SOUNDSCAPE AND NOISE MAP OF A HOSPITAL AREA IN A SMALL CITY

PAISAGEM SONORA E MAPA DE RUÍDO DE ÁREA HOSPITALAR EM UMA CIDADE DE PEQUENO PORTE

PAISAJE SONORO Y MAPA DE RUIDO DE UN ÁREA HOSPITALARIA EN UNA CIUDAD PEQUEÑA

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ABSTRACT
This article investigates noise pollution in hospital areas, focusing on the Hospital de Caridade e Beneficência (HCB) in Cachoeira do Sul, Rio Grande do Sul. Through field measurements and simulations using the iNoise software, sound pressure levels around the hospital and the local population's perception of noise impact were analyzed. The results indicate that noise levels exceed the limits established by NBR 10.151, with values reaching up to 61.7 dB, while the allowed limit for residential and hospital areas is 50 dB. The main noise-generating factors are vehicular traffic and machinery. Despite the high noise levels, respondents' perceptions revealed an adaptation to the noise, with many considering the environment calm. It is concluded that, even in smaller cities, noise pollution affects sensitive areas such as hospitals, making it necessary to implement acoustic mitigation measures to ensure user comfort.

KEYWORDS
Noise Pollution; Acoustic map; Hospitals; Sound pressure levels

RESUMO
Este artigo investiga a poluição sonora em áreas hospitalares, com foco no Hospital de Caridade e Beneficência (HCB) de Cachoeira do Sul, Rio Grande do Sul. Através de medições de campo e simulações com o software iNoise, foram analisados os níveis de pressão sonora no entorno do hospital e a percepção da população local sobre o impacto do ruído. Os resultados indicam que os níveis de ruído ultrapassam os limites estabelecidos pela NBR 10.151, com valores de até 61,7 dB, enquanto o limite permitido para áreas residenciais e hospitalares é de 50 dB. Os principais fatores geradores de ruído são o tráfego veicular e máquinas. Apesar dos altos níveis de ruído, a percepção dos entrevistados revelou adaptação ao barulho, com muitos considerando o ambiente tranquilo. Conclui-se que, mesmo em cidades menores, a poluição sonora afeta áreas sensíveis, como hospitais, sendo necessária a implementação de medidas de mitigação acústica para garantir o conforto dos usuários.

PALAVRAS-CHAVE
Poluição sonora; Mapa acústico; Hospitais; Níveis de pressão sonora

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RESUMEN
Este artículo investiga la contaminación acústica en áreas hospitalarias, centrándose en el Hospital de Caridade e Beneficência (HCB) en Cachoeira do Sul, Rio Grande do Sul. Mediante mediciones de campo y simulaciones con el software iNoise, se analizaron los niveles de presión sonora en el entorno hospitalario y la percepción de la población local sobre el impacto del ruido. Los resultados indican que los niveles de ruido superan los límites establecidos por la NBR 10.151, con valores de hasta 61,7 dB, mientras que el límite permitido para áreas residenciales y hospitalarias es de 50 dB. Los principales factores generadores de ruido son el tráfico vehicular y la maquinaria. A pesar de los altos niveles de ruido, la percepción de los entrevistados reveló adaptación al ruido, y muchos consideraron que el ambiente era tranquilo. Se concluye que, incluso en ciudades más pequeñas, la contaminación acústica afecta a zonas sensibles, como los hospitales, siendo necesario implementar medidas de mitigación acústica para garantizar el confort de los usuarios.

PALABRAS CLAVE
Contaminación Acústica; Mapa Acústico; Hospitales; Niveles de Presión Sonora

1. INTRODUCTION

Noise pollution, a pressing issue that significantly impacts people's quality of life, has now surpassed water pollution, ranking second in the list of major causes of diseases (PERIS, 2020; WHO, 2011). The primary culprit is traffic, which generates intense noise in urban areas. The rapid urban growth further exacerbates this issue, making it crucial to conduct acoustic mapping studies to address this pressing issue.

Noise is a public health issue, according to the European Environment Agency (AEMA), there are 12,000 premature deaths and 48,000 unprecedented cases of ischemic heart disease per year in Europe, due to the degradation of environmental quality in people's lives (PERIS, 2020). Thus, Europe established the need for a noise map for cities with more than 100 thousand inhabitants. Meanwhile, other countries carry out this in limited locations, with potential noise sources, such as educational and urban centers, airports and railways, and roads with a large flow of cars.

In hospital areas, noise pollution becomes an even more pronounced obstacle, significantly impacting the health and well-being of patients, visitors, and employees. The hospital environment, already naturally stressful and anxious for many, can be further disrupted by additional noise, making it difficult for patients to rest and recover and interfering with communication between healthcare professionals and patients. The lack of research in this area, particularly in acoustic mapping, is a significant gap that urgently needs to be addressed (ANDRADE et al., 2021).

In this context, it is possible to verify that it is crucial to carry out studies that evaluate nighttime, daytime, internal, and external sound pressure levels by NBR 10.151 (ABNT, 2021). This paper evaluates sound pressure levels in hospital areas in a small city, Cachoeira do Sul, in Rio Grande do Sul, Brazil. The intention is to evaluate the different conditions of the soundscape surrounding hospitals in this city, questioning users, taking sound pressure level measurements and simulating them using the iNoise software and creating noise maps of these contexts.

2. BIBLIOGRAPHIC REVIEW

Considering the devaluation of acoustic mapping studies in hospital areas, comparing case studies in different locations where similar conclusions were reached was possible. The study at Hospital Rocha Faria in Campo Grande, Rio de Janeiro, revealed the urgent need to control urban noise in the region.

Intense vehicle traffic, disorderly growth, and a lack of road safety contribute to excessive noise levels exceeding recommended limits. Infrastructure improvements, driver awareness, and public policies are essential to mitigate noise and promote a safer and quieter environment around the hospital (SILVA; TORRES, 2023).

External measurements of hospitals in the municipality of Sorocaba show that noise levels exceed the limits recommended by NBR 10151 and the WHO, both day and night. Acoustic maps confirm high noise levels on facades, even on streets with less traffic. Combined actions are necessary to reduce noise levels and meet recommended standards (ANDRADE, 2022).

At the National Institute of Traumatology and Orthopedics in Rio de Janeiro, after noise simulations, traffic data collection, and field measurements, it was found that noise levels in the daytime and afternoon periods around the hospital are far above those standards of NBR 10.151 (ABNT, 2019), with minimums of 70.1 dB, more than 20 dB above recommended. These high levels can cause discomfort and worsen health problems. Strategies to reduce external and internal noise in the hospital are necessary, given the proximity to busy roads (CRUZ, 2022).

In Santa Maria, in Rio Grande do Sul, the soundscape surrounding the Hospital de Caridade Astrogildo de Azevedo (HCAA) was characterized, revealing sound pressure levels above the 50 dB recommended by ABNT NBR 10.151 and municipal legislation, mainly due to vehicular flow. The sound map and parameter evaluation highlighted the negative impact of noise in the hospital area (FERREIRA, 2021).

Passers-by found the sounds of traffic and machines unpleasant, while natural and human sounds were seen as calmer. Familiarization with noise is worrying, as the adverse effects are cumulative. However, the results showed that the nuisance is not very significant, possibly because people have become accustomed to the noise, which is worrying due to the cumulative adverse effects of noise (FERREIRA, 2021).

Finally, two cases were compared in the neighborhoods of João Pessoa, Paraíba. The first, carried out in the Jardim Oceania neighborhood, concludes that the noise map is crucial for managing noise pollution. It is useful both for public administration in urban planning and for designers at the building level. This study focused on the Jardim Oceania neighborhood, reveals a worrying scenario of noise pollution due to vehicular traffic.

Mapping allows a visual noise propagation analysis, highlighting the need for public policies for the neighborhood's growing population. This work expands the debate on urban noise in João Pessoa and seeks improvements to citizens' environmental quality and quality of life (MORAIS; SANTOS, 2023).

In the Tambaú neighborhood, using the SoundPLAN software, it was revealed that all the points studied are out of compliance with NBR 10151, with 62.5% exceeding the daytime limit by more than 10 dB. Using the maps, he analyzed the excess noise in the collector roads, indicating potential harmful exposure to health (ARAÚJO; MENESES; MORAIS, 2023).

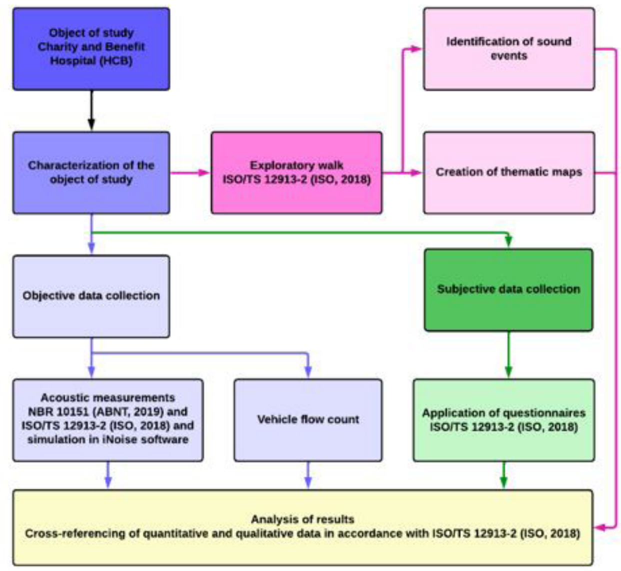

Figure 1: Flowchart with study stages.
Source: The authors (2024).

3. METHODOLOGY

The methodology used in this research follows the following steps: (I) Preparation of the soundscape questionnaire and approval by the Human Research Ethics Committee (CEP); (II) Sound pressure level measurements in the hospital area of Cachoeira do Sul in conjunction with the application of the questionnaire; (III) Simulation in iNoise software for noise maps; (IV) Preparation of the data obtained.

When analyzing the particularities of each location studied in this work, a series of factors that cause frequent noise were noticeable, among which the following can be listed: sounds coming from vehicles, pedestrians, children on the playground, construction machinery, and occasional natural sounds. Questionnaires were applied to the surrounding population to understand better the sound agents that influence the study spaces. Perception can be subjective for each individual. Therefore, repetition in the questionnaire responses helped to consider the most relevant items.

Finally, an in-depth analysis relating the results obtained through objective and subjective methods was carried out.

Figure 1 shows the flowchart with the study steps, detailed below.

3.1. Object of study and its characterization

The study was conducted in the cities of Cachoeira do Sul, located in the center of Rio Grande do Sul. The object of study was taken in the southern region of the city of Cachoeira do Sul, the roads in front of the Charity and Charity Hospital (30° 03' 07" S 52° 53' 24" W), which can be viewed on the map shown in Figure 2.

Figure 2: Location of the study area.
Source: The authors (2024).

Road traffic noise, especially when the flow is high density, easily spreads throughout the city and can even affect areas sensitive to excessive noise levels, such as schools, hospitals, and residential areas. Therefore, this study analyzes a sensitive building (hospital) located in a

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predominantly commercial use and occupation zone, as classified in the Brazilian standard NBR 10151 (ABNT, 2021).

The study site is located in the commercial area, according to the Master Plan of Cachoeira do Sul (CACHOEIRA DO SUL, 2024), Rua Saldanha Marinho has commercial use, Via Tuiuti has a residential area. Tiradentes Street has a high vehicular flow, with public transport and bus stops. Furthermore, the bus stop on the corner of the hospital is the starting and ending point of the urban vehicular line where these buses are often parked there, with the engine running, generating constant noise throughout the day.

As for the road hierarchy, the Hospital de Caridade e Beneficência (HCB) area is located on a corner plot, with the influence of noise on three of its facades, Rua Tiradentes and Tuiuti are local roads. At the same time, Saldanha Marinho and 7 de Setembro are collector streets, according to the Cachoeira do Sul Master Plan. The measurement points are shown in Figure 3, and the views of the roads are shown in Figure 4.

Figure 3: Thematic map with the demarcation of the HCB sound measurement points.
Source: GOOGLE EARTH (2024).

Figure 4: Views of the HCB study area.
Source: GOOGLE MAPS (2024).

To characterize the object of study, data, and information on urban morphology were collected, as well as a description of the users of the environments. The concepts of Bistafa (2018) on sound propagation and Kohlsdorf (1996) for urban morphology were used to support the characterization. According to the two authors mentioned, each element considered relevant for studying the soundscape within the environment is indicated in the flowchart in Table 1.

Characterization of the environment		
Demographic profile	**Characterize the profile of each environment user (age, gender, education...) This information is part of the context, which is intrinsically linked to the analysis of the soundscape**	
Urban morpho-logy	Road network	Where sound pressure level measurements were carried out by NBR 10151 (ABNT, 2019) and ISO/TS 12913-2 (ISO, 2018)
	Green areas	Dense areas of vegetation in the urban environment can influence the soundscape, promoting sound absorption and scattering (BISTAFA, 2018).
	Built density	This analysis is essential for constructing the sound map, as it identifies the interference of the built environment in the sound landscape due to sound propagation, absorption, reflection, and diffusion.
	Vehicle flow	Counting vehicle flow is essential for creating sound maps and understanding the SPL (sound pressure level) generated by this linear source.

Table 1: Elements of characterization of the study environment.
Source: Adapted from FERREIRA (2021).

3.1.1. Preparation of the questionnaire on soundscape and approval by the human research committee (CEP)

The development of a questionnaire to be applied to users and passers-by of the locations evaluated in the research aims to capture subjective impressions about the local soundscape, equipment, or noisy points. In this way, the questionnaire was organized starting with respondents' identification questions - gender, age group, and education; followed by questions related to the use of the locations - frequency, motivation, and satisfaction; and, finally, it addresses specific questions about local noise - main sources and which noises are considered unpleasant. The last two questions followed a 5-point Likert scale pattern, based on what is recommended by ISO 12913-2 (ISO - INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, 2018), with ranges between 0 (very calm) and 5 (very noisy).

Before being applied, the questionnaire was submitted to the CEP (Ethics and Research Council on

Human Beings of UFSM), which approved it through the substantiated opinion CAAE: 67621823.0.0000.5346. It is presented in full in "Annex A."

Through the population of the neighborhood in which the HCB is located. 25,194 (IBGE, 2020), the sample size was calculated for a confidence level of 90% and a margin of error of 12%, in this way, the sample should be 48 interviewees, the SurveyMonkey platform was used for this definition. In the time allocated for the questionnaire, 49 people were willing to answer the questions, whether local or not.

To calculate the probabilistic sample analyzed, equation (1), established by Santos (2018), was followed, being:

$$Sample = \frac{\frac{z^2 \times p\,(1-p)}{e^2}}{1+\left(\frac{z^2 \times p(1-p)}{e^2 N}\right)} \qquad (1)$$

In which the variables correspond:

p = proportion expected to meet

N = population size = margin of error

z = number of standard deviations between proportion and mean

3.2. Field measurements and vihicle counting

Sound pressure level measurements and vehicle counts were carried out on a weekday (Monday) and during daytime hours of peak vehicle flow in August 2023. Peak vehicle hours were defined as 4 p.m. to 6 p.m. A noise measurement was recorded for each measurement point, with signal recordings over 15 minutes with integration time every 1 second.

The A-weighted equivalent total continuous sound pressure level, integrated over a time interval T, in dB, is calculated according to Equation 2, where N is the number of samples in the reference time interval and $L_{Aeq,T}$ is each reading (per second) of the sound pressure level in dB (ABNT, 2021).

$$L_{(Total),Aeq,T} = 10log\left[\frac{1}{N}\sum_{i=1}^{N} 10\frac{\left(L_{Aeq.T}\right)i}{10}\right] \quad (2)$$

To begin the measurements, meteorological conditions were measured to carry out sound pressure level measurements. Data collection is not recommended on days of precipitation and high wind intensity, as they interfere with the results obtained (RENTERGHEM; BOTTELDOOREN, 2010).

Vehicle counting was carried out using manual counters, separating motorcycles and light and heavy vehicles (two axles, three axles, or more). The vehicle count was carried out simultaneously with the noise measurements. Five (5) individuals were involved in this process, carrying out both sound level measurements and vehicle counts. For each measurement point, the sound level meter, coupled to the tripod, was positioned 1.5 meters above the ground by NBR 10151 (ABNT, 2019) and ISO 12913-2 (ISO, 2018), referring to the height of the average human ear.

The equipment used in all measurements were three SLM, Class 1 Type-2270 (Brüel & Kjær) [37]; three 1/2" free-field microphones, Type 4189 (Brüel & Kjær); three SLM calibrators, Type-4231 (Brüel & Kjær); three 1.50 m high tripods (Brüel & Kjær); three windscreens, Type-UA-1650 (Brüel & Kjær); a thermo-hygrometer; five manual numeric counters; and a GPS to record the UTM coordinates of the measurement points. All equipment had a calibration certificate, valid during the measurement campaign.

3.3. Noise map simulation in iNoise

The iNoise software was used to model the road traffic noise map for the acoustic indicator Lday. Horizontal maps were performed at 1.50 m from the ground level, the same height as the SLM. To represent and analyze the objectives of this study, the horizontal grid size for the map was 10 m × 10 m.

ISO 9613-2 (ISO, 2024) was used to calculate traffic noise. To characterize traffic noise as a linear noise source, iNoise was configured for source power per frequency band dB/(A).

Table 4: Combinations and beam nomenclature.
Source: The authors.

The simulation area was imported using shapefiles obtained from the city's planning department, which contained information on the heights of buildings, topography, street layout, blocks and type of paving that make up the study area. The collection point was located approximately in the middle of the stretch, on the side of one of the avenue's lanes, away from intersections.

Within this calculation area (Grid), iNoise generated a grid of receiving points, the spacing between which was defined based on accuracy and calculation time. For the maps, a spacing of 10.00 m was adopted, since this is an urban region (GUEDES; BERTOLI; ZANNIN, 2011; FIEDLER, 2013). The height of the calculation plane was defined as 1.20 m, corresponding to the position of the sound level meter in relation to ground level.

To validate the proposed acoustic model, the sound level calculated by the iNoise software was compared with the value measured at the reference point. For this purpose, the logarithmic mean of all the equivalent continuous sound levels (L_{Aeq}) measured was adopted. Directive 2002/49/EC (EUROPEAN PARLIAMENT AND OF THE COUNCIL, 2002) stipulates this descriptor as the basis for the sound level indicator – day (L_{day}), which is determined by the acoustic simulation software.

3.4. Thermatic map

The thematic map that integrates the methodology of this work was created from GOOGLE EARTH maps (2024) to illustrate the measurement points within the environment, facilitating the visualization of the quantitative data collection milestones. The decision-making of the sound measurement points was made through the exploratory walk-in by ISO 12913-2 (ISO, 2018). Walks were carried out around the environment, aiming to identify sound events. After the entire accessible area had been analyzed, the measurement points were defined in certain places by filling in Table 2 to identify each sound event.

Points	Sounds events	Predominant sound	Sensation
P. 1 e 2	Intense traffic, people walking and talking	Traffic sounds: acceleration, deceleration and horn	Discomfort, difficulty listening and talking
P. 3 e 4	Intense traffic; machines and equipment; people walking and talking; barely perceptible natural sounds	Traffic sounds: acceleration, deceleration and horn	Discomfort, difficulty listening and talking

Table 2: Identification of sound events at each HCB measurement point.
Source: The authors (2024).

4. ANALYSIS AND DISCUSSION OF RESULTS

Firstly, the results obtained when describing the soundscape of the environment being analyzed are discussed. Initially, the data collected through surveys (demographic profile, sound perception, quality, and tranquility) is presented descriptively, accompanied by quantitative graphs. We then explored the correlations between the responses obtained.

4.1. Results of sound pressure level measurements and noise maps

Table 3 describes the vehicle count at each measurement point. Analyzing the study area, the streets with the most significant impact in this section are Tiradentes and Sete de Setembro, as they have a greater flow of vehicles than the remaining, mainly due to the continuity of these roads. Despite Saldanha Marinho's great directional importance in the city, the analysis section ends at the end of the study block. Therefore, there is not much vehicular flow there.

Figure 5 presents the noise map calibrated from sound pressure level measurements at the highlighted points, demonstrated by colors, from 0 to 100 dB.

Vehicle flow count - HCB			
	Heavy	Light	Motorcycles
Point 1	7	51	2
Point 2	2	58	2
Point 3	0	38	3
Point 4	1	10	1

Table 3: Vehicle flow count of measurement points.
Source: The authors (2024).

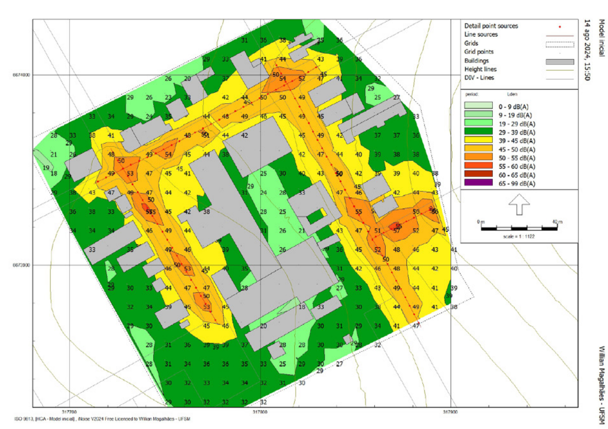

Figure 5: Noise map of the HCB hospital area.
Source: The authors (2024).

Table 4 presents the Average L_{Aeq} and the L_{Aeq} values per frequency band of the measurement points and is demonstrated in Annex B.

The noise map shows that the highest noise concentration comes from the roads, especially Rua Tiradentes, 7 de Setembro, and Saldanha Marinho. Notably, levels lower than 50 dB were measured in the frequency range.

According to the criteria of NBR 10151:2019 (ABNT, 2019), the maximum level allowed for strictly urban residential areas, hospitals, or schools during the daytime is 50 dB (ABNT, 2019). Therefore, the recorded noise levels are beyond the limits established by the standard, especially when highlighting the average values of $L_{Aeq15min}$.

Point 1 is Rua Saldanha Marinho. This measurement location presented an $L_{Aeq15min}$ of 60.6 dB. The main noise source in this location was vehicular traffic, which can be seen by recording the highest sound pressure levels relating to medium frequencies. This road is the main route for users from the center to the hospital (arrival).

Point 2 is measured on Rua Tiradentes, which presented the highest value for $L_{Aeq15min}$, 61.7 dB. The street is the main facade of the hospital building, and the bus stop for public transport is on site. The sound events that result in higher sound pressure levels are the accelerations and decelerations of the public transport fleet at the bus stop, in addition to the engine noise itself, shown in Figure 6.

Considering the measured and simulated values, it is possible to estimate the response of users in this area to the sound level to which they are exposed, as shown in Table 5.

Value at which the corrected sound level exceeds the criterion level [dB(A)]	Estimated Community Response	
	Category	Description
0	None	No reaction observed
5	Little	Sporadic complaints
10	Average	Generalized complaints
15	Energetic	Community action
20	Very energetic	Vigorous community action

Table 5: Estimated Community Response.
Source: ISO 1996:1 (ISO, 2016).

Figure 6: 3D noise map of the HCB hospital area.
Source: The authors (2024).

Measuring point 3, on Rua 7 de Setembro, on the side of the hospital, presented an $L_{Aeq15min}$ of 60.2 dB. Notably, the last two measurement points presented lower values, a fact that is directly related to the lower vehicular flow in the surrounding area. However, the difference does not become so significant as these roads do not have asphalt paving; the friction noise tire pavement contributes to raising the measured sound pressure levels.

Measuring point 4, on Rua Tuiuti, presented lower sound pressure levels than the other points due to its location further away from the main roads. Sound pressure levels attenuate as the distance from the main roads increases as vehicular flow is reduced.

On the noise map, orange represents the highest noise values, ranging between 50 and 60 dB. These noisier areas are mainly concentrated along the Saldanha Marinho and Tiradentes roads, where traffic is heaviest. According to NBR 10152: 2017, reference values for internal hospital environments must be a maximum of 40 dB for uses such as nurseries, surgical centers, offices, and individual rooms (ABNT, 2017).

Considering that Saldanha Marinho and Tiradentes streets have $L_{Aeq15min}$ of 60.6 and 61.7 dB, respectively, sound insulation strategies on the facades must be implemented so that the hospital's internal environments can achieve the acoustic comfort values required by regulations, attenuating at least 22 dB. Implementing acoustic barriers and improvements to window seals can help reduce internal noise levels, ensuring patient comfort and compliance with current acoustic standards.

When comparing the measured and simulated sound pressure levels, we can see the difference between them in Table 6. Although the difference of + 4.7 dB(A) exceeds the uncertainty of +/- 4.0 dB(A), established by WG - AEN (2006) for noise maps in urban areas, it was adopted as acceptable, given the simplifications made to the acoustic model and the main objective of this paper.

Period	Simulated sound level [dB(A)]	Measured sound level [dB(A)]	Difference [dB(A)]
Afternoon	55	61,7	+ 6,7

Table 6: Measured and simulated sound pressures levels.
Source: The authors (2024).

4.2. Perception of the sound landscape by users

The questionnaires were administered around the Hospital de Caridade e Beneficência de Cachoeira do Sul on August 14, 2023, from 4:00 pm to 6:00 pm. Covering profiles of different users of the location through questions aimed at interpreting sound perceptions of places close to the location.

Of the 49 respondents, 63.3% were female, and 3.7% were male (Figure 7). Furthermore, the entire questionnaire is available in Annex A: Questionnaire applied in the research.

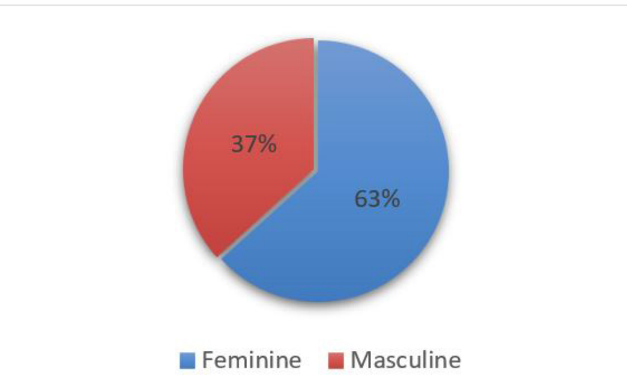

Figure 7: Gender of respondents.
Source: The authors (2024).

The most significant number of respondents were women, representing more than half of the responses. Notably, at the bus stop, most hospital staff were women. When walking on the sidewalks, females also showed greater interest in participating and answering the questionnaire. These data highlight a significant participation of women in the research, both as interviewees and as active participants in the areas observed.

The ages of the participants who responded to the questionnaire, shown in Figure 8, range from under 20 to over 81, with all interviewees over 18. Notably, the 20 to 35-year-old age group records the highest frequency of responses, followed by the 36 to 50-year-old age group and the 51 to 65-year-old age group. As it is an area with a bus stop, it is common to observe employees from the surrounding area gather in this location. Furthermore, it was noted that people who accompany family members in the hospital tend to be older, especially the partners of the person undergoing treatment.

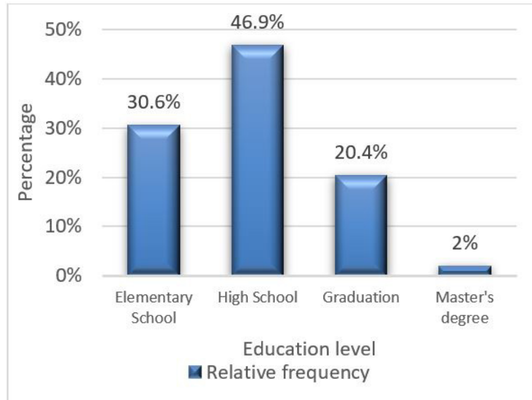

Figure 8: Age of respondents.
Source: The authors (2024).

Figure 9 shows the respondents' education level. The highest percentage (46.9%) corresponds to people who have completed secondary education, followed by those who have only completed primary education. Thirdly, there is a significant representation of people in the process of graduating or who have already completed their degree. This distribution reflects educational diversity in the sample, with a notable concentration at the high school level.

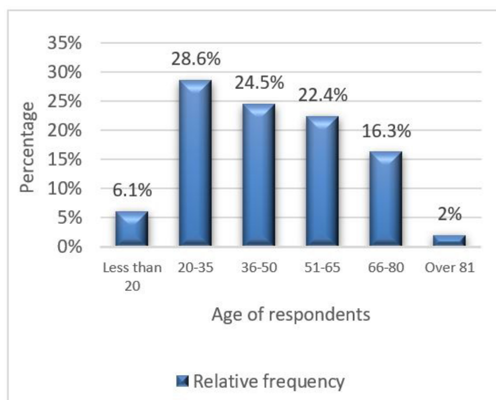

Figure 9: Educational level of respondents.
Source: The authors (2024).

The frequency of visits to the site is predominantly five times a week, which suggests the regular presence of users in the surrounding area. On the other hand, visiting once a week or at most once a month is more common among hospital patients. This can be attributed to many of these patients coming from other cities and visiting Cachoeira do Sul only when they need to return for medical appointments. These data can be seen in Figure 10.

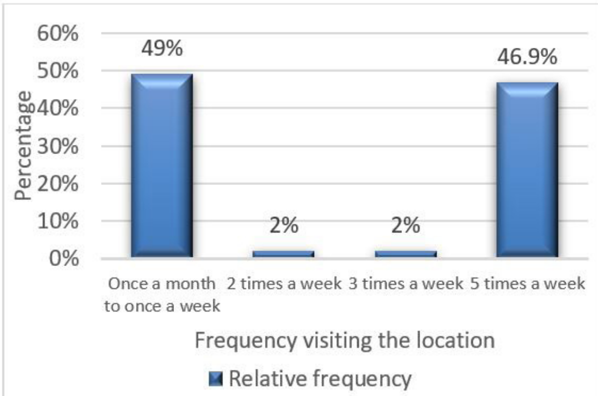

Figure 10: Regularity of visits to the respondents' location.
Source: The authors (2024).

The main motivation for being there is commerce and services (Figure 11). This trend is observed among surrounding residents and in the responses of individuals at the bus stop working in the area. Secondly, health-related motivation, due to the presence of the hospital, is mentioned as a significant reason for people to be there.

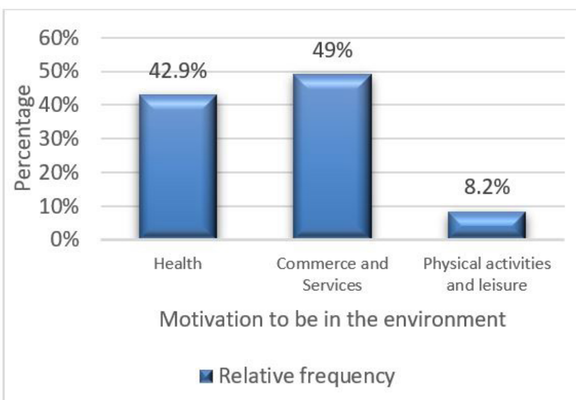

Figure 11: Motivation inherent to presence in the environment.
Source: The authors (2024).

Among the responses about satisfaction with the infrastructure at the location (Figure 12), a significant number of participants indicated that they were satisfied, followed by those who declared themselves very satisfied. Furthermore, another portion expressed a neutral position. These responses suggest that most respondents perceive the area as well cared for. Notably, many people from other cities compared their places of origin, concluding that Cachoeira do Sul has better care and infrastructural conditions.

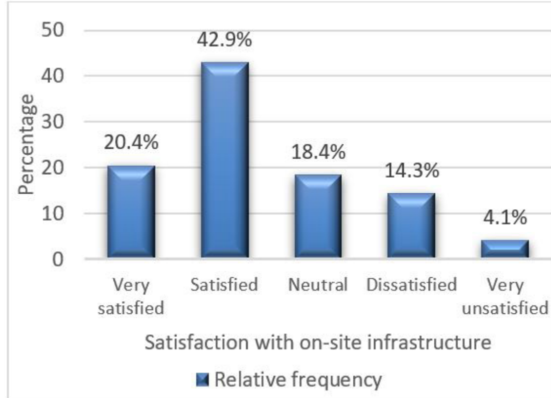

Figure 12: Satisfaction regarding environmental infrastructure conditions.
Source: The authors (2024).

Regarding satisfaction about the aesthetics of the surroundings, the responses indicate that the highest percentages are from people who declared themselves satisfied and neutral. Collecting responses on-site made it possible to note that many participants could not provide a clear opinion on this aspect, suggesting a lack of concern or specific attention regarding the area's aesthetics. This can be seen in Figure 13.

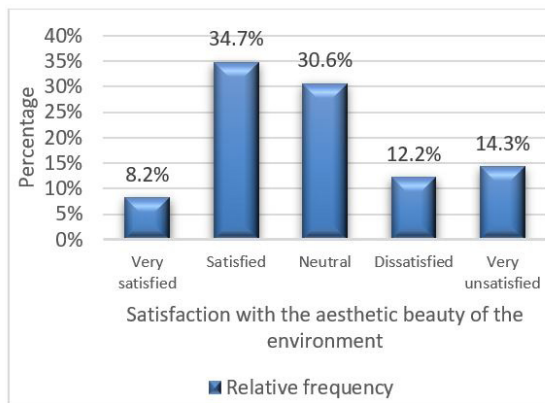

Figure 13: Respondents' satisfaction with the aesthetics of the environment.
Source: The authors (2024).

People often mentioned vehicle traffic, including trucks, when asked about the main noise source. Also, they pointed out machinery that uses the roads as a route to the industrial region close to the river. The responses relating to the main noise sources are shown in Figure 14.

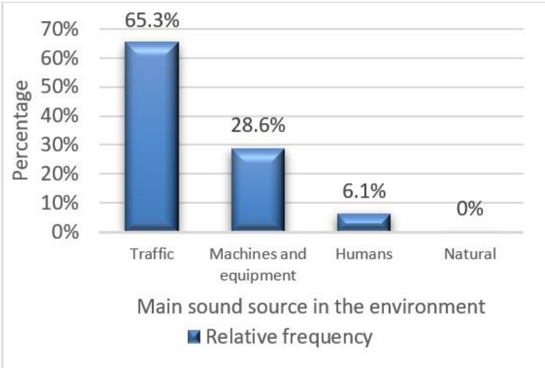

Figure 14: Responses regarding the main sound source of noise in the environment.
Source: The authors (2024).

When asked about the noises that bothered them most (Figure 15), most responded that they came from vehicle traffic, especially trucks, followed by machinery and equipment. Surprisingly, many people said they were not bothered by the noise. When asked why they did not feel uncomfortable, even though they noticed the surrounding noise, many explained that this was because they did not stay in the area long. It is also estimated that the population has normalized sound pressure levels, reducing discomfort.

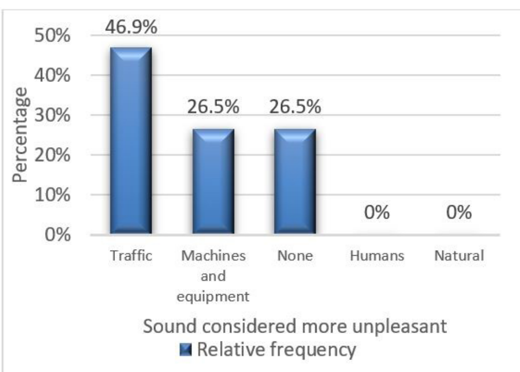

Figure 15: Responses regarding the most unpleasant sound elements.
Source: The authors (2024).

A significant value disparity was observed when asking people to rate their level of noise annoyance on a scale of 1 to 5. The most significant percentage assigned the maximum nuisance level (5), followed by a portion that indicated the lowest nuisance value (1), and an intermediate group that chose levels 3, 2, and 4. This significant variation in responses highlights the diversity of perceptions and sensitivities about the noise present in the area, showing how relative it can be between users. The responses related to the level of discomfort are shown in Figure 16.

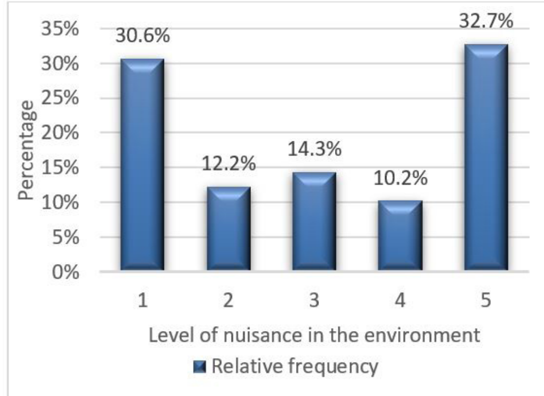

Figure 16: Responses regarding the nuisance of noise generated in the surroundings.
Source: The authors (2024).

Regarding the level of tranquility in the environment (Figure 17), the most common response was attributed to the maximum level (5), indicating that people consider the area calm. Secondly, a significant choice was observed for intermediate levels 3 and 2. This distribution of responses suggests a predominant perception of tranquility in the region.

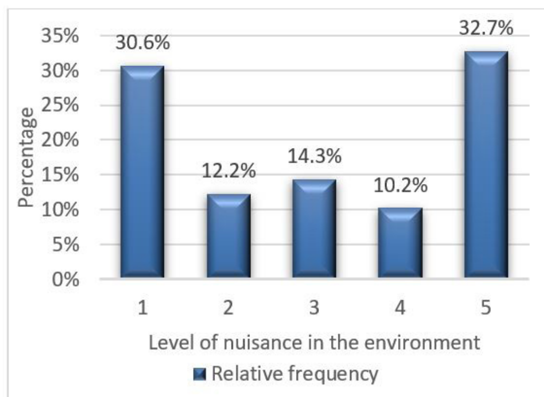

Figure 17: Responses regarding the level of tranquility in the environment.
Source: The authors (2024).

5. CONCLUSIONS

This research demonstrates that, even though it is a small city with a total population of around 80 thousand inhabitants, the urban environment can still present sound pressure levels above the values allowed by standard 10,151 (ABNT, 2019). From this perspective, urban centers are constantly intrinsic to noise pollution.

Furthermore, hospital environments, which, due to their use, should protect the recovery of patients, are affected by sound pressure levels like any other regions of cities, which further demonstrates the need to devise strategies to achieve values lower than 50 dB during daytime periods and 45 dB during nighttime periods, as determined by NBR 10.151 (ABNT, 2019).

None of the four measurement points obtained values below 50 dB. When dealing with roads with a greater flow of cars, these values exceeded 61 dB, as demonstrated in point 2, which added the noise from vehicular traffic with the acceleration and deceleration of public transport at the bus stop.

Furthermore, the questionnaires demonstrated that the population still considers the environment peaceful. Some perspectives can be drawn from the regularity of visits to the site, the majority of respondents are HCB employees, and in addition, users consider the aesthetics of the environment to be very pleasant, these factors can corroborate results that tend to get used to noise pollution.

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WML: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project management, resources, supervision, validation, visualization, writing - original draft and writing - review & editing.

BCG: data curation, formal analysis, investigation, methodology and writing - original draft.

AFB: data curation, formal analysis, investigation, methodology and writing - original draft.

GM: conceptualization, funding acquisition, methodology, resources and writing - original draft.

MJS: funding acquisition, methodology, resources, writing - original draft and writing - review & editing.

Conflict declaration: nothing to declare.

ANNEX 1 - QUESTIONNAIRE ASSIGNED IN THE RESEARCH

Questionnaire			Relative frequency (%)	Absolute frequency
1	What is your gender?	Feminine	63,3	31
		Masculine	36,7	18
2	What is your age?	Less than 20	18	3
		20-35	28,6	14
		36-50	24,5	12
		51-65	22,4	11
		66-80	16,3	8
		Over 81	2	1
3	What is your education level?	Elementary school	30,6	15
		High school	46,9	23
		Graduation	20,4	10
		Master degree	2	1
4	What is the motivation for being in the environment?	Once a month to once a week	49	24
		Two times a week	2	1
		Three times a week	2	1
		Five times a week	46,9	23
5	How satisfied are you with the on-site infrastructure?	Health	42,9	21
		Commerce and services	49	24
		Physical activi-ties and leisure	8,2	4
6	How satisfied are you with the on-site infrastructure?	Very unsatisfied	4,1	2
		Dissatisfied	14,3	7
		Neutral	18,4	9
		Satisfied	42,9	21
		Very satisfied	20,4	10
7	Regarding satisfaction with the aesthetic beauty of the environment?	Very unsatisfied	8,2	4
		Dissatisfied	12,2	6
		Neutral	30,6	15
		Satisfied	34,7	17
		Very satisfied	14,3	7
8	What is the main sound source in the environment?	Traffic	65,3	32
		Machines and equipments	28,6	14
		Humans	6,1	3
		Natural	-	-
9	What is the most unple-asant sound?	Traffic	46,9	23
		Machines and equipments	26,5	13
		Humans	-	-
		Natural	-	-
		None	26,5	13

10	What is the level of discomfort in the environment?	1	30,6	15
		2	12,2	6
		3	14,3	7
		4	10,2	5
		5	32,7	16
11	What is the level of tranquility in the environment?	1	8,2	4
		2	16,3	8
		3	16,3	8
		4	14,3	7
		5	44,9	22

Table 7: Questionnaire assigned in the research.

Source: The authors.

ANNEX 2

Point 1 - $L_{Aeq15min}$ 60,6 dB									
Frequency (Hertz)	31	63	125	250	500	1000	2000	4000	8000
L_{Aeq} (dB)	55,9	56,9	57,2	58,5	60,4	65,1	63,8	62,1	57
Point 2 - $L_{Aeq15min}$ 61,7 dB									
Frequency (Hertz)	31	63	125	250	500	1000	2000	4000	800
L_{Aeq} (dB)	59,1	59,9	60,3	60,5	63,5	67,1	64,9	64	62,7
Point 3 - $L_{Aeq15min}$ 60,2 dB									
Frequency (Hertz)	31	63	125	250	500	1000	2000	4000	8000
L_{Aeq} (dB)	58,1	58,9	59,6	59,8	62,2	66	64,5	63,2	60,1
Point 4 - $L_{Aeq15min}$ 56,1 dB									
Frequency (Hertz)	31	63	125	250	500	1000	2000	4000	8000
L_{Aeq} (dB)	50,5	53,2	54,1	54,2	56,3	58,1	55,6	54,2	51,2

Table 4: Sound pressure levels measured around the HCB.

Source: The authors.