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Influence of vehicular traffic on environmental noise spectrum in the tourist route of Santa Marta City

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Abstract

Transportation demands large amounts of fuel. In particular, road transport greatly contributes to both criteria air pollutants and noise within cities. The influence of vehicular traffic on the environmental noise spectrum (as an indirect indicator of energy emission) was measured and assessed in the tourist route of Santa Marta along a 12-km road segment where five points were selected (three in the peripheral urban and two in the suburban areas). The number and type of vehicles as well as the noise levels were recorded at thirds of octave twice per day during two different weekdays. The traffic flow was composed of automobiles, with higher values in the peripheral urban area. According to the ANOVA, the noise spectrum indicated that low frequencies both had more energy than those with high frequencies and were influenced by the time of day. Low frequencies were influenced by all type of vehicles during the day, while high frequencies at both day and night, except for trucks (which were influenced in all spectrum). The results agreed with both the high velocities reached and the vehicle distribution.

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Keywords: Acoustic pollution; Freeway; Traffic flow dynamics; Urban air quality

1. Introduction

Transportation sector is the main fuel consumer in the world. Likewise, road transport is responsible for 85% of the average global energy [1], which makes it both the second sector responsible for hazardous gas emission worldwide [2] and the main source of noise within cities. All this contributes to approximately 80% of the total environmental noise [3,4]. Noise is considered a form of energy [5] that can be estimated by acoustic spectrum analysis [6,7]. Despite this, most studies have typically focused on vehicular emission by combustion processes [2] and not on this aspect (energy) of noise.

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In 2003, it was estimated that approximately 56 million people are exposed to high levels of noise [8], which has received great concern as noise acts as a stress factor that disturbs the body and affects both physiological and psychological health. In Colombia, noise levels exceed 75 dBA. Some studies have both found that the main source of noise is road traffic [9] and reported that high levels of noise are not related to high levels of road traffic. Instead they are more correlated with certain categories of vehicles [10–13]. Tourism is one of the main economic activities of Santa Marta City. There is a large number of hotels and neighborhoods close to the touristic road called Ruta del Sol. This highway is vital for the city's mobility and also used for the transportation of goods and supplies, which causes a high vehicle traffic flow. The route then may be associated with the increasing environmental noise. Therefore, the aim of this study is to determine the influence of vehicular traffic (as an indirect indicator of energy emission) on the environmental noise spectrum in the tourist route of Santa Marta.

2. Materials and methods

The Ruta del Sol Highway, in southern Santa Marta City, was taken as the study area, which consisted of a 12-km section from 0+000 km of the alternate route (where is diverted the flow of heavy vehicles) Ye de Gaira to Santa Marta City. The highway was designed to allow vehicles to reach speeds between 80 and 100 km/h, with two roads and two lines per road, and one 4-m road separator [14]. The five sampling points selected were distributed along the route with an approximate linear spacing of 2 km (Fig. 1 upper). Points 1, 2, and 3 were the closest to the urban area of Santa Marta, and were surrounded by the most populated neighborhoods of the eight communities. Points 4 and 5 were located far from the city, in the suburban area with a low population density. Point 5 was located close to the bifurcation of the alternate route, where heavy vehicle flows are diverted.

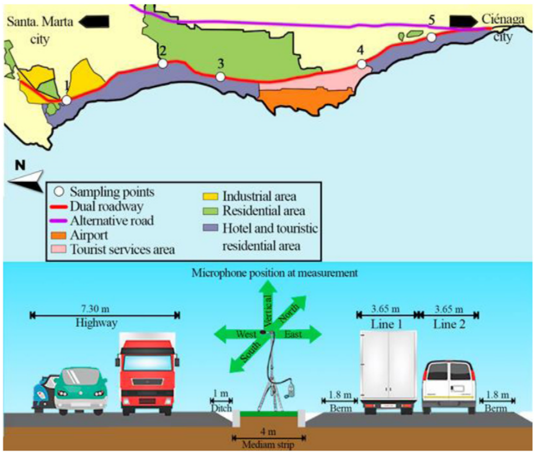

Fig. 1. Study area (upper) and scheme of a transverse section at a sampling point (lower).

Traffic flow was categorized by the number and type of vehicles, namely autobuses, automobiles, motorcycles, and trucks. The traffic flow was estimated at each point during a 70-min lapse that began 5 min before and ended 5 min after the 60-min environmental noise measurement period. The flow was assessed during two periods of the day, in the day and night, and on two different days of the week, during business and non-business days. Sixteen (16) records were taken per point: (a) eight on business days (Monday to Friday) and (b) eight on non-business days (Saturday, Sunday, and holiday). The records included six samples during the day and two samples during the night.

Environmental noise was measured according to Annex 3, Chapter II of Resolution 627 of 2006 of Colombia, which is equivalent to the ISO 1996 standard guide [15]. Five records of five-minute measurements were taken. The records were distributed uniformly throughout one hour per sample. The microphone of the sound level meter was oriented towards a different direction for each of these records, facing north, south, east, west, and vertical (upward). Measurements were also taken on the road divider/separator at an altitude of 4 m above the road surface. The noise was recorded using a Type-I Casella sound meter (model CEL-633-C1K1) programmed to record data every 100 ms (fast mode), using the Z-weighting filter frequency (Fig. 1 lower).

An analysis of variance (ANOVA) test was conducted (with an $\alpha = 0.05$) in order to determine the possible differences between noise levels and the flow of vehicles [16]. Similarly, a hierarchical ANOVA (with $\alpha = 0.05$) was conducted to determine the factors (points, time of the day and day of the week) that exhibited the greatest influence on the environmental noise level [17–19]. Finally, a Spearman-Rho correlation test was performed between the types of vehicles and frequencies of spectrum depending on the time of the day.

3. Results

The vehicle fleet was composed of 57% automobiles, 24% motorcycles, 14% buses, and 5% trucks. Automobiles and motorcycles exhibited a greater variation between points (Fig. 2). The number of automobiles was higher (65.9%) during the day and night. This was similar for the other types of vehicles, but with smaller differences. Daytime flow accounted for 61.9% of the total for both day and night. There was greater variation in the vehicles flowing through the sample points at night (Fig. 2).

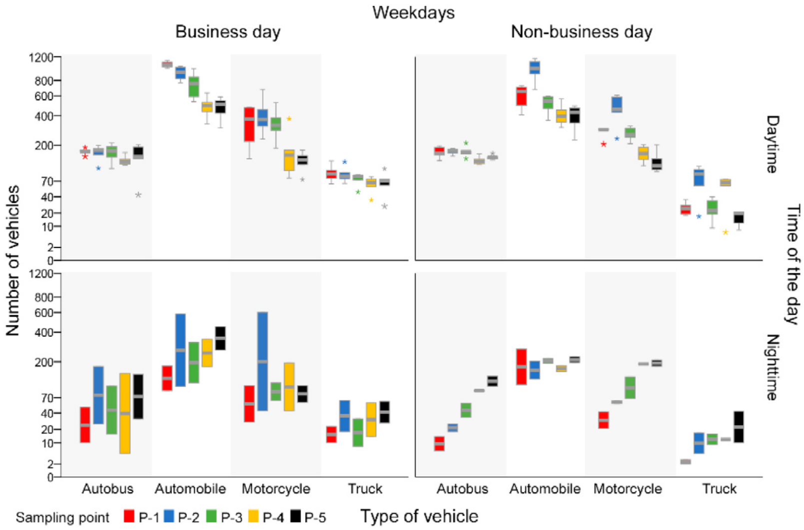

Fig. 2. Quantity of vehicle types recorded per day of the week, time of day and sampling point.

Fig. 3 shows the result of the noise spectrum levels measured at the points by the time of the day and day of the week. The results show similar values for all points, with higher values during the day than those at night. Likewise, the levels were greater on business days with greater variability between the different records. The low frequencies show the highest values of noise following by medium and high frequencies.

The traffic flow ANOVA test showed that the time of the day and the points influenced the variation in vehicle quantities. However, when the ANOVA considered the types of vehicles, the day of the week influenced variance in all categories. The environmental spectrum noise ANOVA test showed that there was no significant difference between days of the week. However, there was significant difference between the points at low and medium frequencies, as well as by time of the day in all octave bands (Table 1). The analysis of the influence of the time of day on noise spectrum between points evidenced that there was a few frequencies that show a significant difference between them (Table 1). In Table 1, it can be observed the significant difference in the noise level between the day (low difference between the points) and night (high difference between the points), confirming high variation in the latter period. The low influence and variability between the days of the week can be verified if the results of the ANOVA are nested. The point>day of the day nesting showed some significant differences (Table 1).

The Spearman-Rho correlation was established according to the ANOVA results, so the time of day (day and night) and type of vehicle were used as design variables in the test (the results showed that during the day). The results indicated that in the daytime the low and high frequencies exhibited correlation within all categories; while trucks have a correlation with all frequencies. In the case of nighttime, trucks are the only category that did not have a correlation with the medium and low frequencies (Fig. 4).

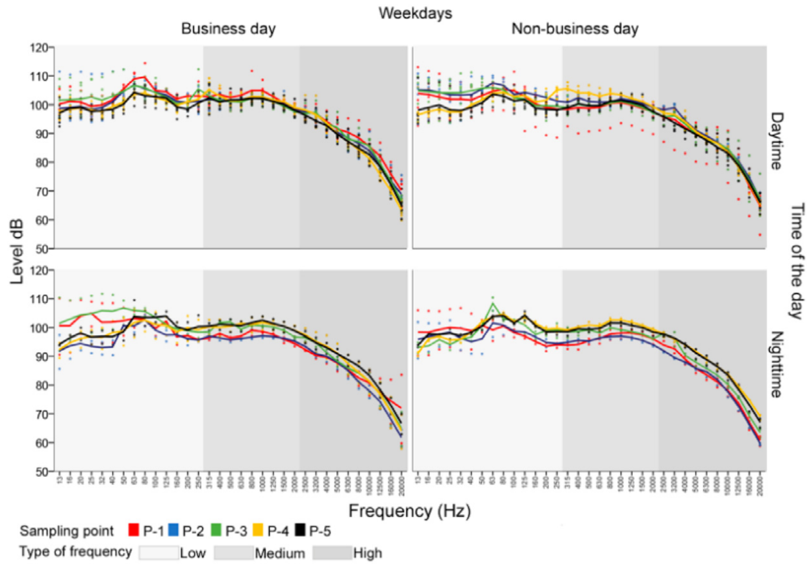

Fig. 3. Noise Levels by frequency of the environmental noise spectrum on each day of the week, time of day, and sampling point.

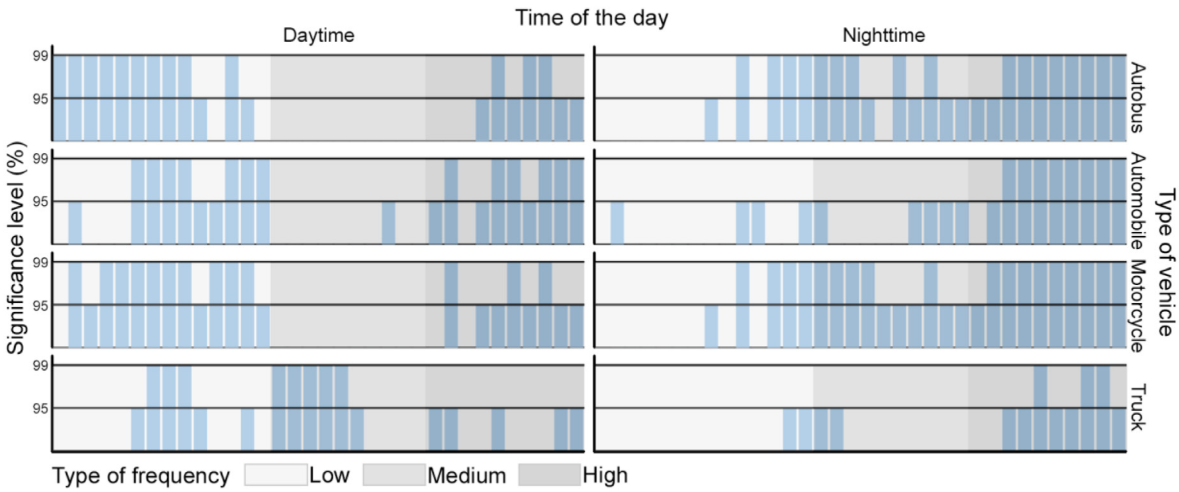

Fig. 4. Results of Spearman-Rho test and their significance between frequencies and vehicles types for each time of the day.

4. Discussion

The values recorded at points 1, 2, and 3 greatly differed from those recorded at the other points as they were located close to the urban area, where commercial and tourist activities are developed. Ramis et al. [20], who conducted a study in Motilla de Palancar (Spain), also observed high traffic flow in areas close to the urban area, which decreased towards the urban boundary. Additionally, the traffic flow was similar on highways with the same numbers of lanes, with an average number of vehicles ranging between 700 and 1145 per hour [21]; as well as the national scale with a minimum of 725 vehicles/hour and maximum of 973 vehicles/hour [22]. The traffic flow mostly contained automobiles, which is in accordance with Paviotti and Vogiatzis [21], who found that 57.1% of traffic constituted of automobiles. Findings similar to the ones of this study were observed in the traffic of a road with four lanes in Bogotá that was composed of 70.2% automobiles, 13.1% motorcycles, 16.1% buses, and 0.6% trucks [12].

Table 1. P-value of ANOVA one-way and hierarchical tests by factor of design and different nested.

		One-way*			Hierarchical*[1]			
	Frequency [Hz]	Point (PT)	Weekday (WD)	Time of the day (ToD)	PT WD<	PT ToD<	WD ToD<	PT WD< ToD<<
Low	12.5	0.041	0.720	0.001	0.558	0.809	0.160	0.772
	16	0.228	0.700	0.006	0.475	0.767	0.228	0.468
	20	0.127	0.957	0.038	0.422	0.664	0.124	0.542
	25	0.050	0.893	0.136	0.165	0.418	0.112	0.368
	32	0.031	0.977	0.066	0.396	0.458	0.130	0.405
	40	0.047	0.784	0.009	0.473	0.208	0.193	0.429
	50	0.005	0.457	0.002	0.236	0.123	0.308	0.215
	63	0.045	0.717	0.002	0.163	0.009	0.412	0.973
	80	0.715	0.284	0.003	0.372	0.035	0.968	0.759
	100	0.633	0.298	0.002	0.850	0.017	0.999	0.985
	125	0.283	0.819	0.005	0.089	0.002	0.900	0.781
	160	0.575	0.922	0.001	0.318	0.003	0.782	0.783
	200	0.213	0.191	0.000	0.332	0.010	0.647	0.904
	250	0.017	0.099	0.000	0.261	0.097	0.439	0.326
Medium	315	0.003	0.010	0.000	0.754	0.219	0.513	0.761
	400	0.010	0.024	0.000	0.113	0.008	0.489	0.969
	500	0.000	0.066	0.000	0.140	0.002	0.978	0.662
	630	0.007	0.054	0.000	0.531	0.028	0.547	0.589
	800	0.005	0.152	0.000	0.236	0.028	0.232	0.933
	1000	0.001	0.117	0.000	0.315	0.002	0.493	0.620
	1250	0.002	0.261	0.000	0.642	0.005	0.656	0.538
	1500	0.002	0.471	0.001	0.978	0.018	0.704	0.608
	2000	0.005	0.695	0.006	0.985	0.016	0.851	0.617
High	2500	0.029	0.758	0.030	0.996	0.003	0.290	0.605
	3200	0.115	0.690	0.001	1.000	0.002	0.358	0.479
	4000	0.099	0.546	0.006	0.936	0.034	0.937	0.757
	5000	0.266	0.356	0.023	0.795	0.032	0.860	0.882
	6300	0.574	0.829	0.011	0.659	0.022	0.921	0.997
	8000	0.658	0.923	0.002	0.649	0.013	0.996	1.000
	10000	0.598	0.902	0.001	0.671	0.043	0.752	0.998
	12500	0.719	0.667	0.004	0.395	0.062	0.607	0.989
	16000	0.725	0.423	0.028	0.091	0.089	0.472	0.934
	20000	0.675	0.233	0.174	0.024	0.071	0.590	0.802

*If the P-value is less than or equal to 0.005, there is a statistically significant difference at 95% among the means of the frequency of the different levels of the analyzed parameter (grey cells). [1]The nested order is shown on the row name.

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The results also showed that the traffic flow increases from nighttime to daytime (61.9%). Automobiles constituted the largest proportion of traffic (65.9%), followed by trucks (62.3%). These values are greater than those observed in Belgrade (Serbia), with general values of 52.3%, 58.3% for automobiles, and 51.9% for trucks [23]. The differences in traffic flow at different times of the day could be attributed to the working period of the day (mainly daytime), when the numbers of automobiles and buses increases due to their high demand. The variation between business and non-business days exhibited a decrease in all categories on non-business days, except at point 5 for trucks. This result is in accordance to what was found in New York (U.S.) by Ross et al. [24], where the number of trucks significantly decreased on non-business days. While the number of automobiles and buses increased.

The noise level for each frequencies agreed with other studies [7,25,26], with large values on low frequencies followed by medium and high frequencies. On the other hand, the large values observed at the suburban area, when compared to the peripheral urban area in the high frequencies, may be explained by the presence of rolling velocities. Other studies had shown an increasing noise emission levels with the increase of rolling velocities. In fact, this increase can be greater in the high frequencies [7,25,27,28]. Despite of that, the high values seen in the low frequencies evidence their potential to deteriorate urban soundscape by low frequencies due to road traffic flow [29,30].

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As to the results of the correlations, it can be observed that, at daytime, the high and low frequencies showed a relationship with all types of vehicles. However, at nighttime, the relationship tended to be in the middle and high frequencies. This is due to the fact that, at nighttime, the speed could have increased by the absence of traffic because of the partial or total cessation of activities in the urban and suburban area, which generates a greater incidence of aerodynamic noise associated with high frequencies. This can also indicate higher gas emissions, since fuel consumption increases significantly at speeds greater than 90 km/h, using up to 25% more than cruising speeds [31]. During daytime, the behavior is the opposite. Lower rolling velocities were registered, which made possible to perceive more the rolling noise (low frequencies) than the aerodynamic noise (high frequencies). Finally, the lowest correlation of trucks with high frequencies with respect to the rest, which could be attributed to the fact that trucks release six times the amount of sound energy produced by other type of vehicle [32]. Therefore, trucks tended to exhibit a greater influence on the mechanics and rolling energy emission associated with low frequencies. This can also be similar to autobuses, which are typically lighter than trucks. However, a high quantity of vehicles can produce a comparable amount of noise to that of one truck, as the ratios of noise produced by vehicles are 10:1 automobiles per truck and 4:1 per autobus [33].

5. Conclusions

The high traffic flow was mainly composed of automobiles, with low proportions of buses and trucks, and greater variation at the points close to the urban area and during the day. The mean noise level was similar throughout the week, but lower during the night. The noise and peak value were correlated with heavy vehicles, trucks and buses, and the high flow of automobiles. Finally, the results herein allow us to infer that the amount of energy released by the road traffic shown in the acoustic spectrum can be reduced if (i) the maximum speed is restricted and controlled, and (ii) the heavy vehicle diversion process is improved by an alternate way.

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