h)	L_{Aeq} (dB)	L_{10} (dB)	L_{90} (dB)	TNI (dB)	Q_L (veh./h)	Q_H (veh./h)	L_{Aeq} (dB)	L_{10} (dB)	L_{90} (dB)	TNI (dB)
S1	351	13	73.3	76.3	58.8	98.8	302	8	55.3	58.3	50.4	51.9
S2	9013	452	83.6	86.6	63.7	125.6	10,213	299	73.9	76.9	59.1	100.3
S3	8023	320	62.0	65.0	53.6	69.4	7042	227	62.4	65.4	53.8	70.4
S4	1300	310	74.4	77.4	59.4	101.6	1806	415	57.6	60.6	51.5	57.8
S5	4512	110	61.0	64.0	53.1	66.7	3534	216	54.3	57.3	50.0	49.4
S6	7502	504	75.7	78.7	59.9	104.9	6642	397	75.2	78.2	59.7	103.8
S7	8014	430	74.4	77.4	59.3	101.5	6231	361	59.5	62.5	52.4	62.7
Mean	5530.7	305.6	72.1	75.1	58.3	95.5	5110.0	274.7	62.6	65.6	53.8	70.9
SD	3515.60	182.74	7.99	7.99	3.73	20.78	3413.06	141.14	8.61	8.61	4.02	22.38
Min	351	13	61.0	64.0	53.1	66.7	302	8	54.3	57.3	50.0	49.4
Max	9013	504	83.6	86.6	63.7	125.6	10,213	415	75.2	78.2	59.7	103.8

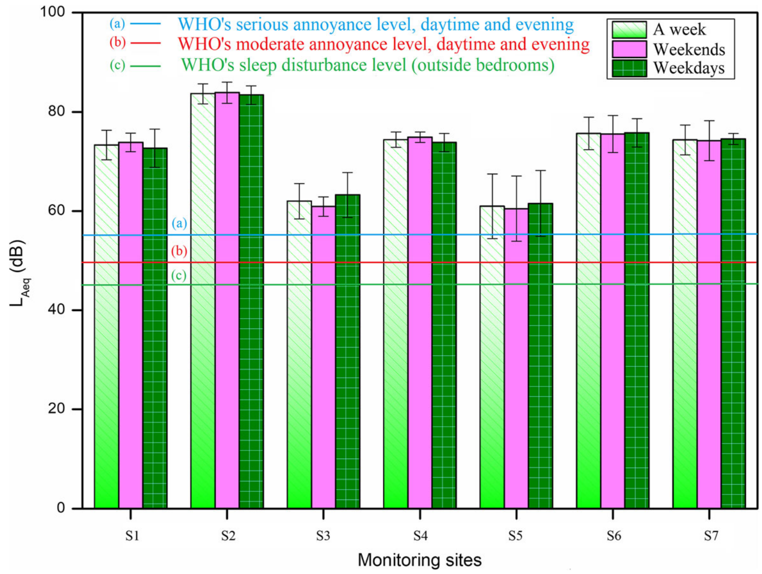

Fig. 2 Variation of road traffic noise in 2015

The results showed the high vehicle density areas and the places in the city center such as sites S2 and S6, where the highest TNI values were recorded at 125.6 dB and 104.9 dB (in wet season, 2015) and 100.3 dB and 103.8 dB (in dry season, 2016), respectively. The results showed that automobiles and public traffic systems were the major sources of noise pollution in the studied area. This is similar to the findings studied in Delhi published by the authors such as Singh and Davar (2004), Pathak et al. (2008), and Foraster (2013).

3.2.2 Variation of Road Traffic Noise During Weekdays and Weekends

The overall average measured values for L_{Aeq}, L_{10}, L_{90}, and TNI are shown in Table 5. The average values of L_{10} and L_{90} were recorded at 70.3 ± 9.44 and 56.0 ± 4.41 dB in weekdays and 70.4 ± 9.34 and 57.5 ± 4.36 dB in weekends, respectively. The maximum values of L_{Aeq} were recorded at site S2 with 83.4 dB in weekdays and 83.9 dB in weekends. The study of Zia et al. (2017)

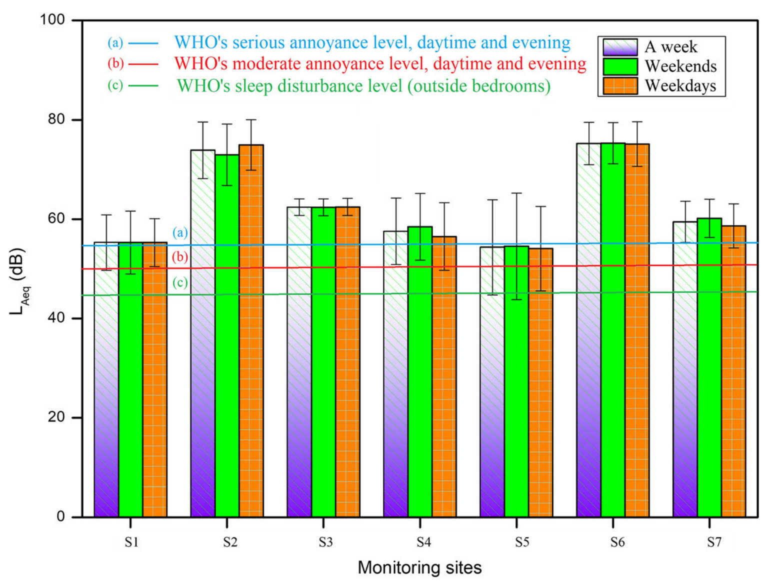

Fig. 3 Variation of road traffic noise in 2016

Table 4 Comparison of traffic noise index for the monitoring periods

Paired t-test	Traffic noise index (dB)			
	TNI_{2015}	TNI_{2016}	t	Sig.
Pair 1	98.8	51.9	9.701	<0.001
Pair 2	125.6	100.3	3.196	<0.001
Pair 3	69.4	70.4	3.375	<0.001
Pair 4	101.6	57.8	9.070	<0.001
Pair 5	66.7	49.4	6.301	<0.001
Pair 6	104.9	103.8	4.393	<0.001
Pair 7	101.5	62.7	7.035	<0.001

showed that the maximum noise at traffic area in Faisalabad, Pakistan was 107.2 dB. It was higher than that in HCMC. Table 5 also represents the noise levels at seven different locations where they were recorded during different periods (wet and dry seasons) of 2 years. In addition, the variation of road traffic noise (L_{Aeq}) during weekdays and weekends at the monitoring sites is also shown in Figs. 2 and 3.

According to the study of Skanberg and Ohrstrom (2002), the traffic is a main reason and dominating source of noise in urban areas. Road traffic noise sources include all vehicles in roads and streets of a city such as cars, trucks, busses, motorcycles, etc. These are the important source of community noise specially areas with high traffic volume (Marathe, 2012). Noise pollution is recognized as a major environmental issue and risk factor leading to the effects on human health (Liu et al., 2021; Marius et al., 2005; Singh et al., 2018). Furthermore, authors such as Gokdag (2012) and Zuo et al. (2014) have found that traffic vehicle weight and volume are important causes affecting the traffic noise status. The results obtained from this investigation showed that the sites S2, S3, S6, and S7 have high traffic density in the weekdays as shown in Table 5. The maximum contribution of vehicles was counted at about 12,301 light vehicles per hour (site S2) and 537 heavy vehicles per hour (site S6). Thus, city center is considered as the place with high noise pollution. The mean values of Q_L and Q_H calculated in the weekends were 4763.1 ± 3317.81 and 216.4 ± 128.10 (veh./h),

Table 5 Variation of average values for traffic volumes and noise levels in weekdays and weekends

Year	Sites	Weekdays						Weekends					
		Q_L (veh./h)	Q_H (veh./h)	L_{Aeq} (dB)	L_{10} (dB)	L_{90} (dB)	TNI (dB)	Q_L (veh./h)	Q_H (veh./h)	L_{Aeq} (dB)	L_{10} (dB)	L_{90} (dB)	TNI (dB)
2015	S1	241	11	72.7	75.7	58.6	97.2	210	10	73.9	76.9	60.5	96.0
	S2	12,301	390	83.4	86.4	63.5	124.9	10,032	395	83.9	86.9	65.2	122.0
	S3	9121	507	63.3	66.3	54.1	72.6	8213	352	60.9	63.9	54.4	62.3
	S4	1913	419	73.8	76.8	59.1	100.1	1325	347	74.9	77.9	61.0	98.7
	S5	6031	269	61.5	64.5	53.3	68.1	5506	107	60.5	63.5	54.3	61.2
	S6	8042	537	75.8	78.8	60.0	105.3	7524	407	75.6	78.6	61.3	100.4
	S7	7301	401	74.6	77.6	59.4	102.1	6074	236	74.2	77.2	60.7	96.8
2016	S1	305	16	55.3	58.3	50.4	51.9	292	13	55.3	58.3	51.8	47.7
	S2	11,023	385	75.0	78.0	59.6	103.0	9209	202	73.0	76.0	60.1	93.7
	S3	7913	229	62.5	65.5	53.8	70.6	5041	124	62.4	65.4	55.1	66.1
	S4	1545	298	56.5	59.5	51.0	55.1	1201	219	58.5	61.5	53.3	56.0
	S5	5028	291	54.1	57.1	49.9	48.7	3136	214	54.6	57.6	51.5	45.8
	S6	7608	454	75.1	78.1	59.7	103.5	6140	247	75.3	78.3	61.2	99.8
	S7	8470	373	58.7	61.7	52.0	60.6	2781	156	60.2	63.2	54.1	60.3
Mean		6203.0	327.1	67.3	70.3	56.0	83.1	4763.1	216.4	67.4	70.4	57.5	79.1
SD		3876.96	158.77	9.44	9.44	4.41	24.54	3317.81	128.10	9.34	9.34	4.36	24.28
Min		241	11	54.1	57.1	49.9	48.7	210	10	54.6	57.6	51.5	45.8
Max		12,301	537	83.4	86.4	63.5	124.9	10,032	407	83.9	86.9	65.2	122.0

Table 6 Comparison of TNI for the weekdays and weekends

Paired t-test	2015				2016			
	$TNI_{weekday}$	$TNI_{weekend}$	t	Sig.	$TNI_{weekday}$	$TNI_{weekend}$	t	Sig.
Pair 1	97.2	96.0	4.197	<0.001	51.9	47.7	2.679	0.013
Pair 2	124.9	122.0	1.017	0.316	103.0	93.7	3.695	<0.001
Pair 3	72.6	62.3	5.893	<0.001	70.6	66.1	0.362	0.721
Pair 4	100.1	98.7	11.629	<0.001	55.1	56.0	−4.571	<0.001
Pair 5	68.1	61.2	1.647	0.112	48.7	45.8	1.923	0.064
Pair 6	105.3	100.4	4.418	<0.001	103.5	99.8	2.669	0.011
Pair 7	102.1	96.8	2.354	0.024	60.6	60.3	5.177	<0.001

respectively. Other hourly traffic volume data corresponding to all sampling sites are also shown in Table 5. These results can be used to determine the noise levels in HCMC as well as suggesting solutions for minimizing the noise pollution in the studied area.

The comparison of noise levels in the study of Malakootian et al. (2012) indicated that there was a significant difference between holiday and workday. Meanwhile, road traffic noise is one of the important environmental issues which can affect the human health in urban areas (Iungman et al., 2021; Monazzam et al., 2014; Paiva et al., 2019; Pirrera et al., 2010). Traffic noise pollution is related to engine noise and can be due to the road surface quality (King et al., 2009). The average traffic noise index (TNI) at different locations for the weekdays and weekends is shown in Table 5. In the weekends, the TNI values at 7 different locations were in the range from 45.8 to 122.0 dB. TNI levels of the weekdays varied from 48.7 to 124.9 dB. The maximum values of TNI were recorded at site S2 with 124.9 dB in weekdays and 122.0 dB in weekends. The average TNI values of noise level pollution were 83.1 ± 24.54 dB and 79.1 ± 24.28 dB which were recorded in the weekdays and weekends, respectively. This research also showed noise pollution status at different sites in an urban area of HCMC. The results showed almost of the TNI_{2015} and TNI_{2016} values in the weekdays tended to be greater than those during weekends ($p < 0.05$) as shown in Table 6. However, there was no existence of the statistically significant difference ($p > 0.05$) between weekends and weekdays at sites S2 and S5 in 2015 and sites S3 and S5 in 2016, respectively. Concerning those differences at sites S1, S3, S4, S6, and S7 (2015) and at sites S1, S2, S4, S6, and S7 (2016), it could be explained that because the reduction of the number of passing vehicles in the monitoring locations in the weekends (Saturday and Sunday) compared with weekdays (Monday to Friday), leading to lesser noise levels. In these weekends, the local community trend is used to staying at home instead of going out for the job; this leads to the decrease in the vehicle flow on the streets.

Table 7 Pearson's correlation between traffic noise index and environmental factors

	Q_{RT}	L_{Aeq}	TNI	Temp.	Wind
Q_{RT}	1	0.861(**)	0.889(**)	0.543	0.670
L_{Aeq}	0.861(**)	1	0.976(**)	−0.613(*)	0.439(*)
TNI	0.889(**)	0.976(**)	1	−0.513	0.392(*)
Temp	0.543	−0.613(*)	−0.513	1	0.478
Wind	0.670	0.439(*)	0.392(*)	0.478	1

**Correlation is significant at the 0.01 level

*Correlation is significant at the 0.05 level

Table 8 Linear regression models of the effects of environmental factors on TNI

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std. error	Beta (β)		
Constant	108.469	15.836		6.849	0.000
Q_{RT}	3.94E−05	0.001	0.341	2.328	0.023
Temp.	−0.695	0.446	−0.197	−1.558	0.124
Wind	0.747	0.863	0.190	2.304	0.025
	$R = 0.591$, $R^2 = 0.349$, $F = 5.307$, Sig. < 0.001				

3.3 Effects of Environmental Factors on Traffic Noise Index

To understand the relationship between noise levels and environmental factors, correlation analysis was conducted for all measured samples during the measurement periods. The investigation of this kind of relationship was also conducted in the previous study by Ayansina and Ebunoluwa (1988). The results from previous studies showed the correlations between noise characteristics and traffic volume (Davies et al., 2009; Jeon et al., 2018; Weber & Litschke, 2008). Otherwise, another study showed weak correlations between number of vehicles and noise levels (Seyed & Parvin, 2015).

Table 7 shows that there were high positive correlations between road traffic volumes (Q_{RT}) to L_{Aeq} and TNI with correlation coefficients of 0.86 (with L_{Aeq}) and 0.89 (with TNI), respectively ($p < 0.01$). It means that the vehicular traffic was the significant contributor to the noise pollution in the studied areas. The exposure to road traffic noise, furthermore, was significantly related to risk for the human health. These results revealed that meteorological conditions such as wind speeds had significantly effects on noise level. This result is quite similar to the results published by Nicolas et al. (2009).

In this research, monitored data analysis was carried out to estimate noise effects and linear regression model was used to calculate the path coefficients. The linear regression model about the effects of environmental factors on TNI showed an important impact of Q_{RT} and wind speeds with standardized coefficients ( ) of 0.341 and 0.190 ($p < 0.05$), respectively (Table 8). The regression model illustrated the existence of a positive relationship between TNI and wind velocity. This research demonstrated the overall road traffic noise of a highly urbanized area which might be indicative of poor environmental quality. The relationship is completely similar to the results studied by Kim et al. (2012). This will provide the opportunity to examine different aspects of traffic noise pollution. Thus, based on the conducted research of the correlation between noise and environmental factors, it could reveal the potential of predicting noise levels for similar areas.

4 Conclusions

From the sample measurements at the different typical sites in HCMC which were conducted during the periods of wet season 2015 and dry season 2016 in HCMC, some conclusions have been drawn as follows:

> The average L_{Aeq} values in 2015 and 2016 were 72.1 ± 7.99 dB and 62.6 ± 8.61 dB, respectively. These values exceeded the WHO's suggested values for the human health protection and those stipulated in Vietnam National Technical Regulation on Noise (VMONRE, 2010). It means that in general, the studied area and HCMC were polluted with road traffic noise. The maximum value of L_{Aeq} and TNI was registered at the same site S2 which represents the urban area of HCMC with high vehicle density. It showed that the public had to face and suffer from the road noise pollution. The weekdays statistical noise levels $TNI_{2015–2016}$ throughout the studied area had an average of 83.1 ± 24.54 dB and ranged between 48.7 and 124.9 dB. The weekends statistical noise levels $TNI_{2015–2016}$ had an average of 79.1 ± 24.28 dB with the minimum and maximum values of 45.8 and 122.0 dB, respectively.

Paired samples t-test indicated that there was a statistically significant difference between the measured TNI and noise levels among the monitoring sites and time ($p < 0.05$). The results also indicated that there was a significant difference in TNI between weekends and weekdays ($p < 0.05$) in almost of monitoring sites. Noise levels were found to be high, which was due to the main roads running through the city from urban to suburban areas. Furthermore, the road traffic volume (Q_{RT}) was highly positive correlated to L_{Aeq} and TNI ($p < 0.01$). It means that the road traffic volumes affected the noise levels significantly. These indices would be more useful to further examine the effects of noise pollution on the public health as well as considering the overall noise pollution status of HCMC and contributing to the sustainable urban planning as well. Based on the results of this study, intensive researches should be done to further examine road conditions and traffic management influencing the traffic noise level. In addition, more sampling sites within HCMC should be chosen to investigate the existing status of road traffic noise level in aiming to give the overall picture of the city's road traffic noise pollution for the urban air environment management, contributing to the public health protection.

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Declarations

Conflict of Interest The authors declare no competing interests.

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