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Road traffic noise assessment in a hospital area in Umuarama - Brazil

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ABSTRACT

In hospital environments, high noise levels can result in damage to patients' treatments, delaying their rest and recovery. The sound pressure level (SPL) in hospital areas during the day must not exceed 50 dB and 45 dB (A) at night, according to NBR 10.151/2019. This research aimed to carry out environmental monitoring of equivalent sound pressure levels (L_{Aeq}) at fifteen points in the vicinity of three hospitals in the central region of the municipality of Umuarama-PR, during working days, at four different times, in the months of August, September and November 2018 and continued in March 2019. To this end, we sought to map the L_{Aeq} of the points, compare them with data from municipal and federal legislation and relate the L_{Aeq} to the volume of vehicular traffic. The collected SPL were higher than recommended by NBR 10.151 at all times and measurement points, during the week, and when considering the municipal regulations, only one point is in the equipment's accuracy limit. From the statistical analysis, a very strong correlation was observed between L_{Aeq} and the total volume of vehicles, and also a strong correlation between the descriptors L_{10} and L_{50} and the volume of vehicles. The *Traffic Noise Index* (TNI) was also calculated and the L_{Aeq} values were compared with a subjective noise rating. The results show a scenario of noise pollution in the area and there is a need for the application of mitigating measures.

Key words: noise pollution, environmental monitoring, hospital area.

1 INTRODUCTION

According to the World Health Organization (WHO), noise pollution is considered the third largest cause of pollution in the world, only behind chemical pollution of air and water (WHO, 2011).

The WHO also advises that sound pressure levels (SPL) above 65 dB already have negative effects on health, and that above that, the body suffers stress, which increases the risk of various other diseases, such as: irritability, low concentration, insomnia, headache and high blood pressure (WHO, 1999; ZANNIN, CALIXTO, DINIZ and FERREIRA, 2002; ZANNIN, ENGEL, FIEDLER and BUNN, 2013; ZANNIN and FERRAZ, 2016; ANDRADE et al., 2021; WHO, 2011; ÇOLAKKADIOĞLU et al., 2018; CEJA et al., 2015).

Ceja et al. (2015) states that of the noise sources in cities, motor vehicles are responsible for about 70% of them. Hospital areas, environments which are even more sensitive to noise pollution, are mainly affected by noise generated by vehicle traffic (ANDRADE et al., 2021), and are usually located in areas exposed to this noise source (MONTES-GONZÁLEZ et al., 2019; ZANNIN and FERRAZ, 2016).

WHO recommends that noise levels do not exceed 35 dB (A) in rooms where patients are being treated or observed and 30 dB (A) in rooms where they are hospitalized (CUNHA and SILVA, 2015). In Brazil, NBR 10.151/2019 recommends that SPL around hospitals should not exceed 50 dB (A) during the day and 45 dB (A) at night (ABNT, 2019).

Although there are several studies evaluating noise levels around hospitals (ZANNIN and FERRAZ, 2016; RAVINDRA et al., 2016; ZANNIN et al., 2019; ANDRADE et al., 2021; ZANNIN, MILANÊS and DE OLIVEIRA FILHO , 2019), comparisons of sound levels with mitigating measures are generally restricted to simulations in acoustic software, as the scenario around hospitals is dynamic, such as the number of light and heavy vehicles in circulation, which are characteristics of the area, among others (ANDRADE et al., 2021), therefore, studying the areas surrounding hospitals becomes increasingly important.

The city of Umuarama, located in the northwest of the state of Paraná, with a population of 100,676 inhabitants, has a large fleet of 79,133 vehicles (IBGE, 2016). The city stands out among neighboring municipalities, as it has 04 large hospitals that serve the Unified

Health System (SUS). In various parts of the city, areas of conflict between land use and permitted sound pressure levels are detected. As in other cities, the buildings that house hospitals are found in noisy areas, permeated by collecting and arterial roads.

In hospital environments, high noise levels can result in damage to patients' treatments (CUNHA and SILVA, 2015), delaying their rest and recovery (ANDRADE et al., 2021). A calm and pleasant environment can benefit both the patient and the hospital staff in their work, as health professionals will show a reduction in fatigue and psychological stress, and patients will suffer less psychological and physiological damage and have a faster recovery (ZANNIN and FERRAZ , 2016; ANDRADE et al., 2021; MONTES-GONZÁLEZ, 2019).

2 OBJECTIVE

This study aimed to carry out the environmental monitoring of equivalent sound pressure levels (L_{Aeq}) in the vicinity of three hospitals in the municipality of Umuarama, the sound descriptors L_{10}, L_{50}, L_{90} and also the Traffic Noise Index (TNI) were calculated , and data correlated with current legislation.

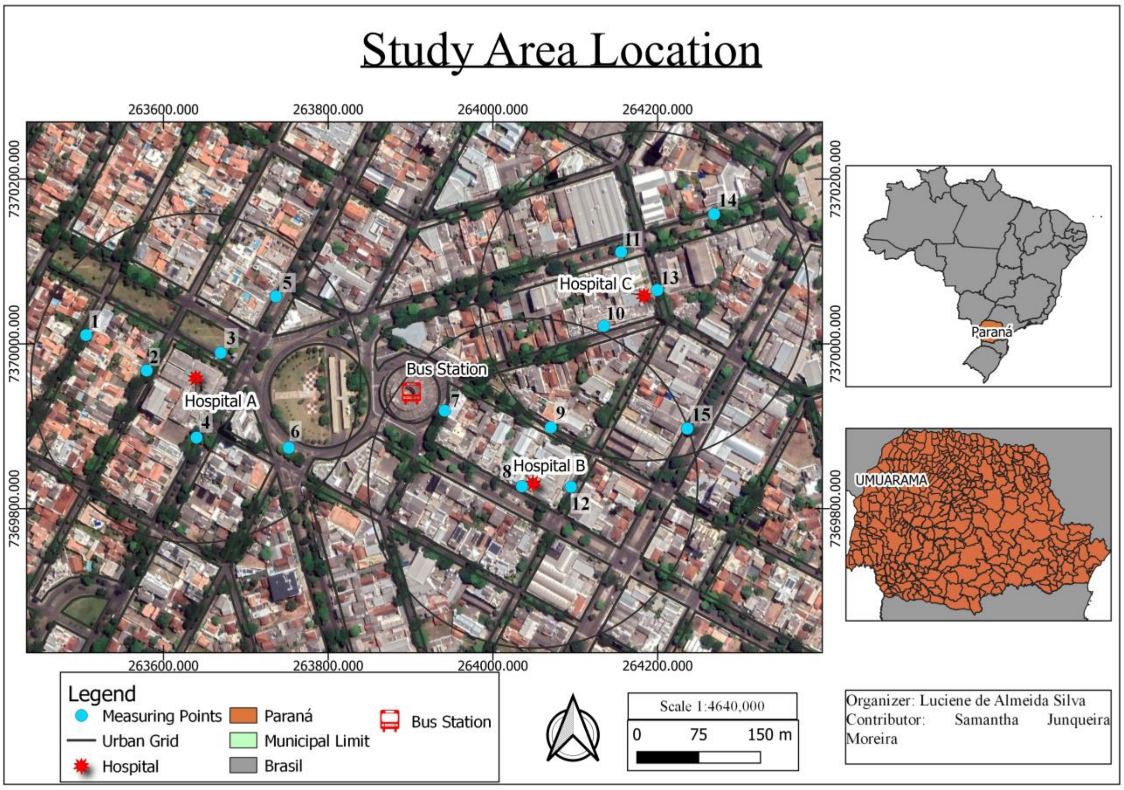
3 METHODOLOGY

For the environmental monitoring of the L_{Aeq}, areas around three hospitals were defined, considering a radius of 200 meters from them, as the Complementary Law No. 065 of Umuarama, establishes as a Sensitive Zone or Silence Zone the area within a radius of 200 meters within the environments of schools and hospitals (PMU, 1999). Fifteen data collection points were determined (Figure 1). The survey was conducted in August, September and November 2018 and continued in March 2019. The acoustic and vehicle count measurements were performed in triplicate, during working days, at four times: 7:00 to 9:00 a.m.; 11:30 a.m. to 1:30 p.m.; 5:00 to 7:00 p.m. and 9:00 to 11:00 p.m.

To perform the acoustic measurements, a sound level meter with data logger, model DEC-490, and an acoustic calibrator, model CAL-4000, both from the Instrutherm brand, with a calibration certificate, were used. For measurements, the sound level meter was configured in fast response mode (fast key) and programmed to record data every five seconds, on the "A" weighting curve, in a dynamic range from 30 to 130 dB. Sound measurements and equipment allocation followed the guidelines of NBR 10.151/2019.

Sound measurements were carried out for a period of five minutes at each point, and during this period the vehicles that passed in front of the sound meter were also counted.

Figure 1- Locations of measurement points around the study area.



Source: Prepared by the authors (2019).

After the measurements, the acoustic data were transferred to a computer, through the equipment's own software, and tabulated on an electronic spreadsheet to generate graphs and tables.

The equivalent sound pressure level (L_{Aeq}), for each point, is obtained by calculating the logarithmic mean of n measurements, according to the expression in equation (1) below (ABNT, 2019):

$$LAeq = 10\ log\ [\frac{1}{n}\sum_{i=1}^{n} n_i \times 10^{Li/10}] \quad (1)$$

Wherein:

n is the number of measurements;

n_i is the partial measurement;

Li is the sound pressure level, in dB (A), read in fast response (fast) every 5 s, during the noise measurement time, corresponding to measurement i.

To obtain a single L_{Aeq} value for the day shift, on weekdays, the arithmetic mean of the values obtained at the three measurement times was taken, while for the night shift, the arithmetic mean was taken between the three readings taken, to obtain the L_{Aeq}.

The obtained sound pressure levels were compared with the management instruments: NBR 10.151/2019 (ABNT, 2019) and with LC nº 065/1999 of the Municipality of Umuarama (PMU, 1999).

In addition to calculating the L_{Aeq}, the statistical descriptors L_{10}, L_{50} and L_{90} were also calculated using an electronic spreadsheet. The sound descriptors obtained in the day shift were compared with vehicle count data, through statistical correlation analysis.

The Traffic Noise Index (TNI) was also calculated (LANGDOM, 1968), to measure the degree of inconvenience generated by road traffic, given by the equation (2) below:

$$TNI = 4.(L10 - L90) + L90 - 30 \quad (2)$$

Wherein:
L_{10}: is the sound pressure level that was exceeded within 10% of the measurement time, in dB (A);
L_{90}: is the sound pressure level that was exceeded for 90% of the measurement time, in dB (A)

4 RESULTS AND DISCUSSION

The level of assessment criteria (LAC) for outdoor environments in NBR 10.151/2019 for Hospital Zones is 50 dB (A) in the day shift and 45 dB (A) at night (ABNT, 2019). The municipality of Umuarama, on the other hand, tolerates 55 dB (A) as a day limit, and the night limit is equal to NBR 10.151/2019 (PMU, 1999). According to Complementary Law nº 065/1999, daytime is considered the period from 7:00 a.m. to 8:00 p.m., and nighttime, from 8:00 p.m. to 7:00 a.m., and on Sundays and holidays the daytime starts at 9:00 a.m.

For measurements performed during the day, 100% of the points had L_{Aeq} values above 50 dB (A) (Table 1). When considering the limit of the municipal law of Umuarama (55 dB (A)), all points are still above this limit, with P1 being the only exception. The sound pressure levels for the analyzed points are between 5.30 and 13.75 dB (A) above the permitted level (PMU, 1999; ABNT, 2019). Points P4 (68.73 dB (A)), P11 (68.75 dB (A)) and P15 (68.17 dB (A)) are the highest values observed for the daytime period. As for the results for the night shift, all points are above the limit of 45 dB (A), as shown in Table 1 (ABNT, 2019; PMU, 1999).

When analyzing the number of vehicles, light vehicles predominate in the results, followed by motorcycles and heavy vehicles. The highest frequency of vehicles can be observed on arterial or collecting roads, for most of the measured points, unlike what occurs on local roads, where a smaller number of vehicles is observed (points 1 to 3; 7 to 9).

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Table 1-L_{Aeq} values and average vehicle count, in the day and night shift, by point.

Sensitive zone	Point	Work Day									
		Daytime					Nighttime				
		L_{Aeq} (dB)	Vehicle count				L_{Aeq} (dB)	Vehicle count			
			M	V.L.	V.P.	V.T.		M	V.L.	V.P.	V.T.
Hospital A	1	54,42	1	4	0	5	52,88	0	1	0	1
	2	61,75	5	8	0	13	52,25	0	1	0	1
	3	60,30	3	10	0	14	52,87	0	1	0	1
	4	68,73	24	58	2	84	62,61	6	17	0	24
	5	67,47	17	60	2	79	58,56	4	7	0	11
	6	67,19	20	51	6	78	61,81	6	11	0	18
Hospital B	7	65,27	7	11	2	20	58,94	1	2	1	4
	8	65,30	7	32	4	43	67,29	1	4	1	6
	9	63,79	4	8	0	12	58,32	1	2	0	3
	12	65,45	9	18	3	30	60,83	1	6	0	8
	15	68,17	29	64	3	96	63,37	7	15	0	22
Hospital C	10	61,99	7	13	1	20	55,07	0	3	0	3
	11	68,75	27	63	1	92	63,71	7	17	0	24
	13	64,16	10	20	1	31	60,09	2	6	0	8
	14	65,70	29	58	1	88	64,33	4	16	1	21
	15	68,17	29	64	3	96	63,37	7	15	0	22

To demonstrate the relationship between vehicular traffic and L_{Aeq} values, the mathematical linearization resource was used with the application of the logarithm of the number of vehicles, and as a result, the graphs in Figures: 2 a) and b); 3 a) and b); 4 a) and b) were obtained.

Figure 2- a) Dispersion and linear regression for the sound descriptors L_{10}, L_{50}, L_{90} and L_{Aeq} as a function of the logarithm of the total volume of vehicles, for the Silence Zone referring to Hospital A (points 1 to 6), in the day shift; b) data referring to the night shift

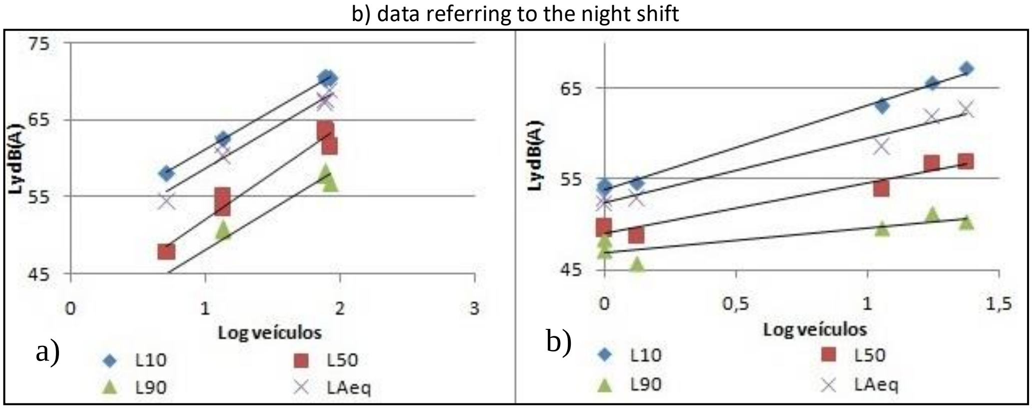

Figure 3- a) Dispersion and linear regression for the sound descriptors L_{10}, L_{50}, L_{90} and L_{Aeq} as a function of the logarithm of the total volume of vehicles, for the Silence Zone referring to Hospital B (points 7, 8, 9, 12 and 15), in the day shift; b) data referring to the night shift.

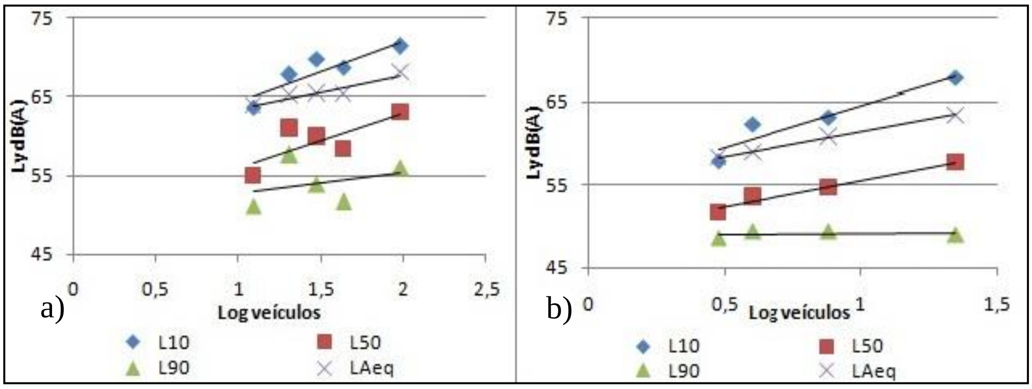

Figure 4- a) Dispersion and linear regression for the sound descriptors L10, L50, L90 and LAeq as a function of the logarithm of the total volume of vehicles, for the Silence Zone referring to Hospital C (points 10, 11, 13, 14 and 15), in the day shift; b) data referring to the night shift.

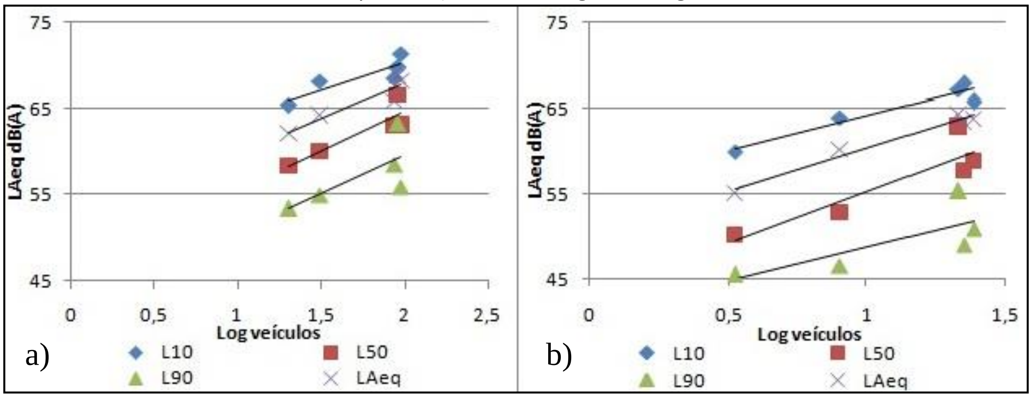

Table 2 shows all the equations obtained together with the calculations of their coefficients of determination (R^2), for each of the three Zones of Silence (ZS).

The use of the L_{Aeq} descriptor as a representative of environmental noise is recommended (ABNT, 2019), although the L_{10} statistical level is the most used for traffic noise studies (GERGES, 2000). The L_{10} is the descriptor that indicates the sound level that was exceeded in 10% of the measurement time (BRUEL & KJAR, 2000) and allows identifying the peak noise. The descriptor L_{90} is the level that was exceeded in 90% of the measurement time, being used as an identifier of the background noise sound level (TORIJA, RUIZ and RAMOS, 2007).

From the R^2 values obtained (Table 2), it is possible to verify that the L_{Aeq} equations found present values close to the maximum possible (1.00), being totally satisfactory for the description of the results.

The equations for calculating L_{Aeq} and L_{10} levels are more accurate than those for calculating L_{90}, which is already expected because the vehicle flow is not continuous and therefore the influence of other noise sources is greater in L_{90} than in L_{10} and L_{Aeq} (CALIXTO, PULSIDES and ZANNIN, 2008). As the study of environmental noise is not a fully controlled experiment, it suffers interference from several other sound sources, in addition to urban traffic noise, and therefore, the coefficients of determination may vary.

Table 2- Equations resulting from the linear regression tests for each Silence Zone studied and its respective coefficient of determination (R_2), for the day and night shifts, on weekdays.

	Day Shift		Night Shift	
Silence Zone	**Equation**	**R^2**	**Equation**	**R^2**
Hospital A	L_{10}= 10,29logVT + 50,78	**1,00(+)**	L_{10}= 9,31logVT + 53,88	**0,99(+)**
	L_{50}= 12,06logVT + 40,03	0,97	L_{50}= 5,47logVT + 49,07	0,95
	L_{90}= 10,70logVT + 37,45	0,96	L_{90}= 2,71logVT + 46,94	0,74
	L_{Aeq} = 10,38logVT + 48,27	0,96	L_{Aeq} = 7,16logVT + 52,29	0,98
Hospital B	L_{10}= 7,72logVT + 56,69	0,80	L_{10}= 9,903logVT + 54,59	0,90
	L_{50}= 6,92logVT + 49,06	0,58	L_{50}= 6,374logVT + 49,10	0,97
	L_{90}= 2,46logVT + 50,35	0,09	L_{90}= 0,222logVT + 48,90	0,05
	L_{Aeq} = 4,40logVT + 58,99	**0,88(+)**	L_{Aeq} = 5,867logVT + 55,50	**1,00(+)**
Hospital C	L_{10}= 6,258logVT + 57,78	0,76	L_{10}= 7,976logVT + 56,14	0,91
	L_{50}= 9,026logVT + 46,48	0,79	L_{50}= 12,02logVT + 43,25	0,81
	L_{90}= 8,795logVT + 41,90	0,52	L_{90}= 7,903logVT + 40,80	0,59
	L_{Aeq} = 8,226logVT + 51,45	**0,85(+)**	L_{Aeq} = 10,09logVT + 50,23	**0,97(+)**

Wherein: logVT = log of total vehicles (motorcycles, light vehicles and heavy vehicles);
(+) = highest correlation coefficient.

In places with a large flow of vehicles, vehicular traffic noise is the main cause for the environmental noise, results observed in the high coefficients of determination in Table 2. The values of R_2 found are very satisfactory in the correlations, possibly reducing the contribution of other aspects that could influence the research results, such as the width and slope of the road, height of buildings that border the roads, or even the reflective surfaces of facades.

The noise percentages L_{10} and L_{90} have a good correlation with the degree of annoyance (irritation) of people, who are exposed to traffic noise on a daily basis. The TNI serves to correlate the degree of discomfort (irritation) of people as a function of the variation in traffic noise, which depends on the flow and composition of vehicles, and the parameter is a subsidy for the planning of mitigating measures for noise control, as it allows to define the distance between the road and the adjacent buildings, in addition to analyzing the acoustic insulation on facades and the implementation of acoustic barriers (LANGDOM, 1968).

From the L_{Aeq} values, it is possible to present a subjective noise assessment. Locations can be considered less noisy when the L_{Aeq} is less than, or equal to 65 dB (A), noisy between 65 and 75 dB (A) and very noisy when it exceeds 75 dB (A) (BRESSANE et al., 2016).

Exceeded limits of 10 dB (A) can provoke complaints from the population, and above 15 dB (A) can cause more energetic responses, such as community actions (GERGES, 2000). Of the fifteen points analyzed in the three areas A, B and C, it is observed that in 7% of the points, the sound level was exceeded from 5 to 10 dB (A), in 53% of the points it was exceeded from 10 to 15 dB (A) and in 33% exceeded above 15 dB (A), which may indicate serious complaint problems (Table 3).

Table 3- Values of the sound descriptors L_{Aeq}, L_{10}, L_{50} and L_{90}, and the respective TNI, by point, by Silence Zone, and degree of inconvenience due to TNI.

Sensitive Zone	Point	Work Day								
		Daytime								
		L_{Aeq} (dB)	Subjective evaluation	Average SZ	L_{10} dB(A)	L_{50} dB(A)	L_{90} dB(A)	TNI dB(A)	Degree of Discomfort	Average SZ dB(A)
Hospital A	1	54,42	A little noisy	A little noisy	57,98	47,80	43,58	71,18	Average	73,90 Average
	2	61,75	A little noisy		62,64	53,49	50,60	68,78	Average	
	3	60,30	A little noisy		62,47	55,19	50,83	67,37	Average	
	4	68,73	Noisy		70,29	61,53	56,71	81,02	High	
	5	67,47	Noisy		70,58	63,44	57,79	78,94	High	
	6	67,19	Noisy		70,16	63,63	58,18	76,09	High	
Hospital B	7	65,27	Noisy	Noisy	67,77	60,99	57,60	68,27	Average	80,93 High
	8	65,30	Noisy		68,73	58,32	51,63	90,03	Very high	
	9	63,79	A little noisy		63,64	54,89	51,12	71,21	Average	
	12	65,45	Noisy		69,79	59,94	53,88	87,52	High	
	15	68,17	Noisy		71,37	63,04	55,94	87,63	High	
Hospital C	10	61,99	A little noisy	Noisy	65,29	58,24	53,39	70,99	Average	73,04 Average
	11	68,75	Noisy		69,90	66,54	63,23	59,90	Low	
	13	64,16	A little noisy		68,19	60,02	54,97	77,86	High	
	14	65,70	Noisy		68,53	62,99	58,43	68,83	Average	
	15	68,17	Noisy		71,37	63,04	55,94	87,63	High	

The TNI results obtained demonstrate that, for the same L_{Aeq} value, the TNI can express a greater degree of discomfort, as the calculation takes into account the values of L_{10} and L_{90}, and not L_{Aeq}, as also shown in Table 3.

The average degree of annoyance of each Silence Zone (SZ average) was calculated and shows for Hospital A the average SZ-A= 73.90 dB (A) which indicates an average degree of annoyance; for the Hospital B area with a mean SZ-B= 80.93 dB (A) and a high degree of discomfort; and finally for Hospital C with a mean SZ-C= 73.04 dB (A) and a medium degree of discomfort.

The influence of noise pollution on sleep and rest periods can influence hospital treatment processes (BRESSANE et al., 2016).

5 CONCLUSIONS

A noise pollution scenario was observed in the 03 silence zones studied. During daytime, in Silence Zone A, points P2, P3, P4, P5 and P6 were between 21 and 37% above the standards NBR 10.151/2019 and PMU/1999 (P1 within the limit). In Quiet Zone B, the values read were between 28 and 36% above this limit. And in Quiet Zone C, all values are also above the limit, between 24 and 37%. At night, all fifteen points do not comply with municipal and federal legislation.

Note that L_{Aeq} values are more intense on roads with greater vehicle traffic, and the correlation was demonstrated by relating L_{Aeq} to the log of total vehicles, with correlation values between 0.85 and 1.00 , which shows that the greater the number of vehicles circulating, the greater the sound pressure level. The category of vehicles does not exert much influence, but the total number of vehicles in circulation does.

The points that presented the highest levels of L_{10} and the lowest values of L_{90} were the ones that presented the highest Traffic Noise Index (TNI), and therefore, the highest degree of inconvenience. The average degree of annoyance is between medium to high for the surroundings of the three hospitals A, B and C.

WHO recommends that noise levels do not exceed 35 dB (A) in rooms where patients are being treated or observed, and 30 dB (A) in those where they are hospitalized. Periodic monitoring, in order to verify the level of acoustic insulation offered by their facades, and, when verifying levels above what is recommended, the hospital environments for hospitalization or treatments must be acoustically treated.

It is recommended to perform maintainanance of the traffic lanes and also revise the municipality's master plan to review distances between the lanes and hospitals, and/or health establishments, to be implemented in the future. We also recommend studies of new traffic routes, which mitigate the levels of noise, or implementation of acoustic barriers, to reduce the noise impact in the urban environment and acoustic treatment on the facades located on the roads. In addition, it is important to elucidate the population about the harmful effects of noise pollution, its causes, and the effects on human beings and the environment.

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