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EXPERIMENTAL ASSESSMENT OF OUTDOOR LEISURE NOISE: SAMPLING METHODOLOGY AND ANNOYANCE INDICATORS

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ABSTRACT

Leisure noise is a significant environmental issue across Europe, particularly in Mediterranean countries where outdoor leisure activities are more prevalent and widespread. These regions experience higher levels of outdoor gatherings, music events, and nightlife activities, which contribute substantially to noise pollution in both urban and suburban areas. Although this type of noise is within the scope of Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 [1], the directive does not impose specific obligations for controlling leisure noise, leaving a gap in its practical application. Additionally, there are no established standards or universally accepted methodologies for the accurate assessment of this noise type. This lack of regulation creates challenges for policymakers and urban planners attempting to mitigate its impact on communities.

In this paper, a comprehensive guideline is proposed to address these limitations. The guideline focuses on key aspects such as spatial and temporal sampling strategies, the processing of noise measurements, and the selection of appropriate indicators to evaluate noise annoyance effectively. By providing a structured approach, the proposed methodology aims to improve the accuracy and consistency of leisure noise assessments, facilitating better decision-making and promoting healthier, quieter environments.

Keywords: *Leisure noise Acoustic measurements Noise assessment Environmental noise Noise limits*

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1. INTRODUCTION

The problem of noise derived from leisure activities in Spain and Europe has specific characteristics and increasing relevance. This noise is closely linked to nighttime and evening leisure activities in bars, terraces, nightclubs, and restaurants, affecting the quality of life of residents by disturbing rest, concentration, and even auditory health.

Leisure noise, particularly in densely populated or tourist areas, causes significant discomfort and an increase in neighborhood complaints. In many Spanish cities (Madrid, Barcelona, Vitoria, Valencia, Málaga, Ibiza, Alicante, Murcia, Logroño, Badajoz, Benidorm, Ciudad Real, etc.), studies based on acoustic measurements have identified notable differences between noise levels during weekdays and weekends, showing an alarming increase during the weekend nighttime period.

European environmental noise legislation, with its main regulation being Directive 2002/49/EC [1], while not excluding leisure noise as an acoustic pollutant, does not explicitly address it as it does with sources such as road, rail, and air traffic, and industry. For example, there is an obligation to carry out Strategic Noise Maps and Action Plans against noise in major cities for the previously mentioned sources, but not for leisure noise. In Spain, strategies such as the designation of Special Acoustic Protection Zones (ZPAE), Acoustically Saturated Zones (ZAS), or Special Acoustic Situations Zones (ZSAE) have been developed. However, leisure noise is not included in the Strategic Noise Maps, and it is often a point of contention whenever a Strategic Noise Map is approved in Spanish cities.

Nighttime leisure noise presents technical challenges for its assessment, such as the absence of valid empirical models for its implementation in acoustic prediction, the difficulty in measuring it representatively, and the impact of factors such as seasonality and tourist density. This article aims to provide a baseline methodology for assessing leisure noise through in situ measurements.

The proposed methodology provides the indicators that best represent the impact of leisure noise, as well as the procedures for the temporal and spatial sampling of measurements. Efforts have been made to draw a parallel with the international standards ISO 1996-1 [2] and 1996-2 [3] (*Acoustics — Description, measurement and assessment of environmental noise*) which provide guidelines for environmental noise measurement, focusing on noise from industry and infrastructure. This article presents the instructions for the experimental assessment of leisure noise.
The recommendations in this work are guidelines; however, the applicable legislation must be taken into account, as it may impose more restrictive conditions in certain aspects.

2. MOTIVATIONS

Leisure noise has many peculiarities and characteristics that differ from other environmental noises such as industrial noise and infrastructure noise. These differences are particularly related to their variability in time and space. There are numerous leisure noise measurements conducted in various studies of cities; however, as mentioned, there is no uniformly accepted methodology.
The behavior over time of leisure noise can be classified as fluctuating sound according to the classification made by ISO 1996-1 [2] (3.4.5). The variation in leisure noise occurs in the short term (in minutes), medium term (different hours of the day with very high variability), and long term (days with high sound emission, such as weekends or differentiated periods like summer and winter). The evaluation method must account for this temporal variation and already indicates that measurement periods should be long, with repeated intervals across the week and over several weeks. Additionally, the selected indicator for measurement should reflect the concentration of emission over short periods of time, especially during the night. Evaluation over periods of several hours (day, evening or night) could attenuate the emission that occurs during shorter periods, typically between 1 and 3 hours.
Regarding spatial variability, it can also be very high, as the typical area for this type of noise is the city center. It is possible to have a high noise level on a street with a high concentration of activities or people, which can decrease drastically just a few meters away on an adjacent street. Since these measurements involve long recording times, it will be necessary to optimize the number of measurement points, as each one will incur high costs.
In conclusion, the high variability of leisure noise over time and space makes it necessary to have a thorough understanding before proposing a spatial or temporary sampling method for its assessment. It may even be necessary to evolve in successive measurement campaigns, expanding points and measurement time based on previous experiences.
The figure below shows the evolution of the 1-hour equivalent level throughout the days of the week in a beachfront leisure area in summertime. The equivalent levels are over 70 dB(A) in the worst night period. There is a clear increase in levels between 1:00 AM and 6:00 AM, with a more pronounced rise on the weekend. The levels during the daytime period are stabilized between 60-65 dB(A).

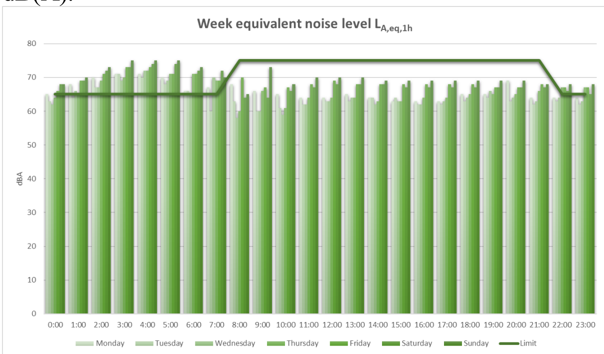

Figure 1. Noise level ($L_{A,eq,1h}$) for one week.

Another special characteristic of leisure noise is that the noise measurements themselves can change the behavior of people or the activities that are intended to be measured. Therefore, measurements with the sonometer at street level over a short period of time should be avoided, as could be done in industrial or infrastructure measurements.

3. ANNOYANCE INDICATORS

3.1 Time-weighted and frequency-weighted sound pressure level

The frequency behavior of leisure noise is broadband, with no low-frequency components or high impulsivity. Therefore, measurements with A-weighting and FAST time weighting are valid.
The appropriate frequency range for the assessment of leisure noise is between 20 Hz and 10,000 Hz. In addition to providing the overall value, it is recommended to perform measurements in third-octave bands or at least in octave bands.

3.2 Noise descriptors

The most appropriate indicator to estimate the annoyance of leisure noise is the equivalent continuous sound pressure level. The reference time interval to process the equivalent noise level is the day, evening, and night reference periods (in dependence of each country), but it is not sufficient. At least during the nighttime period, it should be accompanied by the evaluation of the continuous level over 1 hour. Shorter evaluation periods may not be suitable due to their low representativeness for this type of fluctuating noise. The assessment over a 1-hour period during the night is appropriate for determining the potential sleep disturbance caused by leisure noise.
The maximum level should be recorded in each measurement period ($L_{F,max}$) for each sampling day.
N percent exceedance level, ($L_{N,T}$) are very useful from a technical perspective to determine the behavior of the noise throughout the measurement period, but they are difficult to interpret for non-technical people and are not practical for setting emission limits.

4. MEASUREMENT PROCEDURE

To select appropriate observation and measurement time intervals, it may be necessary to conduct survey measurements over relatively long periods.

4.1 Time intervals, time sampling

About the long-term time interval, leisure noise can exhibit periodic behavior both during the week and throughout the year. During the week, it is common for high noise levels to occur on weekends (from Friday to Sunday). Throughout the year, noise levels typically increase during summer periods, when leisure activities take place outdoors. This is added to the fact that during hot weather, it is more common to have windows open in residences, which increases the noise impact. Therefore, in the long term, measurements should be evaluated as day-week averages, ensuring that high noise level events are repeated for at least three consecutive weeks.

4.2 Spatial sampling

Measurements should preferably be conducted in outdoor spaces, although indoor spaces may be monitored for specific purposes.
At least one measurement point should be placed on each of the streets affected by leisure noise, in the area where the highest impact is expected. For streets longer than 100 meters, a second measurement point should be installed.

4.3 Microphone location

The measurement points should preferably be located at a height of 4 meters. Measurement stations can be placed on balconies, windows (exterior part), or façades, taking into account potential corrections for reflections.
Locations on streetlights or electricity poles may also be acceptable, provided that the anchoring element does not transmit noise or vibrations to the measurement equipment.
In all cases, the equipment should be positioned in such a way that it is not visible from the leisure areas, either by the users or by the staff of the establishments, to avoid altering the behavior of the business owners or users.
In the case of indoor measurements, it must be ensured that the measurement space is not occupied during the measurements. It must also be ensured that the noise coming from the outside is predominant.

4.4 Instrumentation

Depending on the purpose of the measurements, the following types can be established.
Measurements aimed at establishing corrective measures or delineating special action zones by local authorities:
• Class 1 sound level meters according to IEC 61672-1, calibrated before and after each measurement.
• Class 1 acoustic calibrator to verify the proper functioning of the equipment.
Control measurements carried out directly by the local authorities or regulatory bodies may use Class 2 sound level meters according to IEC 61672-1 [4].
For measurements in octave or one-third-octave bands, the class 1 and class 2 instrumentation systems shall meet the requirements of a class 1 or class 2 filter, respectively, specified in IEC 61260:1995.
In all cases, microphones should be protected with windshields and weatherproof kits to prevent wind disturbances and damage from rain.

4.5 Weather conditions

The weather conditions shall be representative of the noise exposure situation under consideration, and it should be registered on the measurement period.

4.6 Other parameters to be controlled.

The noise assessment should include a list of the leisure activities present in the area with at least the following information:

- Name of the activity.
- Type of activity (pub, restaurant...).
- Operating hours.

- Venue capacity.
- Terrace capacity.

Alternatively, other parameters can be monitored, such as the occupancy level of the area being measured. There are person-counting systems supported by Artificial Intelligence that allow the establishment of an occupancy level for terraces or public streets, which can be related to the recorded noise levels.

4.7 Residual sound

The measurements must be corrected for the presence of residual sound (total sound remaining at a given position in a given situation when the specific sounds under consideration are suppressed) with levels similar to those of the leisure activity itself. These levels can be evaluated during the hours of the day when leisure activity decreases, such as in the early hours of the morning. The type of noise may change, with leisure activity being predominant at night, while traffic noise tends to be higher during the day.

5. EVALUATION OF THE MEASUREMENT RESULT

5.1 Correction factors

If the residual sound pressure level is 10 dB or more below the measured sound pressure level, make no corrections.
If the residual sound pressure level is 3 dB or less below the measured sound pressure level, no corrections are allowed. The measurement uncertainty is then large. The results may, however, still be reported and may be useful for determining an upper boundary to the sound pressure level of the source under test.
For cases when the residual sound pressure level is within a range from 3 dB to 10 dB below the measured sound pressure level it should be corrected according to ISO 1996-2 method.
Regarding meteorological corrections, measurements taken in conditions of rain or winds exceeding 5 m/s should be discarded.
Corrections for reflections may be applied in the case of measurements taken near façades, subtracting 3 dB(A) from the average level obtained.

5.2 Noise limits

The competent authorities (usually local authorities) should establish limits for each of the equivalent level parameters for the day, evening, and night periods for leisure activities, as well as for the 1-hour equivalent level parameter for night period.

In the case of equivalent levels, the limits can be the same as the acoustic quality objectives for the designated area. For the 1-hour equivalent level, the limit can be set at 5 dB(A) above the nighttime acoustic quality objective.
Exceedance ranges can be established to determine the types of actions to be taken in each case. For example,

- Exceedances between 0-5 dB(A) may involve implementing zonal plans for the gradual reduction of noise and controlling emissions.
- Exceedances between 10-15 dB(A) may require immediate actions such as time restrictions or limiting terrace areas.
- Exceedances above 15 dB(A) may result in the establishment of Acoustically Saturated Zones with the application of corrective measures, including the closure of establishments.

6. INFORMATION TO BE RECORDED AND REPORTED

For measurements, the following information shall, if relevant, be recorded and reported:
a) time, day and place for measurements.
b) instrumentation and its calibration.
c) measured and, if relevant, corrected sound pressure levels ($L_{A,eqT}$), A-weighted and, optionally, in frequency bands.
d) estimate of the measurement uncertainty together with the coverage probability.
e) information on residual sound pressure levels during the measurements.
f) time intervals for the measurements.
g) thorough description of the measurement site, including ground cover and condition, and locations including height above ground, of microphone.
h) description of the operating conditions, including the list of leisure activities in the area with is main operating description.
i) description of the meteorological conditions, including wind speed, wind direction, cloud cover, temperature, barometric pressure, humidity and presence of precipitation and location of wind and temperature sensors.

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8. REFERENCES

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[3] ISO 1996-2:2017. (2017). Acoustics – Description and measurement of environmental noise – Part 2: Acquisition of data pertinent to land use. International Organization for Standardization.

[4] IEC 61672-1, Electroacoustics — Sound level meters — Part 1: Specifications