SOUND POLLUTION IN THE FURNITURE INDUSTRY OF THE FEDERAL DISTRICT

POLUIÇÃO SONORA EM INDÚSTRIAS MADEIRO MOVELEIRAS DO DISTRITO FEDERAL

CONTAMINACIÓN ACÚSTICA EN LAS INDUSTRIAS MADERERAS Y DE MUEBLES DEL DISTRITO FEDERAL

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ABSTRACT

The paper presents an evaluation of sustainable practices in furniture industries through the analysis of their productive processes. Sound pollution was studied in two furniture wood industries of different sizes of the Federal District. Through measurements it was possible to measure the excessive noise emissions and compare them with the standards established by existing national and international Laws, Resolutions, Ordinances and Regulatory Technical Standards. Excess noise was observed in both industries at specific points. To control the problem, actions were suggested based on the good practices of sustainable projects.

Keywords: Sustainability. Furniture Industry. Noise.

RESUMO

O trabalho apresenta uma avaliação de práticas sustentáveis em indústrias moveleiras por meio da análise de seus processos produtivos. Foi estudada a poluição sonora em duas indústrias madeiro moveleira de diferentes portes do Distrito Federal. Por meio de medições foi possível aferir as emissões de ruído excessivo e compará-las com os padrões estabelecidos por Leis, Resoluções, Portarias e Normas Técnicas Regulamentadoras nacionais e internacionais existentes. Observou-se excesso de ruído em ambas as indústrias, em pontos específicos. Para controle do problema foram sugeridas ações com base nas boas práticas de projetos sustentáveis.

Palavras-chave: Sustentabilidade. Indústria Moveleira. Ruído.

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RESUMEN
El trabajo presenta una evaluación de prácticas sostenibles en industrias madereras mediante el análisis de sus procesos productivos. Se estudió la contaminación acústica en dos industrias madereras de diferentes tamaños del Distrito Federal. Mediante mediciones, fue posible evaluar las emisiones de ruido excesivo y compararlas con los estándares establecidos por las leyes, resoluciones, decretos y normas técnicas reguladoras nacionales e internacionales existentes. Se observó un exceso de ruido en ambas industrias, en puntos específicos. Para controlar el problema, se sugirieron acciones basadas en las buenas prácticas de proyectos sostenibles.

Palabras clave: Sostenibilidad. Industria del Mueble. Ruido.

1 INTRODUCTION

The last decades have been marked by an evolution in discussions on environmental issues, changing the world panorama in relation to the environment. Companies have been directly affected by these changes, given that the market is beginning to value products that minimally interfere with the environment, becoming as feared as the environmental agencies themselves and their respective inspection agents. (Mieli, 2007)

In the furniture sector, the concept of sustainable development has an additional weight. This industry, at a global level, was one of the most demanded in terms of environmental responsibility. During the 1990s there were boycotts by developed countries of tropical timbers. Later, this strategy evolved into the requirement of certification of responsible forest management. This certification, although not a legal obligation, has become a market requirement, leading several companies to seek to act in a more environmentally responsible way voluntarily. (Coutinho & Macedo-Soares, 2002) (Nardelli, 2001)

One of the ways to verify the sustainability of an industry is to analyze its production processes. This analysis may involve aspects related to existing physical and chemical risks. In this context, measurements of quantities related to pollution from the furniture industry can be considered fundamental in the production process. The presence of noise is one of the main factors of concern. Machinery used in industry can produce noise levels above the limits tolerable by humans. In this case, the use of personal protective equipment is a mandatory measure to avoid occupational sequelae. (Lima et al., 2016) (Filipe et al., 2014)

Continued exposure to high levels of sound pressure can cause noise-induced hearing loss and, consequently, cause effects on the individual's quality of life. The consequence resulting from a hearing loss is a psychosocial alteration characterized by isolation, stress, difficulties in family relationships, anxiety, sleep difficulty, decreased self-esteem and depression. (Holanda et al., 2011)

Occupational hearing loss represents an important public health problem due to its high prevalence in the most diverse industrial segments. stated that from the age of 50, male individuals have considerable hearing loss. (Alves & Fiorini, 2012) 8

NR 15 addresses the permitted noise limits depending on the worker's exposure time. In addition, it establishes that continuous or intermittent noise levels must be measured in decibels (dB) with a sound pressure level instrument operating in the compensation circuit "A", slow response circuit (SLOW) and with the readings captured close to the worker's ear. (Brazil, 1978)

Annex I of NR 15 reports that exposure to noise levels above 115 dB is not allowed for individuals who are not adequately protected. According to Annex I, activities or operations that expose workers to noise levels, continuous or intermittent, above 115 dB, without adequate protection, will offer serious and imminent risks. Standards for non-impact noise are also set out in Annex I. The same standard, in its annex II, establishes that impact noise has acoustic energy peaks of less than 1 (one) second at intervals greater than 1 (one) second and also according to Annex II the tolerance limit for impact noise will be 130 dB that can be done with the fast response reading (FAST) and when this limit is exceeded the risk is serious and imminent. (Brazil, 1978)

This paper addresses the concept of sustainable development related to environmental variables in the furniture industry. Two companies with different profiles were analyzed. An industry with a more common profile, representing the universe of small companies spread throughout Brazil, many even informal. Another medium-sized industry with the characteristic of working in a specialized and poorly verticalized way. It represents a smaller universe of companies that are dedicated to serving large corporate consumers and that combine different raw materials in the manufacture of their furniture. Both companies were monitored and evaluated for noise pollution caused by the production activity.

2 MATERIAL AND METHODS

The research was carried out in furniture industries in the Federal District (DF), in the administrative areas of Brasília and Águas Claras. These two areas have a population of more than 350 thousand inhabitants, equivalent to 12% of the Federal District. The region has an HDI of 0.824, considered high by Brazilian standards, and a GDP *per capita* of R$ 62.8 thousand, the highest in the country. (GDF, 2017)

The first industry involved in the study (small company) has a production system tending to be artisanal. The second industry, considered medium-sized, has a production process with a good level of automation. The two types of industries represent around 90% of the establishments in this segment in the Federal District. For practical reasons, the industry with artisanal characteristics is called 'Industry 1' and the second, whose production process has a high level of automation, is called 'Industry 2'. (Garcia, 2007)

For the analysis of environmental pollution in the industries studied, a quantitative field research was developed. Noise measurements were performed. This data was obtained through captures at different work points in the industry, representing all work areas.

2.1 DATA COLLECTION OF ENVIRONMENTAL FACTORS

The assessment of exposure to a substance is carried out from an instrumental measurement followed by comparison of the result with the exposure limits. (DellaRosa & Colcaioppo, 1994)

Measurements were carried out at specific points in each of the industries. The locations chosen for the measurements represented areas involved in the production chain (

Table **1**). Within these areas, random points were chosen.

Table 1

Description of the areas analyzed in the two industries

Area	Industry 1	Industry 2
1	Covered patio for the reception and storage of raw materials and finished products.	Covered patio for the assembly and finishing of products, the locksmith sector and the warehouse of raw materials and finished products. The machines in this area have an industrial scale, are automated and have a usage time of less than ten years.
2	Predominantly open-air region, intended for the storage of hardware and circulation of employees.	An open-air region for loading and unloading materials, with the circulation of trucks, a support mechanical workshop and silos for the storage of waste from the woodworking processes.
3	Covered patio where the company's carpentry and metalwork shop operates. In this place are arranged various machines, with a time of use of more than ten years, divided into benches.	Covered patio where the company's carpentry shop operates. In this place are arranged the machines of less sophistication to support production.

Source: Casella CEL. (2015)

The measurements carried out were analyzed through three levels of integration: companies, areas of the companies and measurement blocks.

The company represents the highest level of integration and includes all measurements carried out during the field campaign. The integration by 'area of the company' aimed to differentiate the physical spaces analyzed within each of the company. Measurement blocks correspond to a set of data collected at the same point in a work shift.

Random working days were chosen for data collection, between 8:00 a.m. and 6:00 p.m. (opening hours of the industries). The sampling rate of the measurements used was one capture per minute. The data collected were carried out over four months and totaled more than 271 uninterrupted hours, carried out at 77 different points, with an average of 179

measurements per point. In total, 16,298 measurements were taken, providing a sampling error of 0.55%, considering a normal distribution, a confidence level of 95% and *p=q=0.5.*

2.2 STATISTICAL DESIGN

The data were statistically analyzed using the IBM SPSS® software, where the following statistical variables were selected: mean, standard deviation, coefficient of variation and percentiles. The data were evaluated according to the hypotheses of the parametric tests. (Mendenhall & Sincich, 2006) (Field, 2009)

The means were evaluated using the t-test for a single sample. The percentiles were used as a parameter for identifying critical areas and equipment.

2.3 EQUIPMENT USED IN THE MEASUREMENTS

Sound pressure or noise measurements were made near the employee's auditory zone using the professional Sound Pressure Level meter CEL-35X. The equipment has sensitivity for capturing continuous noise in the range between 65 and 140.3 dB and for continuous or intermittent noise in the range between 95 and 143.3 dB. (Casella CEL, 2015)

Figure 1

Used noise measuring equipment

Source: Authors (2026)

3 RESULTS AND DISCUSSIONS

Table 1 presents the statistical summary of the sound pressure measurements carried out in Industries 1 and 2.

According to IEC 61252, for the measuring equipment used, the PicoC measurement corresponds to the peak sound pressure level in the instantaneous condition. The LAeq measurement considers continuous noise to a pattern of audible frequencies with a close response approximation to the human ear. To evaluate the measurements, the qualitative method provided for in Annex I of Regulatory Standard No. 15 (NR 15) of the Ministry of Labor was used. According to the Standard, noises in continuous regime must not exceed 85 dB and in instantaneous conditions cannot exceed 115 dB.

Table 2

Statistical summary of the measurements carried out in Industries 1 and 2

Parameter		Industry 1		Industry 2	
		PicoC	LAeq	PicoC	LAeq
N	Valid	1789	2084	4237	4830
	With error	6367	6072	3905	3312
Average		109,81	79,38	108,98	80,76
Median		108,90	77,80	107,40	81,80
Standard deviation		9,84	11,17	8,70	7,59
Percentile	25	101,20	69,70	102,70	76,00
	75	117,50	87,18	113,70	86,10

*Values in dB, with the exception of N, which corresponds to the number of measurements performed for the parameter.
Source: Authors (2026)

For continuous noise emissions (LAeq) in Industry 1, it can be seen that the median was below the limit of 85 dB, which means that most of the measurements carried out in the company did not identify transgression of the noise pollution limits established by NR 15. On the other hand, observing the 75th percentile, it is clear that there are more than 25% of valid measurements exceeding the noise pollution limit. It is observed that the 75th percentile for LAeq was 87 dB. Considering the t-test for one variable, it can be stated that, on average, continuous noise emissions in Industry 1 were 79.38 dB (below the limit of 85 dB of NR 15), with a standard error of ±0.244 dB and a confidence interval of 95%. For peak noise emissions (PicoC), the median was also observed below the limit of 115 dB, indicating that most of the measurements proved the regularity of the installation regarding the emission of peak noise. However, the 75th percentile was 117.5 dB, above the limit established by NR 15. Thus, it was clear that at least 25% of the measurements presented problems in relation to the regular limits. Considering the *t-test* for one variable, it can be stated that, on average, peak noise emissions in Industry 1 were 109.81 dB (below the 115 dB limit of NR 15), with a standard error of ±0.235 dB and a confidence interval of 95%.

Regarding Industry 2, for the measurement of continuous noise, we observed that the median (81.80 dB) was below the limit established by NR 15 (85 dB), indicating that most of the sources emitting noise operate within the acceptable range. However, as in Industry 1, the 75th percentile (86.1 dB) was above the tolerable limit, indicating that there are points of continuous noise emissions of concern. Considering the t-test for one variable, it can be stated that, on average, continuous noise emissions in Industry 2 were 80.76 dB (below the limit of 85 dB of NR 15), with a standard error of ±0.109 dB, considering a confidence interval of 95%. Regarding peak noise, both the median (107.4 dB) and the 75th percentile (113.7 dB) were below the limit established by NR 15 (115 dB), which suggests less concern about

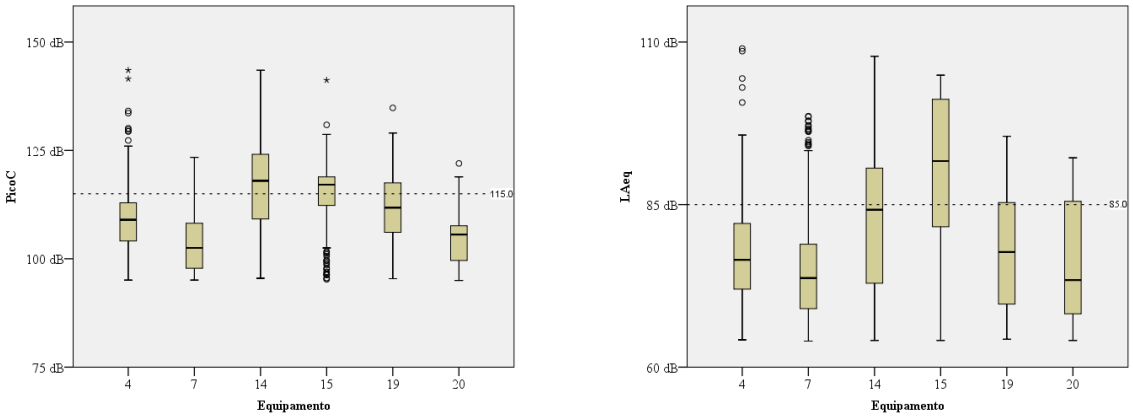
this type of emission for Industry 2. Considering the t-test for one variable, it can be stated that, on average, peak noise emissions in Industry 1 were 108.98 dB (below the limit of 115 dB of NR 15), with a standard error of ±0.134 dB and a confidence interval of 95%.

Comparing the results between the companies analyzed, it is possible to notice a slightly higher performance of Industry 2, both in data homogeneity and performance, since the 75th percentile for peak noise was below the limits of NR 15. The machines used in Industry 2 are more modern when compared to Industry 1 and this may explain the observed performance. The detailed analysis of Industry 1 revealed the significant presence of noise-emitting sources above the tolerance limits in area 3, which contains equipment with more than ten years of use and where the company's carpentry and metalwork works. For both continuous and peak noise measurement, it observed the 75th percentile above tolerance limits. This means that there is a representative amount of problematic measurements.

At Figure 2 the numbers indicated on the ordinate axis correspond to the existing equipment in area 3 of Industry 1. Thus, for peak noise emissions, the equipment that presented significant measurements above the limits were the router, the circular saw and the lathe (equipment 14, 15 and 19 respectively). In the case of router, considering the test *t* for one variable, it can be stated that on average, peak noise emissions were 116.73 dB (above the 115 dB limit of NR 15), with a standard error of ±0.454 dB, considering a confidence interval of 95%. Considering the continuous noises, it was observed that the circular saw (equipment 15) is the most critical equipment. The median for this equipment was well above the limit of 85 dB. Considering the test *t* for one variable, it can be stated that on average, the continuous noise emissions for the circular saw were 90.05 dB (above the limit of 85 dB of NR 15), with a standard error of ±0.66 dB and a confidence interval of 95%. The router, the lathe and the drill (equipment 14, 19 and 20 respectively) also presented values above the limit, but in smaller quantities. For the other equipment analyzed (planer and thickness), no worrying measurements were identified.

Figure 2

Box and whisker diagram for peak (a) and continuous (b) sound pressure measurements in Industry 1 area 3 equipment



(a) (b)

Source: Authors (2026)

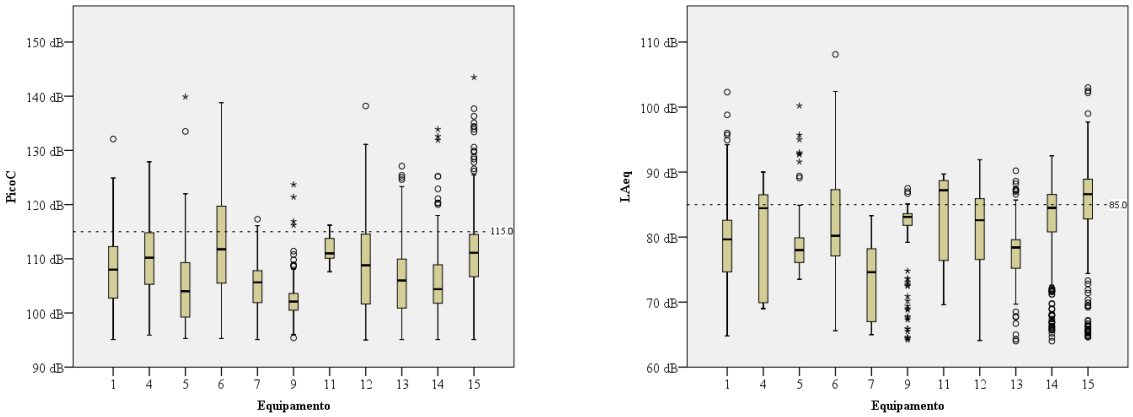
It is clear that router, circular saw, lathe and drill equipment must be operated with ear protection. Given the *layout* of the production plant, even the equipment adjacent to those identified as critical must be operated with this protection.

Regarding Industry 2, the detailed analysis revealed the significant presence of noise emitting sources above the tolerance limits in areas 1 and 3. For both continuous and peak noise measurement, the 75th percentile was observed above the tolerance limits. This means that there is a representative amount of problematic measurements.

Analyzing area 1 by sector, it is clear that only the 'process of washing metal parts' (point 6 of the Figure 3) exceeds peak noise limits in more than 25% of measurements. Considering the test *t* for one variable, it can be stated that, on average, the continuous noise emissions for the washing process of metal parts were 112.79 dB (below the limit of 115 dB of NR 15), with a standard error of ±0.416 dB and a confidence interval of 95%. It is important to highlight that the analyzed process is positioned adjacent to the roll forming machine sector, which is significantly noisier than the washing process. It is possible to infer that the captures of peak noise above the limits are related to the profilers.

Figure 3

Enclosure and whisker diagram for peak (a) and continuous (b) sound pressure measurements on Industry 2 Area 1 equipment



(a) (b)

Source: Authors (2026)

The continuous noise analysis in area 1 allows us to observe significant transgression of the limits in five sectors: metal packaging machine (point 4), washing machine (point 6), sliding table (point 11), gluing and assembly process (point 12), special cutting machine (point 14) and finished products packaging machine (point 15). In the 'squaring' and 'packaging of finished products' sectors, transgression was observed in more than 50% of the catches. Considering the *t-test* for one variable, it can be stated that, on average, only the finished products packaging machine presented measurements above the 85 dB limit of NR 15 and even then within the margin of error. The mean observed was 84.51 dB, with a standard error of ±0.50 dB and a confidence interval of 95%.

In area 3, noise emissions above the limits were also captured. For peak noise, it was identified that the amount of captures above the limit of 115 dB was between the average and the 75% percentile. That is, between 25% and 50% of the catches breached the limit. For continuous noise, the median corresponding to the captures was above the limit of 85 dB. This means that most of the measurements infringed the limit.

The analysis of area 3 revealed that the process with peak noise emissions above the threshold is 'billet cutting'. In this case, the transgressions exceed the median line, that is, more than 50% of the catches made. Considering the continuous noise, three of the four sectors analyzed presented problems: routers, carpentry and billet cutting. In the case of carpentry, all measurements recorded transgression of the continuous noise limits.

The greater number of noisy sources can be explained by the larger size of Industry 2 in relation to Industry 1.

The results observed regarding excess noise have also been reported in similar studies carried out in furniture industries in Rio Grande do Sul and Rondônia. (Girardi & Sellitto, 2011) (Lopes et al., 2009)

4 CONCLUSIONS

It was possible to identify point sources of excessive noise emissions. It was observed that noise levels are associated with the intensity of productive activity, with the highest levels found in medium-sized industry. Equipment such as the router, circular saw, lathe and drill must be operated with ear protection, aided by individual protective covers on the equipment. Given the *layout* of the production plant, even equipment adjacent to those identified as critical must be operated with protection. In these cases, the intensive use of hearing protectors is recommended for all workers who work with this equipment.

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