

**Objective and subjective evaluation of environmental noise in the  
Polytechnic Center Campus - UFPR**

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## ABSTRACT

Noise pollution affects quality of life, well-being, and is a public health problem. In educational environments, high noise levels affect the concentration and performance of students. The Polytechnic Center Campus of UFPR is affected by several sound sources and frequented by a large number of users, which points to the need for noise management. Faced with this problem, the present study objectively and subjectively evaluates the noise in the campus. The methodology consisted of measurements that followed the standards of NBR 10151/2019 at 20 points in the region; the elaboration of maps from the insertion of parameters of relief, traffic, and characteristics of buildings and roads, calibrated according to the data collected in the measurements; and questionnaires about noise nuisance in the campus, answered by 400 users of the site. Measurement results show that the limits established at national and municipal level were not respected in a large part of the area under study. Sound maps show the surroundings of the campus delimited by dark colors that indicate high levels of noise, and internal areas demarcated by colors that represent sound pressure levels above the allowed. Interviews indicate that 60% of respondents feel annoyed by noise in the campus, and 40% consider the level of environmental noise to be reasonable. The conclusion regarding noise pollution and the influence on performance points to the need for noise control measures in the area.

**KEYWORDS:** Noise measurements. Sound mapping. Sound perception.

## 1 INTRODUCTION

Noise pollution is an important public health problem that affects quality of life and well-being (NOISE IN EUROPE, 2014). According to the World Health Organization, noise ranks second among the factors of environmental risk to public health, second only to ultrafine particle air pollution (PM<sub>2.5</sub>) (WHO, 2011).

This problem is one of the main agents of loss of quality of life and environmental quality in a city. It is increasingly present in leisure activities and in moments of rest and work. However, its perception depends on the interrelationship between person, place, and activity in space and time (DAVIES et al., 2013).

Annoyance is one of the main effects of noise exposure on human health (WHO, 2011; OKOKON et al., 2015; HAMMERSEN et al., 2016), and an important indicator of noise sensitivity. The degree of sensitivity to noise is an intrinsic characteristic that allows the assessment of an individual's vulnerability to noise exposure. This vulnerability is influenced by negative emotional reactions generated by the difficulty of getting used to certain types of noise (OKOKON et al., 2015; FRYD; PEDERSEN, 2016).

Health effects caused by environmental noise can be auditory and nonauditory. The former correlate with noise-induced hearing loss, which can be caused by a single exposure to an intense impulse sound or by long-term exposure to high levels of sound pressure, for example, in industrial environments (BASNER et al, 2014). In turn, nonauditory effects refer to sleep disorders, high blood pressure, cardiovascular diseases, and negative emotions such as annoyance, anger, disappointment, and depression (MUNZEL et al., 2014; GERAVANDI et al., 2015; MUNZEL et al., 2018; RAJA et al., 2019).

In the context of educational environments, high noise levels affect behavior and understanding, thus influencing learning and work performance. University campuses are key elements of these environments because, in addition to all the educational issues involved, these places train and qualify future professionals (ÇOLAKKADIOĞLU, 2018).

In view of its Teaching, Research, and Extension activities, the Polytechnic Center Campus of the Federal University of Paraná is of great importance both for academics and professors, as well as for the community in general. The outer perimeter of the campus is

surrounded by two expressways with intense vehicular traffic. Internally, the site is marked by the circulation of motorcycles, cars, and buses on lanes that surround the campus buildings, by the renovation and construction of buildings close to classrooms and work stations, and by various maintenance activities, mainly gardening and waste collection services.

Given all these issues, the study and management of environmental noise in a university is extremely necessary. The combination of objective and subjective results provides a more comprehensive diagnosis of the soundscape under study, which helps in making management decisions to mitigate noise pollution impacts.

The present study characterizes environmental noise in the Polytechnic Center Campus of the Federal University of Paraná, Brazil, through measurements and sound mapping. Moreover, it assesses the perception of people who attend the campus in relation to noise and its effects on the activities performed.

## **2 METHODS**

The research is descriptive regarding its objective since it analyzes the characteristics of a phenomenon, namely the influence of urban noise and sound perception in a university environment. For collection and analysis methods, the study considers different procedures: acoustic measurements, acoustic mapping, and interviews with users in the study area.

The Polytechnic Center Campus houses 4 sectors of the Federal University of Paraná (Biological Sciences, Exact Sciences, Earth Sciences, and Technology). The campus is located in Jardim das Américas neighborhood and has two highways around it: Marginal Linha Verde (also known as the highway Régis Bittencourt - BR 116) and BR 277. The site houses 68 buildings and has an area of 588,156.44 m<sup>2</sup>, with 176,179.94 m<sup>2</sup> of built area (UFPR, 2016).

### **2.1 Sound measurements**

The methodological sequence suggested by Bunn (2013) served as the basis for the study of environmental noise in the study area: site survey; recognition of existing noise sources at the site; measurement of equivalent sound pressure levels ( $L_{eq}$ ); manual counting of vehicle flow; and analysis of results.

For data accuracy and standardization, the procedures described in NBR (Brazilian Standard) 10.151/2019 and the recommendations of the ISO (International Organization for Standardization) 1996 standards were followed. The B&K 2238 and B&K 2250 sound pressure level analyzers were used at 20 measuring points. These points were strategically located so as to cover the highways and avenues that surround the campus, the internal streets with the highest traffic volume, areas with greater circulation of students and employees, as well as places with different characteristics – considered less noisy. As recommended by NBR 10151, the analyzers were positioned at a minimum distance of 2 m from sound-reflective surfaces, such as walls and buildings, and at a height of 1.2 m from the ground. Measurements were taken on days with favorable weather conditions, without the presence of wind or rain.

For each point, the measurement interval was 15 minutes, period in which the necessary information for mapping was listed: number of vehicles according to category (motorcycles, light vehicles, buses, light trucks, and heavy trucks), type of pavement, and average road speed at each point. Sound measurements were carried out between August and November 2019, always during daytime class hours.

## **2.2 Acoustic mapping**

Acoustic mapping softwares are important impact assessment tools as they enable the calculation of sound levels from the insertion of topographical characteristics and traffic data of the study site. The maps were prepared using Predictor software version 8.13, which was fed with information on topography, buildings, and traffic.

Level lines were obtained from data from the Institute for Research and Urban Planning of Curitiba – IPPUC, and orthophoto charts were requested and made available by e-mail by the same agency. In addition to absorbing sound, buildings help in reflection and alter sound propagation in the medium. Therefore, buildings were manually digitized using orthophoto charts as a background and face-to-face observation, as well as the visualization of images available on Google Earth. The same method was adopted for vegetation.

Regarding traffic information, the following were observed and documented during measurements: traffic flow of each vehicle category per hour - obtained by the previous count carried out at the time of measurements (the value was multiplied by 4 since measurement time was 15 minutes); type of pavement; and average speed of each category of vehicles – taken as the maximum speed allowed for light vehicles and motorcycles, and as 10 km/h below the maximum speed allowed for the other two categories.

The grid of receiving points was 10 x 10 m, and grid height was 4 m, following the recommendations of the Environmental Noise Directive (2002/49/EC). Model calibration occurs from the comparison between the simulated values and the actual measured values, with correspondence analysis between them.

## **2.3 Interviews**

Regarding the subjective analysis of this research, questionnaires on sound perception were applied to a sample of 400 users of the campus, including students, professors, and employees of the institution. The questionnaire used for this study was based on questions developed in a previous study by Zannin et al. (2013). The issues covered include: general characteristics of the user, information related to permanence in the place, and opinions about the perception and discomfort of noise.

The questionnaire was applied between September and November 2019 so as to maintain consistency between measurements and interviews. The interview system used in the study area is personal and individual; for selection criteria, the only question is whether the individual attends the campus regularly or casually.

The questionnaire contains multiple choice and scale measurement questions, with the assignment of grades to some items, characterizing a structured interview. Questions are asked verbally to the interviewee and transcribed or marked by the interviewer without interference of their interpretation so as to maintain neutrality. The data collected with the application of the questionnaire were tabulated in the SPSS Statistics software v. 17.0, which enables the calculation of statistical data resulting from the subjective evaluation of the research.

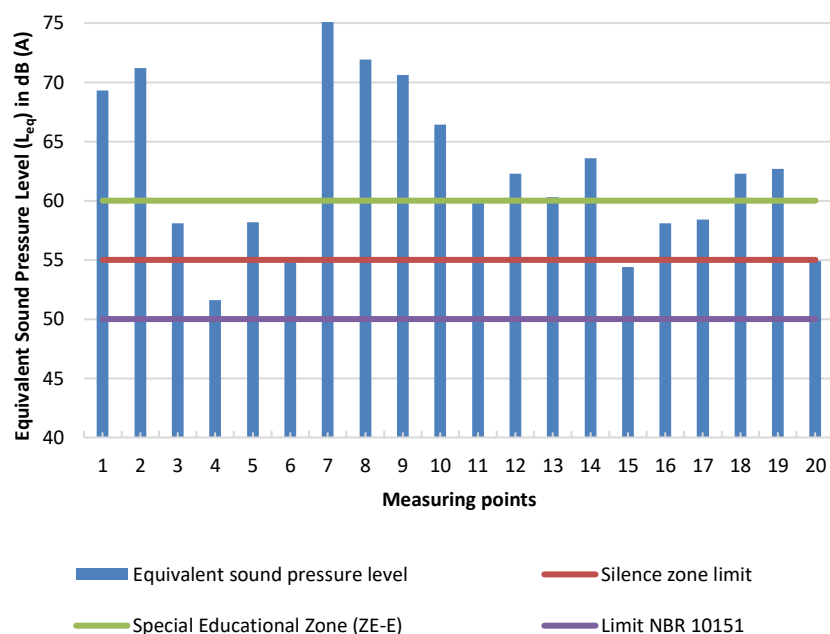
### 3 RESULTS

In line with the way in which the methods for conducting this study were subdivided, the presentation of the results was subdivided into objective analysis (information obtained through measurements and the sound maps elaborated) and subjective analysis (data resulting from the application of the questionnaires).

#### 3.1 Objective analysis

Figure 1 shows the equivalent sound pressure level ( $L_{eq}$ ) obtained at each of the 20 points measured in the campus. The graph is cut by three horizontal lines: the value of 50 dB (A) defined by NBR 10151 for urban areas with schools and hospitals, and two other straight lines that concern the municipal legislation. The Municipal Law of Curitiba No. 10.625 of 2002 defines 60 dB(A) as the maximum limit for the region where the university campus is located — Special Educational Zone (ZE-E), and the value of 55 dB(A) for Silence Zones. The latter is the most appropriate classification for the area under study, as this law defines the noise limit for places within the 200-meter range in relation to schools, hospitals, health units, etc.

Figure 1 – Comparison between in situ measurement and limits allowed by law



Source: The authors, 2020.

Regarding the first limit, 10 points showed values above 60 dB (A), which corroborates the study by Vieira (2018), in which approximately only 50% of the measured points respected the Special Educational Zone limit. The assessment based on the Silence Zone classification aggravates the scenario, as only 4 points showed values below the determined threshold. Noise pollution is confirmed through comparison with the values of NBR

10151/2019 - which determines the limit of 50 dB(A) in school areas - since all points do not comply with the limit established. This corroborates the study by Soares et al. (2014).

The calculation model is calibrated so as to bring the computer simulation as close as possible to the real measurement for the calculation of noise propagation of the map to agree with the values measured *in situ*. For that purpose, receiving points are introduced in the model at the measured locations and the model is considered calibrated when the difference between the measured and simulated values (shown in Table 1) does not exceed  $\pm 4$  dB (A) (SILVA, 2010).

**Table 1 - Difference between *in situ* measurement and simulated noise level**

Point	Measured Leq [dB (A)]	Simulated Leq [dB (A)]	Difference [dB (A)]	Point	Measured Leq [dB (A)]	Simulated Leq [dB (A)]	Difference [dB (A)]
P01	69.3	67.9	1.4	P11	59.8	57.8	2
P02	71.2	68.5	2.7	P12	62.3	58.5	3.8
P03	58.1	55	3.1	P13	60.3	56.7	3.6
P04	51.6	53.9	-2.3	P14	63.6	59.7	3.9
P05	58.2	59.9	-1.7	P15	54.4	58.2	-3.8
P06	54.8	58.7	-3.9	P16	58.1	61.9	-3.8
P07	75.2	72.9	2.3	P17	58.4	54.7	3.7
P08	71.9	70.5	1.4	P18	62.3	65.3	-3
P09	70.6	70.3	0.3	P19	62.7	66.2	-3.5
P10	66.4	64.5	1.9	P20	54.9	52.4	2.5

Source: The authors, 2020.

As a way to assess surface soundscape, Figure 2 illustrates the sound map of the campus, with the identification of colors by noise exposure areas.

Figure 2 – Sound map of the Polytechnic Center Campus



Source: The authors, 2020.

It is noteworthy the predominance of colors that correspond to the highest established noise levels. The two darkest shades of green, which represent the lowest levels, were not found in any region of the map. Thus, as already proven by the measurements, the 50 dB (A) limit established by NBR 10151 is not respected in any region of the campus, which points to the critical situation of the location.

The yellow color, which exceeds the value of 55 dB (A) (the maximum allowed for Silence Zones, according to Municipal Law 10.625), is present in several areas of the map. Likewise, other places are marked by orange color in the weakest tone, which exceeds the limit of 60 dB(A). This color scale occurs due to the internal vehicular lanes of the campus, which are covered by motorcycles, cars, buses, and some trucks.

As observed in the measurements, the calculation of the noise map shows that the areas closest to the highways are the most affected by noise pollution. The research by Su, Kang, and Jin (2013) found the same result. The authors concluded that in the area around the campus, surrounded by highways, the sound pressure level was higher than allowed in 87% of the measurement points. The colors corresponding to the highest noise levels are on these roads and in the regions that surround them. Both BR-277 and Linha Verde are clearly marked by a red color, which is equivalent to levels above 75 dB (A).

### 3.2 Subjective analysis

Respondents were asked about feeling annoyed by noise in the campus. The objective was to compare the answers with those from a study carried out previously, which had this question as a point of analysis. As a result, 62.5% of individuals said that noise in the campus bothers them. This value was considerably higher than that found by Zannin et al. (2013), which showed that 47% of people felt annoyed by the noise produced in the campus.

Regarding the relationship between the gender of respondents and the answer to this question (Table 2), women reported greater discomfort. Within this group, almost 70% responded feeling uncomfortable. Male participants demonstrated a relative balance between responses: men who answered “yes” represent about 55% of the group. This conclusion corroborates the research carried out by Ismail and Ahmed (2018), which reveals that young females are more sensitive to noise pollution than young males at a university in Delhi, India.

**Table 1 – Relationship between gender and the answer to the question “Do you feel annoyed by noise in the campus?”**

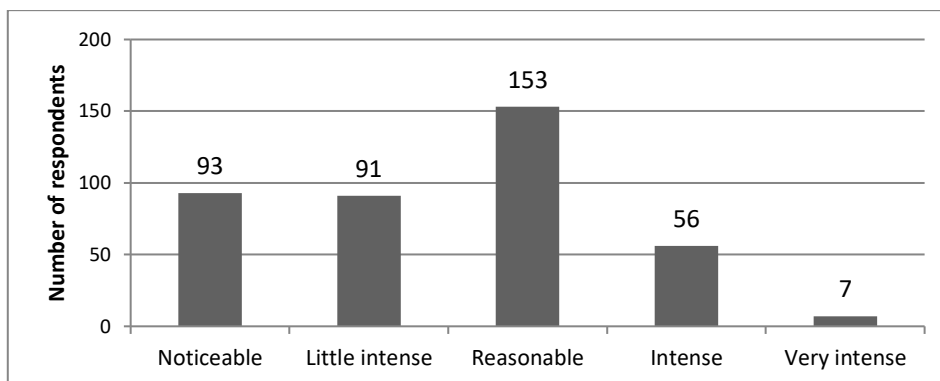
Gender	“Yes” answer	“No” answer	Total
Female	142	65	207
Male	108	85	193
Total	250	150	400

Source: The authors, 2020.

Within a question with five scale alternatives, users attributed a degree to the noise intensity perceived in the campus, as can be seen in Figure 3. The option that stood out was the medium level, almost 40% of respondents classified noise in the campus as reasonable. Lower levels were also predominant: each of the options “noticeable” and “little intense” corresponded to approximately 23% of the total. The higher levels of annoyance, on the other hand, amounted to just over 15%, with only 2% of responses for the “very intense” degree.



**Figure 3 – Campus noise level classification according to respondents**



Source: The authors, 2020.

In addition to directly questioning about noise nuisance, we sought to investigate the degree of nuisance of each of the main sources of noise in the study site. This analysis is important to understand if there is and which source (or sources) stands out in the perception of campus users, and whether there is a relationship between the options placed. Table 4 presents the median, mean, and standard deviation for the question “How much does each of these noise sources bother you in the campus, on a scale from 0 to 10” according to the sources suggested by the interviewer. Users were also asked whether there was any other source to be suggested, but of the 400 interviewees, only 3 mentioned a different option (namely the drum rehearsal sessions at the university), which became statistically insignificant in this research.

**Table 4 - Measures of central tendency for the degree of nuisance of noise sources**

Noise source	Degree of nuisance attributed			
	Median	Mean	Standard deviation	Coefficient of Variation (%)
Internal vehicle traffic	3.00	3.36	2.497	74.37
Vehicle traffic in the surroundings	2.00	2.60	2.665	102.61
Civil construction	4.00	4.04	2.890	71.54
Garden maintenance	5.00	4.57	3.346	73.29
People	5.00	4.60	2.582	56.10
Loud music	2.00	2.87	2.960	103.13
Passage of airplanes	0.00	1.12	1.739	155.27

Source: The authors (2020).

The sources with the highest mean and median were “Garden maintenance” and “People”, but none of these exceeded the average degree of nuisance. Furthermore, the standard deviation and the coefficient of variation (relationship between the deviation and the mean) were high for all sources. This demonstrates a significant dispersion of data and points to a heterogeneous sample with regard to the degree of nuisance of sources, especially traffic (road and air).

In addition to the issue of noise nuisance, another question asked with options of “yes” or “no” concerned the opinion of respondents on the relationship between noise in the campus and the health of users. The answers show that the vast majority of people (just over 80%) do not believe in the potential for noise perceived in the campus to harm their health.

Just as users were able to assign a nuisance scale to each source present in the campus, the final question in the questionnaire allowed users to input a value for the intensity of symptoms associated with campus noise. Table 5 includes the measures of central tendency for this question.

**Table 5 - Measures of central tendency for the degree of nuisance of noise sources**

Noise source	Degree of nuisance attributed			
	Median	Mean	Standard deviation	Coefficient of Variation (%)
Irritation	4.00	3.76	2.942	78.18
Difficulty concentrating	5.00	4.75	2.846	59.98
Insomnia	0.00	0.55	1.436	263.55
Headache	0.00	2.01	2.657	132.36
Tinnitus	0.00	1.33	2.181	164.60

Source: The authors (2020).

The mean and median values are even lower than the results of the question about source nuisance. Of the 5 symptoms, 3 had a median of 0 and means not greater than 2. Thus, it can be understood that when users identify and relate these symptoms to campus noise, they perceive it to have mild effects. Difficulty concentrating stood out among the answers and, even so, the mean and median did not exceed the average level. The standard deviation and coefficient of variation were high in all symptoms, proving the heterogeneity of the sample, especially for insomnia. For this symptom, the vast majority of responses were close to 0; with the few responses for higher scores, the deviation and coefficient of variation had a significant amplitude.

#### 4 CONCLUSION

The objective results point to noise pollution since the limits established at national and municipal level were not respected in most of the study site. The sound maps produced, which represent efficient computational simulation tools capable of quantifying sound pressure level data and graphically representing sound propagation, confirmed the results obtained in the measurements.

The interviews proved to be an important source to understand the perception of users in relation to campus noise. Questions about environmental noise revealed that more than 60% of respondents feel annoyed by this factor and 40% consider the level of environmental noise to be reasonable. Even with a high share of positive responses to nuisance, when the questions concerned noise sources in the campus, most responses had grade 0 or lower scales cores.

Despite the noise pollution in the campus, indicated by measurements and proven by maps, the answers show that the high noise levels do not bother or are not noticed by most users. This highlights the importance of raising awareness about this problem and the damage caused to academics and the environment in general.

The methodology used in this study proves to be a satisfactory alternative for studying noise-exposed areas. The union of the three elements is a strong strategy for acoustic assessment and correct decision-making that prioritizes citizens' quality of life and establishes functional and economically viable measures to control environmental noise.

## 5 REFERENCES

BASNER, M., BABISCH, W., DAVIS, A., BRINK, M., CLARK, C., JANSSEN, S. Auditory and non-auditory effects of noise on health. **The Lancet**, v. 383, n. 9925, p.1325-1332, 2014.

BUNN, F. **Avaliação da poluição sonora gerada pelo tráfego ferroviária cidade de Curitiba**. 185 f. Dissertação (Mestrado em Engenharia Ambiental), Universidade Federal do Paraná, 2013.

ÇOLAKKADDOĞLU, D., YUCEL, M., KAHVECI, B., AYDINOL, O. Determination of noise pollution on university campuses: a case study at Çukurova University campus in Turkey. **Environmental Monitoring and Assessment**, v. 190, n. 4, p.1-14, 2018.

DAVIES, W. J.; ADAMS, M. D.; BRUCE, N. S.; CAIN, R.; CARLYLE, A., CUSACK, P. Perception of soundscapes: An interdisciplinary approach. **Applied Acoustics**, v. 74, n. 2, p. 224-231, 2013.

European Commission Working Group Assessment of Exposure to Noise (WG-AEN): **Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure** – v.2, p. 1-129, 2006.

European Environment Agency. **Noise in Europe 2014**; Publications Office of the European Union: Luxembourg, 2014.

FRYD, J.; PEDERSEN T. H. Noise Annoyance from Urban Roads and Motorways. **Internoise 2016**, p. 5666-5677, 2016.

GERAVANDI, S.; TAKDASTAN, A.; ZALLAGHI, E.; VOUSOGHINIRI, M.; MOHAMMADI, M. J. Noise Pollution and Health Effects. **Jundishapur Journal of Health Sciences**, v. 7, n. 1, p. 1-5, 2015.

HAMMERSEN, F.; NIEMANN, H.; HOEBEL, J. Environmental Noise Annoyance and Mental Health in Adults: Findings from the Cross-Sectional German Health Update (GEDA) Study 2012. **International Journal Of Environmental Research And Public Health**, v. 13, n. 10, p.954-1006, 2016.

ISMAIL, S., AHMED, S. Noise Pollution, Its Sources and Effects: A Case Study of University Students in Delhi. **EPRA International Journal of Economic and Business Review**, v. 6, n. 2, p. B15-B23, 2018.

MUNZEL, T., GORI, T., BABISCH, W., BASNER, M. Cardiovascular effects of environmental noise exposure. **European Heart Journal**, v. 35, n. 13, p.829-836, 2014.

MUNZEL, T., SCHMIDT, F.P., STEVEN, S., HERZOG, J., DAIBER, A., SORENSEN, M. Environmental Noise and the Cardiovascular System. **Journal Of The American College Of Cardiology**, v. 71, n. 6, p.688-697, 2018.

OKOKON, E. O.; TURUNEN, A. W.; UNG-LANKI, S.; VARTIAINEN, A. K.; TIITTANEN, P.; LANKI, T. Road-Traffic Noise: Annoyance, Risk Perception, and Noise Sensitivity in the Finnish Adult Population. **International Journal Of Environmental Research And Public Health**, v. 12, n. 6, p.5712-5734, 2015.

ORGANIZAÇÃO MUNDIAL DA SAÚDE (OMS). **Burden of disease from environmental noise**. Quantification of healthy life years lost in Europe, World Health Organization Regional Office for Europe, Copenhagen, 2011.

RAJA, R.; RAJASEKARAN, V.; SRIRAMAN, G. Non-auditory Effects of Noise Pollution on Health: A Perspective. **Indian Journal Of Otolaryngology And Head & Neck Surgery**, p.1-2, 2019.

SILVA, Â.; SILVA, L.; SOUZA, L. Avaliação do ruído num bairro residencial em Bauru: SP - Situação de pico de tráfego. In: **4º Congresso Luso Brasileiro para o Planejamento Urbano Regional Integrado e Sustentável**. Faro, 2010.

SOARES, P.; ZANNIN, P. H. T.; RIBEIRO, R.; SANTOS, G.; CONSTANTINI, A. **Análise Espectral do Ruído no Entorno do Campus Centro Politécnico da Universidade Federal do Paraná**. Raega – O Espaço Geográfico em Análise; V. 32. 2014.

SU, W.; KANG, J.; JIN, H. Acoustic Environment of University Campuses in China. **ACTA – Acustica United With Acustica**, v. 99, p. 410-420, 2013.

VIEIRA, T.J. **Avaliação da poluição sonora nos campi Centro Politécnico e Jardim Botânico através de medições e mapas de ruído**. 162 f. Dissertação (Mestrado em Engenharia Ambiental), Universidade Federal do Paraná, 2018.

ZANNIN, P. H. T.; ENGEL, M. S.E.; FIEDLER, P. E. K.; BUNN, F. Characterization of environmental noise based on noise measurements, noise mapping and interviews: A case study at a university campus in Brazil. **Cities**, v. 31, p. 317-327, 2013.